RELATIVE INFLUENCE OF CULTURAL IDENTITY AND MARKET ACCESS ON AGRICULTURAL BIODIVERSITY IN SWIDDEN-FALLOW LANDSCAPES OF EASTERN PANAMA

by

Kathryn R. Kirby

M.Sc., McGill University, 2005

B.Sc., University of Toronto, 2001

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

in

THE FACULTY OF GRADUATE STUDIES

(Forestry)

THE UNIVERSITY OF BRITISH COLUMBIA

(Vancouver)

December 2011

Abstract

Agricultural biodiversity is essential to local and global food security, yet is being rapidly eroded world-wide. The increasing reach of global transportation and trade networks is predicted to homogenize agriculture at regional scales. However, relatively little is known about how cultural values and norms, as reflected in local farmer decision-making, will interact with market forces to sustain or erode agricultural biodiversity. Working with farmers from three ethnic backgrounds — Black, Emberá or Kuna — in a region of Panama undergoing rapid landscape change, I determined the relative influence of farmer cultural identity and market access on several indicators of agrobiodiversity. Twelve villages were chosen to minimize environmental differences while maximizing differences in access. Villages were classified as "highway" or "remote" based on time and cost of travel to Panama City markets, with each ethnic group represented by two highway and two remote villages. From 2007-2009, a combination of crop inventories and land-use mapping (for 645 fields) as well as interviews with > 130 farmers were conducted. Diversity of staple food crop varieties, agroforest trees and shrubs, and the spatial and temporal dynamics of shifting cultivation were compared among villages. Farmer cultural identity had a stronger impact on agrobiodiversity indicators than did access. For staple food crops (e.g., maize, rice, yam, cassava, bananas, and taro), ethnicity explained 2.5 to 8.5 times more variation in assemblages than access. Distinct assemblages of staple crop landraces (varieties) and agroforest trees and shrubs were associated with different ethnic groups, even where access was high, reflecting culturally patterned dietary preferences, ceremonial or customary uses, and culturally-bounded seed-exchange networks. Mean number, size, and types of fields maintained (homegardens, outfield agroforests, annual fields, pastures), as well as their

management (e.g., forest felling, herbicide use), also varied among ethnic groups. These differences reflected culturally-based crop preferences, values of land, traditional settlement patterns, and contemporary relationships to other actors, including the Panamanian government. Together, the distinct agricultural practices of individual ethnic groups combined to create diversity across many levels of biotic organization: from landrace, to species, to patch, to landscape. These findings strongly suggest that new approaches to conservation that support and respect heterogeneous socio-cultural systems will be critical to global efforts to maintain agrobiodiversity.

Preface

Statement of co-authorship: The research presented herein benefited from the insights and suggestions of many people at different stages in the research process. I have tried to highlight individual contributions in the Acknowledgements section; however, many contributors, particularly those with whom I lived, traveled and worked in eastern Panama, remain anonymous, as per our research agreements.

Authorship of Chapters 3, 4 and 5 is shared with Dr. Sarah E. Gergel and Mr. Domingo Diaz. Individual contributions to these chapters were as follows: I conceived of the original research questions and study design. I established research agreements with participating congresses and communities, worked with local research teams and research assistants to collect data, entered and analyzed the data, and wrote the first drafts of each chapter. Dr. Gergel was involved as a supervisor in all stages of the research and provided substantial feedback on my writing. Mr. Diaz acted as a translator (both of language and meaning) in work with Kuna congresses, communities and farmers and made significant contributions to the interpretation of results.

I am the sole author of Chapters 1, 2, and 6, though like all chapters they benefited from feedback from my supervisory committee and other reviewers.

Behavioural Research Ethics Board approval: The research was approved by the UBC Behavioural Research Ethics Board under certificate number H06-03927.

Table of Contents

List of Tables

List of Figures

Acknowledgements

First and foremost I would like to thank the people of Eastern Panama who generously received me into their communities and homes, and whose willingness to share their perspectives and experiences made this work possible. In particular, I would like to thank the residents of Akua Yala, Arimae, Arretí, Condoto, Icandí, Ipetí-Emberá, Ipetí-Kuna, La Colonia de Zapallal, La Reserva, Nurra, Quebrada Honda, Rio Congo, Tucutí and Wagandí.

I am grateful to the following organizations for allowing me to carry out the research, for providing constructive feedback, and for help in establishing local-level research relationships: Congreso General de Tierras Colectivas del Alto Bayano, Congreso Regional de Tierras Colectivas Emberá y Wounaan - Región Pusadrua, Congreso General de la Comarca Kuna de Madungandí, Congreso General de la Comarca Kuna de Wargandí, Congreso Regional de la Comarca Emberá-Wounaan - Distrito Sambú, Asociación Afrodarienita Forestal de Zapallal, Asociación Las Amazonas, and Asociación Las Primaveras.

An outstanding team of people helped me with data collection in eastern Panama. Nathaly Guerrero and Alana Clason each spent several months on this project, and it would not have been possible without their insights, initiative, and hard work. Alina Romero worked diligently both to transcribe Spanish-language interviews and to process soils.

In each community, local research teams were instrumental, dedicating time and energy to interviews, inventories, and mapping, and to helping me to understand the information collected. Thank you to Maribel Satiasa, Elia Berrugate, Fidel Sabugara, Inelito Sabugara, Donosi Rosales, Emerson, Susana Mena, Jairo Palacio, Cristian Mena, Evelio

Porras Garcia, Neva Gonzalez, Melecio Garibaldo, Helci Stivinson, Mebelio Herrera, Eustacio, Avelino Hernandez, Abilio Sanchez, Gabriel Garrido, Abel Oller, Palestino Martinez, Omar Caisamo, Wilson Chamapurro, Ezekiel, Andres Jr., Jilma, Arineth Taylor, Yeica, Derys Kojira Lopez, Edgar Garibaldo, Silverio Perez, Omar Perez, Suarez Cansari, Octavio Barrigon, Sixto Guainora.

A number of other people had an important influence on my understanding of local and regional issues: Lorenza Valdespino, Atanacio Mena, Maria Vargas Seveño, Rosaura Blanco, Abraham Satiasa, Bertalicia Sabugara, Inel Sabugara, Alvaro Perez, Doricita Perez, Jose Bacorizo, Victoriano Torres, Olodieptapiler Mendez, Manuel Pereira, Maritza Lopez, Venilda Murillo, Atilio Cansari, Edilma Tocamo, Olga, Rigoberto, Rutilia, and Cervantes.

During a trip to Panama in 2006, I met Domingo Diaz, who became a partner in this research and whose contributions to my understanding of tropical agronomy, Kuna language and cosmology, and the failures of many conservation-development interventions have been invaluable. I look forward to our continued collaboration.

I was fortunate to have an extraordinary supervisory committee: Sarah Gergel, Rob Kozak, Tom Sullivan, Julie Velásquez Runk and Felice Wyndham. I have great respect for their individual approaches to research and advising, from which I continue to learn. I am grateful for the direction and encouragement they provided me at all stages, and especially at critical intersections. I am particularly grateful to my advisor, Sarah Gergel, who allowed me the freedom to develop and carry out this research and who continues to be an invaluable mentor and critic. Thank you.

The Smithsonian Tropical Research Institute served as my base in Panama, and I am grateful for STRI's support. William Laurance was especially generous in providing me with

space to work, logistical support, and research advice. I am grateful to Carmen Galdames, Rodolfo Flores, Rolando Perez, and Nefertaris Daguerre for helping me to identify my plant samples, and to Angel Aguirre, Vielka Chang-Yau, Ricardo Beteta, Nilka Tejeira, Elizabeth Sanchez, Marcela Paz, Celideth de Leon, Raineldo Urriola, Alejandro Arze, and Milton Solano for research and logistical support. I would also like to thank the Programa de Desarollo Sostenible de Darién, Instituto de Investigación Agropecuario de Panamá, Autoridad Nacional del Ambiente, Facultad de Agronomía de la Universidad de Panamá, Herbario de la Universidad de Panamá, Fundación Dobbo Yala, and Voz Sin Fronteras, for support in various forms.

In addition to those already mentioned, I would like to thank the following people for the advice and support they provided at different stages in the research process: Francisco Herrera, Olga Linares, Susan Laurance, Jorn Scharlemann, Benjamin Turner, Catherine Potvin, Fernando Santos Granero, Stanley Heckadon Moreno, Neal Smith, France Lise Colin, Carli Halpenni, Jose Yau, Jose Manuel Perez, Bonarge Pacheco, Herraclio Herrera, Heraclio Lopez, Adolfo Mezua, Leovigildo Doviaza, Ultiminio Cabrera, Trevor Lantz, Geoffrey Hawtin, Terre Satterfield, Jonathan Levine, Justine Karst, Jackie Ngai, Alicia Robinson, Hilary Thorpe, Clare McClean-Wilson, Stephanie Mills, Jessica Morgan, Shanley Thompson, Matt Tomlinson, Hélène Marcoux, Rhianna Nagel, Jenn Mundy, Betzi Perez, Rebecca Van Vlasselaer, Andrew Crawford, John Douglass, Jennifer Balch, Curtis Runyan, Mary O'Connor, William Eaton, Jennifer Williams, Jai Ranganathan, Oonsie Biggs, the Gilberts, Volletts, Andrea Chan, Norman Hodges, and Gayle Kosh.

The following organizations provided the funding that made this work possible: Natural Sciences and Engineering Research Council of Canada, Organization of

American States, International Development Research Centre, Isaak Walton Killam Memorial Fund, University of British Columbia, Namkoong Family Fellowship in Forest Sciences and Smithsonian Tropical Research Institute. The National Center for Ecological Analysis and Synthesis provided me with space to work in 2008-2009.

Finally I would like to thank my family, whose steadfast support allowed me to complete this work. In particular, my parents provided constant encouragement, quiet spaces to work, good food, and perceptive comments on many versions of this work. My sister Julia provided her usual pragmatism, sense of balance and humour.

Ben Gilbert has lived with this project for as long as I have, and the ideas, approaches, and hands-on help he has contributed over the years have shaped the final product. I am grateful for his intellectual contributions, unwavering support and friendship.

For my parents,

Susan Vorner Kirby and Graeme Kirby

Chapter 1: Introduction

Globalization does not advance as a single tendril but as a jumble of economic, technological, cultural and social interactions. An awareness of their synergistic effects on household decisions and biodiversity is essential (Kramer et al. 2009)

Over the last 300 years, agriculture has expanded along with human population growth to cover approximately 32% of the global land surface (Klein Goldewijk and Ramankutty 2004). Since the Green Revolution, this expansion has been accompanied by an industrialization of agriculture and a homogenization of production systems at multiple scales, from field to bioregion (Jarvis et al. 2007:9; Fig. 1.1). The result has been a loss of agricultural biodiversity, or agrobiodiversity (Harlan 1975; Pretty et al. 1995; Thrupp 2000; FAO 2010). Here I define agrobiodiversity broadly to include diversity in cultivated plant and animal species, wild relatives, and associated wild species (Wood and Lenne 1999), as well as diversity in the types of fields and the spatial arrangement of fields in a given landscape (Perfecto et al. 2009).

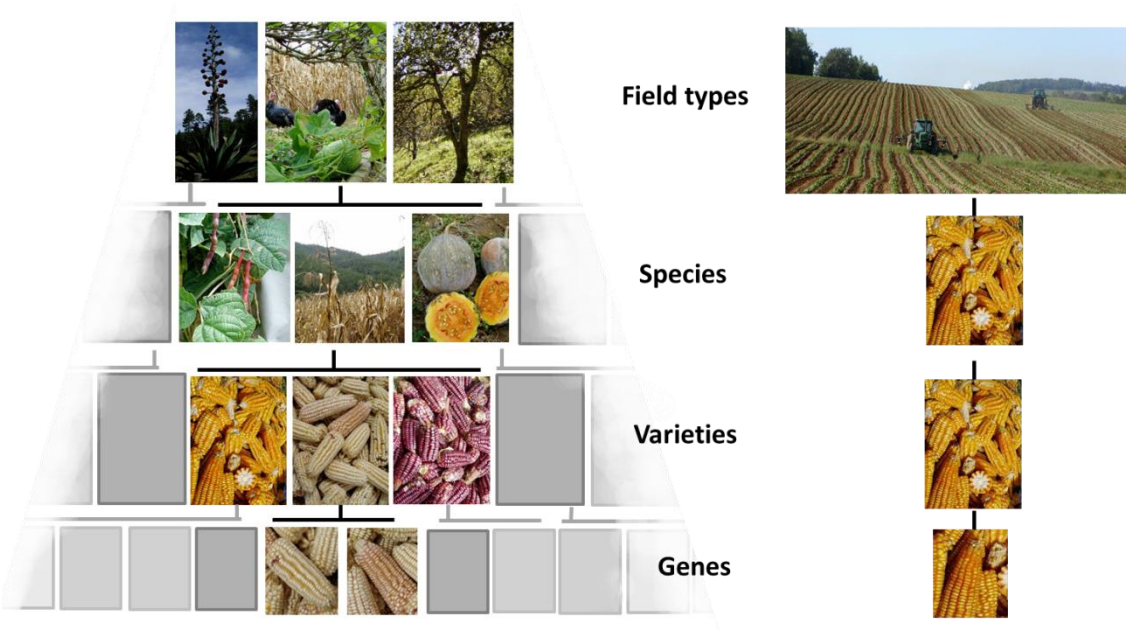


Figure 1.1 Over the last century, dominant models of agricultural development have led to a homogenization of production systems and a loss of agrobiodiversity at the level of fields, species, varieties and genes. In this example, the agrobiodiversity maintained by a small-scale farming household in Oaxaca, Mexico (left) is contrasted with that of an industrial-style monoculture (right). Each of the field types on the left (maguey, milpa, and orchard) contains an array of species, varieties, and genotypes. The field on the right contains a single genotype.

Agrobiodiversity provides resilience to pests, diseases, and climatic and economic shocks (Clawson 1985; Ceccarelli 1994; Smithson and Lenné 1996). As such, losses of agrobiodiversity can threaten local food security and human wellbeing. These threats are of particular concern in regions where peoples' capacity to counter food disruption, either with technology or food imports, is limited. Losses of biological and structural diversity may also undermine the sustainability of agricultural production by negatively impacting ecosystem services such as pollination, seed dispersal, and water and nutrient cycling services (Jackson et al. 2005; Norris 2008). Finally, extinctions of crop varieties with unique traits may impact long-term food

security by limiting the biological diversity available for crop breeding and adaptation (Frankel 1974).

With the growing recognition of the importance of agrobiodiversity to resilience and sustainability, agricultural development initiatives are focusing not just on yields, but also on maintaining or restoring diverse production systems (Pretty et al. 2006; De Schutter 2010). In addition, efforts to conserve rare and underutilized species and varieties are increasingly focused on *in situ* conservation, which allows crops to continue to adapt to changing environmental conditions and ensures that knowledge surrounding their cultivation is maintained. As a result, it is becoming more important that we understand the factors that encourage farmers to maintain (or, conversely, to eliminate) agrobiodiversity from their production systems.

My goal for this dissertation was to explore how cultural contexts moderate farmers' management of agrobiodiversity in response to markets. Previous research on agrobiodiversity has often been constrained by disciplinary boundaries, and thus has not tackled interactions among the biophysical, cultural, and economic factors known to influence farmer decision-making. It also has tended to focus on agrobiodiversity management within one or very few farming communities, making it difficult to extrapolate findings to broader scales. The research presented here uses an interdisciplinary, landscape-level approach to explore the distribution of agrobiodiversity in a tropical region undergoing rapid changes. In particular, I test the relative influence of farmer ethnicity and market access on agrobiodiversity, while controlling for the possible influence of underlying biophysical factors such as rainfall, elevation and soils. In the following sections, I outline theoretical frameworks for considering the effects of market access and cultural identities on agrobiodiversity, review previous work addressing their effects, and

explain how I expect them to work in conjunction to influence broad-scale distributions of agrobiodiversity.

Agrobiodiversity change in response to markets

The connection of tropical agricultural landscapes to regional economies has often resulted in a loss of agrobiodiversity and a simplification of landscape structure (Fig.1.2). In many landscapes, these changes have been attributed to the agricultural practices of new colonists, which often dramatically transform land cover and the proportion of the landscape under cash crops and/or cattle pasture (e.g., Moran 1993). Less attention has focused on how connectivity to markets changes the agricultural practices of shifting cultivators whose communities have long-farmed in a region (Rerkasem et al. 2009). The dearth of research on this topic is particularly notable given that shifting cultivation – traditionally practiced throughout the world's tropics – is among the most biodiverse agricultural systems known. As such, changes in the practices of shifting cultivators may have particularly important impacts on the maintenance of agrobiodiversity in tropical landscapes (Padoch and Pinedo Vasquez 2010).

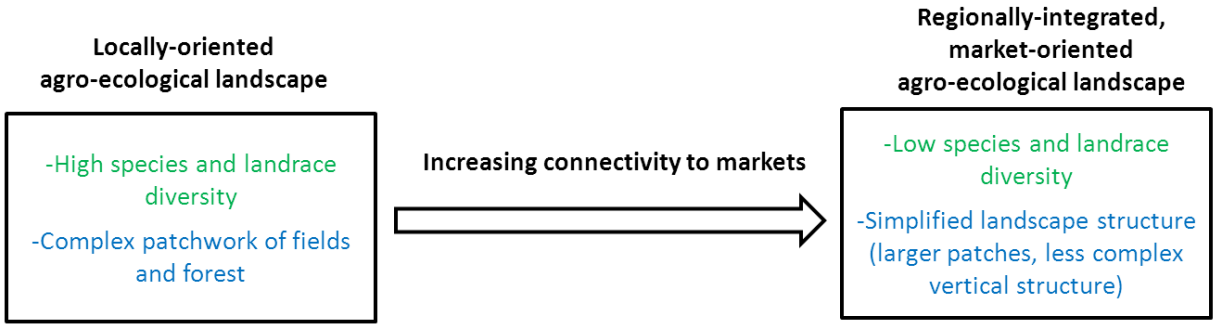


Figure 1.2 What drives the changes often observed in agro-ecological landscapes after an increase in connectivity to markets?

Classical and neoclassical economic theories assume that farmers are rational individuals who respond to markets in ways that maximize their profits (e.g., Ricardo 1821; Heady 1952; Colman and Young 1989; Ellis 1993). According to these theories, maximum profits are typically achieved through specialization in a particular product or production system that maximizes an individual's comparative advantage. As a result of this specialization, (neo)classical economic theories predict losses of agrobiodiversity with market integration. Empirical studies have generally confirmed that market integration leads to losses of crop diversity (e.g., Harlan 1975; Zimmerer 1991; Brush et al. 1992; Humphries 1993; Henrich 1997; Bellon 1996; Van Dusen and Taylor 2005; Peroni and Hanazaki 2002). However, the same studies often reveal that these losses are incomplete. In other words, farmers with high levels of market participation maintain a mix of both commercially optimal varieties and some other varieties (Brush 1995).

Early analyses of farmer variety choice assumed that "inefficiencies" in farmer learning were responsible for farmers' maintenance of varieties other than modern, high-yielding varieties (e.g., Kislev and Schori-Bachrach 1973, and Hiebert 1974, reviewed in Smale 2006). Subsequent work acknowledged that such decisions might in fact be economically rational, motivated by strategies for dealing with risk (Feder 1980; Just and Zilberman 1983; Smale et al. 1994; Vadez et al. 2004), environmental heterogeneity (Bellon and Taylor 1993; Meng 1997), or imperfect markets (de Janvry et al. 1991; Meng 1997 in Smale 2006; Van Dusen 2000; Smale et al. 2001; Vadez et al. 2004; Benz et al. 2007). Finally, many scholars reject assumptions of economic rationality altogether, arguing instead that the economic behaviour of individuals is strongly influenced by the social and cultural systems in which they are 'embedded.' In contrast to western, capitalist societies, these systems may place more value on altruistic behaviours than on

individual profit maximization (Polanyi 1944; Granovetter 1985; Henrich et al. 2005; see also Ellis 1993 for review of alternative theories of peasant economics, including theories that assume farmers are driven by goals other than profit maximization).

Regardless of the whether farmers are motivated by profit maximization, aversion to risk, or by household-level labour constraints (e.g., Chayanov 1986), differences in access to markets will correspond to different sets of opportunities and constraints, over-and-above those encountered at the level of the household. The impacts of market accessibility on agricultural decision-making were recognized in the first location models (Von Thünen 1826 in Hall 1966), which described the optimal spatial distribution of agricultural production strategies in a landscape in which goods were transported to a central market, and where transportation costs varied with distance from this market (Fig. 1.3). Market access continues to be studied for its impacts on the livelihoods and land-use practices of rural populations, and Von Thünen's spatial location model is used as a heuristic tool in many of these studies (e.g., Mertens and Lambin 2000; Castella et al. 2005; Soler et al. 2009; Salonen et al. 2011).

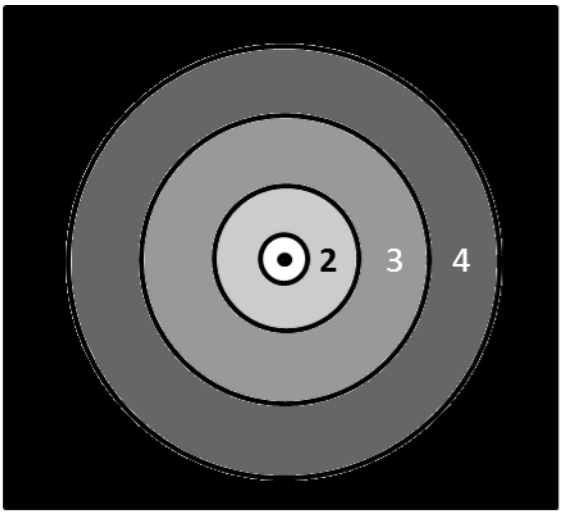


Figure 1.3 "Von Thünen rings": a market city lies at the centre of the diagram, represented by the black dot. The concentric circles around the dot represent zones in the surrounding landscape in which different production strategies (e.g., dairy and vegetables, fuelwood, grains, livestock) are most profitable based on the relative costs of transportation and land. The outer zone (in black) is considered to be a "wilderness" in which commercial agriculture is not possible (Von Thünen 1966).

From an agrobiodiversity perspective, spatial location theories make two predictions. First, under an assumption of profit maximization, location models predict that access to markets will correlate with farmer specialization and thus lower agrobiodiversity. Second, location models predict that two farmers with similar access to markets will have more similar production strategies than two farmers with contrasting access to markets. When applied to crops, these theories allow us to make predictions about both the richness and the composition (e.g., similarity) of crop assemblages based on degree of market access. As such, spatial location models remain useful to any attempts to understand how agrobiodiversity is distributed across a region or landscape in which access to markets varies.

Linking cultural identity and agrobiodiversity

Relationships between ethno-linguistic[1] diversity and crop diversity have long been observed (e.g., de Candolle 1885 in Perales et al. 2005), and have been attributed to the distinct material and non-material values that different cultural[2] groups ascribe to particular crops, or to diversity per se (Boster 1985; Soleri and Cleveland 1993; Brush 1995; Salick et al. 1997; Atran et al. 1999; Tunstall et al. 2001 in Samberg et al. 2010; Ban and Coomes 2004; Benz et al. 2007). However, there are often important differences in the farming environments occupied by different cultural groups (e.g., lowlands vs. highlands, or near vs. far from markets). Perhaps for

[1] Here used to mean a human social unit that differentiates itself from other social groups based on shared language and ethnicity.

[2] I adopt a definition of culture as a "shared pool of information" (e.g., Goodenough 1981; Boster 1986; D'Andrade 1987 in Reyes-Garcia 2001), and assume that factors that tend to bound social networks – and thus social learning – will often correlate with cultural identities. Implicit in this definition is that individuals who identify as sharing a 'culture' will differ in the amount of information they share. In using "ethno-linguistic group" and "cultural group," interchangeably, I recognize that ethnicity, language, and place-based experience commonly bound social networks, and provide powerful sources of cultural identity to peoples around the world.

these reasons, cultural factors have often been assumed to be of secondary importance to ecological and economic factors in influencing distributions of crop diversity (e.g., Brown and Marshall 1995 in Galluzzi et al. 2010).

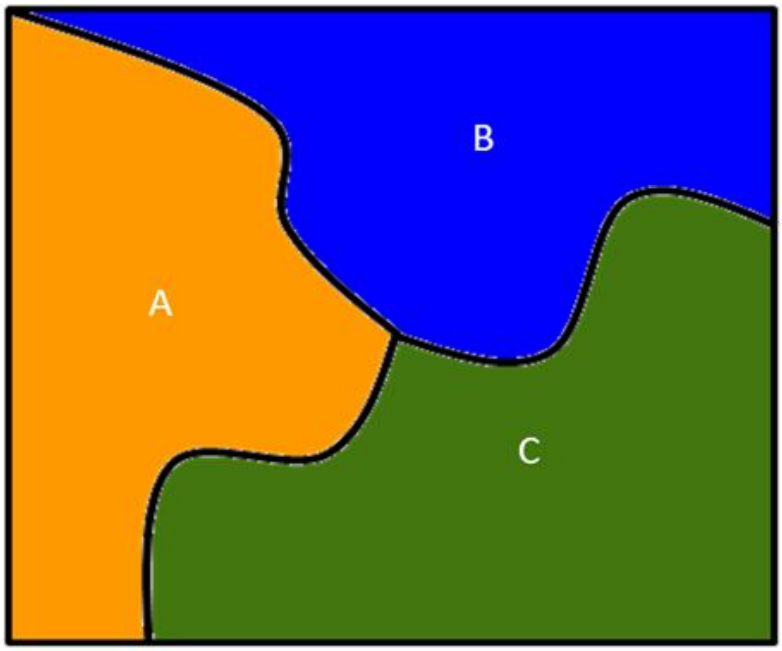
Recently, scholars have attempted to control for confounding variables when exploring relationships between culture and agrobiodiversity. For example, Perales et al. (2005) examined the maize varieties maintained by farmers of two ethno-linguistic groups within a single maize 'ecozone' in central Chiapas, Mexico. Farmers of each group maintained distinct maize varieties despite the higher yields of the varieties of one group (demonstrated in common garden experiments) and ample opportunity for each group to adopt the other group's varieties. In a similar vein, Atran et al. (1999) demonstrated that neighbouring ethnic groups in the Petén region of Guatemala responded to similar socio-economic pressures with markedly different land management practices. The relative difference in land-use practices among groups in part reflected the overlap (or lack thereof) in their social networks, which in turn influenced social learning surrounding 'best' land management practices and the ecological values of local plant and animal species.

While social networks may influence farmers' interests in acquiring particular species or varieties via exchanges of information, they may also directly determine the likelihood that a farmer will be able to acquire the seed (or cutting/sucker) of a particular species and variety. Seed exchange networks are recognized to have an important influence on crop distributions (e.g., Boster 1985; Boster 1986; Louette 1997; Perrault-Archambault 2005; Coomes 2010). There is limited evidence that in some landscapes, seed exchange networks are more important than agro-ecological conditions in determining the varietal distributions of crops (Zimmerer 2003 in Samberg et al. 2010; but see Brush and Perales 2007). This demonstrates the potential

for culturally-bounded seed exchange networks to strongly influence spatial distributions of agrobiodiversity. Guarino and Hoogendijk (2004:37) allude to the conservation implications of cultural patterning of crop distributions in their chapter in the book "Homegardens and Agrobiodiversity":

> *It may well be that more genetic divergence is present between two geographically adjacent homegardens whose owners do not participate in seed exchanges than between two homegardens located in distinct agroecological zones whose owners regularly exchange planting material because they are related or form part of the same cultural group or trading network.*

The idea has important implications for agrobiodiversity given that many small-scale farming landscapes are mosaics of land managed by farmers of different ethno-linguistic groups, reflecting the tendency for different ethno-linguistic groups to partition landscapes into non-overlapping territories (Moore et al. 2002; Manne 2003; Fig. 1.4).



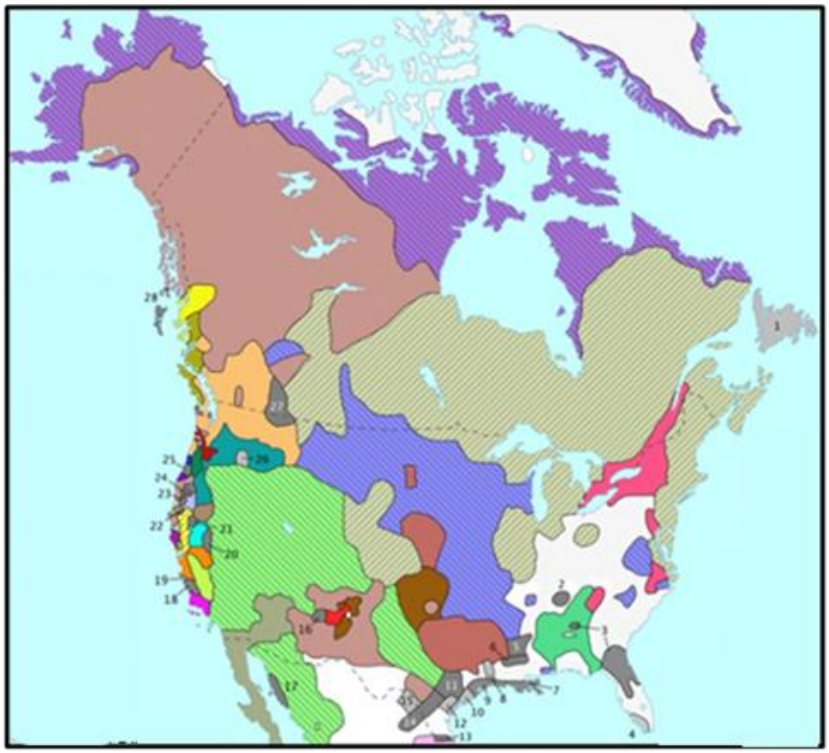


Figure 1.4 (continued on next page) Examples of ethno-linguistic territorial mosaics. The panel at the top is a simple model of a landscape that includes the non-overlapping territories of three cultural groups (A,B, and C). The central panel is a map of the distribution of language groups (indicated by fill colour) in North America prior to European contact (Wikimedia Commons).

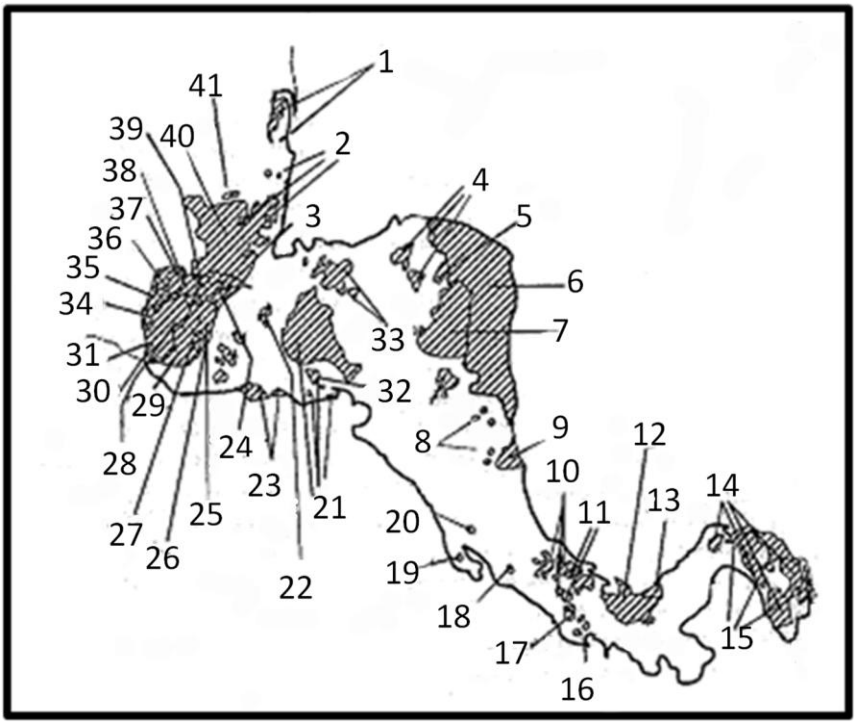


Figure 1.4 (continued from previous page). The final panel is a map of late-20th century distributions of indigenous groups in Mesoamerica, with territories (hatched areas) of different indigenous groups indicated with different numbers (modified from Toledo et al. 2002).

Integrating spatial theories of the effects of markets and culture on agrobiodiversity

The theories and research presented in the previous sections lead to two non-exclusive hypotheses. The first, which I will refer to as the market-loss hypothesis, predicts that agrobiodiversity decreases as access to markets increases as a result of farmer specialization. The second hypothesis, which I refer to as the biocultural-diversity hypothesis, predicts that agricultural diversity will increase with the number of distinct cultural groups in a geographic region, as the distinct seed exchange networks and knowledge and belief systems of the different groups are likely to promote distinct production strategies. Together, these predictions raise the question that is the focus of much of the research presented here: how do market access and cultural identities interact to influence agrobiodiversity? One possible outcome of the interaction

between market- and culture-related factors is depicted in the final panel of Figure 1.5, in which the distinct agricultural strategies of different cultural groups are overwhelmed by market forces in areas closest to markets.

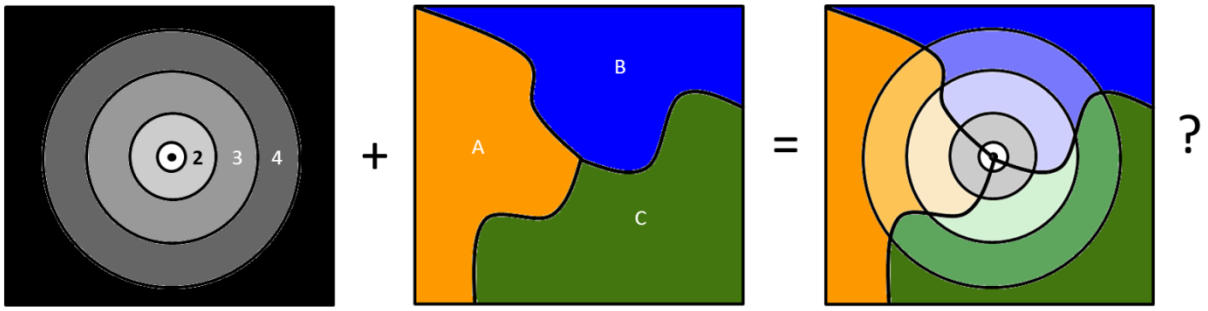


Figure 1.5 Integration of spatial theories of the effects of markets and culture on agrobiodiversity. Here, "Von Thünen rings" surrounding a central market city (see Fig. 1.2) are combined with non-overlapping cultural territories (see Fig. 1.3). In each case, different colours/tones represent different agricultural production strategies and crop assemblages. In the final panel, one possible outcome of interactions between markets and cultural identities on agrobiodiversity is considered, in which market forces in the areas closest to the market overwhelm the distinct production strategies of farmers of different cultural territories. In this example, the distinct strategies of farmers of different cultural identities result in higher agrobiodiversity at the level of the landscape, even in the face of market integration.

The agrobiodiversity literature presents examples and opinions that echo the extremes of the market-loss hypothesis and the biocultural-diversity hypothesis. Differences among the homegardens of different ethnic groups are sometimes presented as static, idealized forms that are perpetuated through time (e.g., Terra 1952, 1953 reviewed in Schneider 2004). In contrast, the loss of agrobiodiversity in Indian homegardens was presented as inevitable in the face of urbanization and commercialization, based on the idea that market integration "transforms individuals and their values" (Soemarwoto 1987). A middle view is presented by Michon and Mary (1990 in Schneider 2004:50), who argue that while market integration leads to adaptations

in the homegardening strategies of rural households, these adaptations are not uniform, and a diversity of garden conversion strategies should be expected.

Testing relationships between agrobiodiversity, market access and farmer cultural identity

In this dissertation, I explore the extent to which market access and farmer ethnicity explain the diversity and distribution of important food crops, cultivated tree species, and agricultural field types in the Darien Region of Panama. The region provides a fascinating landscape in which to explore relationships between agrobiodiversity, markets, and culture. The majority of households in the region maintain a mix of annual and perennial fields that supplement household food consumption and income to different degrees. A strong gradient in market access is present between communities with more or less access to the region's only highway, and thus to the central agricultural market in Panama City. The landscape is a mosaic of territories managed by different ethnic groups. In the following sections, I briefly define the boundaries of the study region and introduce the biophysical environment and human geography of the region. I then provide an overview of the study design and an outline of the remainder of the dissertation.

Overview of study region

Regional boundaries

By "Panama's Darien Region," I refer to the areas of Panama that are east of the town of Chepo (itself about an hour and a half's drive from Panama City), west of the Colombian border, and south of the Comarca Kuna Yala on the Caribbean coast (Fig. 1.6). Politically, the region includes the districts of Chepo and Chiman in Panama province (including the Comarca Kuna de

Madungandí), the entirety of Darien province (including the Comarca Kuna de Wargandí), and the Comarca Emberá-Drua.

Until the 1970s, the Pan-American Highway ended at Chepo. As such, the region as a whole faced a similar level of isolation from national markets, and river-based transport was the norm throughout (e.g., Wali 1989:98; Mendez 2004:347-369). Today, the region is bisected by an extension of the Pan-American Highway (Fig. 1.6). The highway, which reached its current end-point in Yaviza, Darien, in 1984, and which was paved from 2001-2009, has created a strong gradient in market access between villages on the highway and villages with less access to it. A detailed discussion of the history and impacts of the highway on farming communities is presented in Chapter 2.

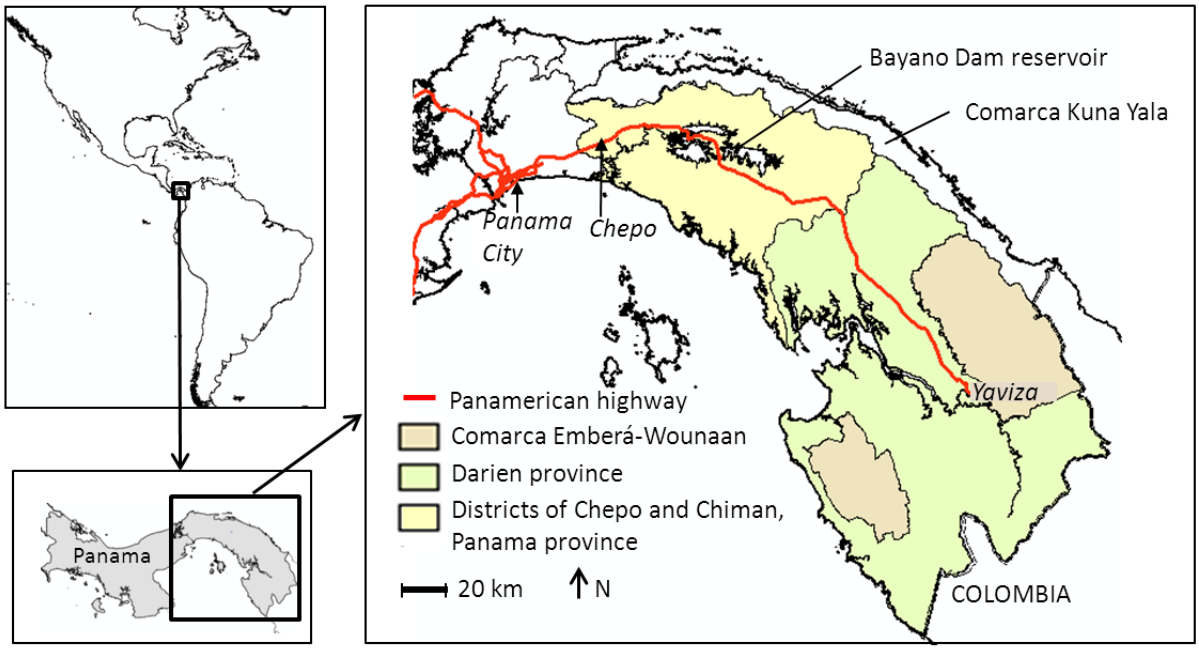


Figure 1.6 Panama's Darien region includes the province of Darién, the Comarca Emberá-Drua (also called Comarca Emberá-Wounaan), and the districts of Chepo and Chiman in Panama province. The region is separated from the Caribbean coast by the narrow Comarca Kuna Yala. The Darien Region encompasses approximately 22,283 km^2.

Environment

The Panamanian isthmus was one of the last areas of the Americas to be formed, emerging three million years ago from the ocean as a narrow land bridge connecting North and South America (Coates 1997; Velasquez Runk 2005:75). Elevation in the Darien Region ranges from 0-1,875 meters above sea level, rainfall from 1700-4500 mm annually and temperature from 16°-35°C (Fig. 1.7a and b; Hijmans et al 2005; Bliss et al. 2006). In lowland areas where almost all human settlements are located, rainfall ranges from 1700-2800 mm annually and there is a marked dry season with less than 100 mm monthly from January through March-April. The annual mean temperature in the lowlands is 26°C. Soils range from inceptisols to vertisols (Dames and Moore 2001). However, the region's soils remain poorly studied (IDIAP 2006).

The Darien Region represents the northern limit of the Chocó bioregion, an internationally recognized biodiversity hotspot (Conservation International 2005). The dominant natural vegetation in the region is semi-deciduous moist tropical forest (Golley et al. 1975). Common and notable tree species of these forests include cuipo (*Cavanillesia platanifolia*), espavé (*Anacardium excelsum*), cedro espinoso (*Pachira quinata*), bongo (*Ceiba pentandra*), cedro amargo (*Cedrela odorata*), caucho *(Castilla elastica)*, mahogany (*Swietenia macrophylla*), higueron (*Ficus spp.*), chunga palm (*Astrocaryum standleyanum*), and jira palm (*Irartea exhorriza*) (Herlihy 1986:38; Velásquez Runk 2005:26). Mangrove forests, marsh and swamp forests, and broad evergreen riparian forests are also important in the lowlands (ANAM 2009).

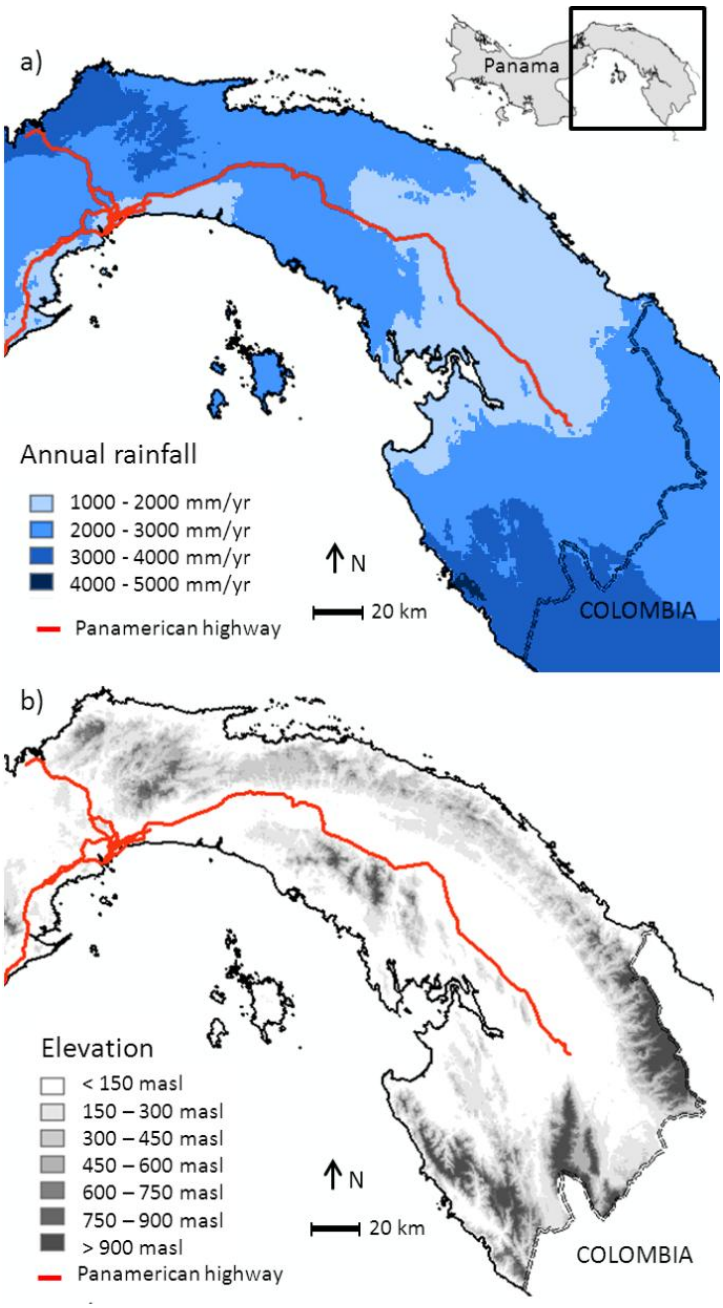


Figure 1.7 Biophysical characteristics of the Darien Region, including (a) annual rainfall (Hijmans et al. 2005) and (b) elevation (Bliss et al. 2006).

Study population

For over five centuries, Kuna, Emberá and Black communities have co-inhabited and co-managed the landscape of the Darien Region and adjacent areas of Colombia. I worked with

farmers who identified as belonging to each of these three ethno-linguistic groups. The Kuna and Emberá are indigenous to the region and belong to the Chibchan and Choco language groups, respectively (Lewis 2009). The Black population of Darién is descended from Africans who arrived in the Americas as slaves beginning in the early 1500s (West 1957; Losonczy 1997). Despite their diverse origins in Africa, a shared identity among slaves and their descendants emerged over the course of the colonial period (Losonczy 1997). Today members of this group identify as members of '*la etnia negra*' (the Black ethnicity). The three groups have maintained long-standing exchange networks for goods, labour, and healing services (Vargas 1991; Losonczy 1997). However, the majority of the region's settlements remain segregated along ethnic lines[3], a fact that has not changed with the arrival of *Latino* settlers from western Panama in the region over the last century (Hernandez 1970). The histories of each group are presented in more detail in Chapter 2.

Most households in the region rely on shifting cultivation (also known as swidden or slash-and-burn agriculture) for subsistence and/or income. Typically, households maintain one or more agroforests in addition to annual rice, maize and tuber swiddens. Agroforests are planted in perennial species (especially fruit trees and *Musa spp.*) and located either immediately around the home (e.g., homegardens) or within walking distance from it (outfield gardens, managed fallows). In addition most households have unmanaged fallows (previously cleared and cultivated areas left to return to forest).

[3] Exceptions are large towns; however even those tend to have voluntarily segregated neighbourhoods. The voluntary segregation along cultural lines reflects inter-group marriage taboos that historically were held by all groups.

Surplus agricultural products are typically sold in Panama City or to an intermediary traveling to Panama City. Because most goods are transported to markets along the region's only highway, there is a sharp gradient in access to markets between highway villages and villages not connected to the highway by road. This gradient in market access was key to our study design and is discussed in more detail in the section "Quantifying market access," below.

Study design

My objective was to disentangle the broad scale effects of market access and farmer ethnicity on the distribution of agrobiodiversity in the region. Working with regional indigenous congresses and institutions, I selected twelve villages with varying access to Panama City markets. Each cultural group was represented by four villages, two with good access to markets (located on the highway with all-season road access to the highway; hereafter "highway villages") and two with difficult access to markets (located in areas not connected to the highway by an all season road, hereafter "remote villages"; Fig. 1.8). In the second year of the study a fifth Kuna village (K1b in Fig. 1.8) was added to replace another (K1a) for remaining surveys (Appendix 1). Because biophysical differences among villages could also be important drivers of agrobiodiversity distribution, I was careful to select villages in locations that minimized the potential confounding effects of biophysical variables known to influence agriculture in the region. In particular, all villages were in lowland areas (<135 masl) and there were no systematic differences in annual precipitation among villages of particular cultural groups and among remote vs. highway areas (Hijmans et al. 2005; Table 1.3). While it was not possible to control for soil differences a priori, soils were sampled in each village as part of the research presented in Chapter 3. The results of this sampling are discussed therein.

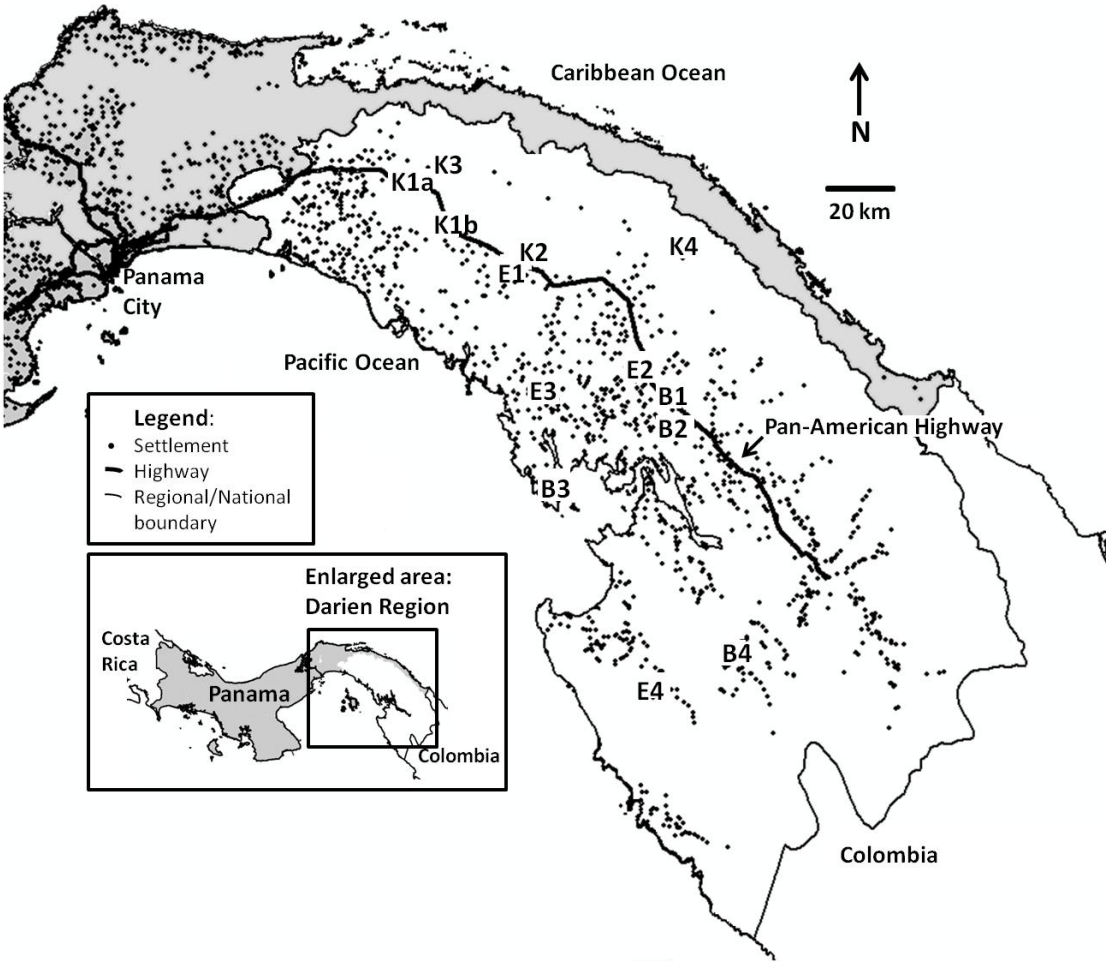


Figure 1.8 Study design. Study villages are indicated by a two-character code where the prefix indicates the cultural group of the village (B=Black, K=Kuna, E=Emberá) and the suffix indicates whether the village was considered a highway village (1-2) or remote village (3-4). In mid-2008 we added a thirteenth village to the study (K1b), as competing activities in one of the original villages (K1a) meant that we had difficulty finding participants for the second round of surveys (focusing on annual fields). Tables 1.1 and 1.2 summarize the characteristics of each village.

Quantifying market access

Almost all agricultural goods produced for markets in eastern Panama are sold in the main agricultural market in Panama City, or to an intermediary in eastern Panama who then transports the goods to Panama City (and adjusts purchase prices according to travel time/cost).

The presence of intermediaries is extremely unpredictable except along the highway. Occasionally farmers we worked with reported selling small quantities of surplus products to neighbours in their own village or in a nearby town, but such sales were relatively rare and resulted in lower prices for sellers. Inputs (pesticides and herbicides) were not available in any of the study villages but could be purchased in large towns. Just as prices received for agricultural products were much higher in Panama City than in eastern Panama, chemical inputs were much cheaper when purchased in the capital city. As a result, farmers often traveled to Panama City to purchase agricultural supplies (and other household supplies) rather than buying them in towns along the highway.

For each of the study villages, market access was quantified in two ways: time to reach Panama City (one-way trip), and the cost of transporting 20 *quintales* (approximately 2000 lbs) of agricultural goods to Panama City markets. In addition, we distinguished between villages in which transport was available daily (or even multiple times per day) and villages where transport had to be arranged in advance. The above proxies for market access were chosen because they capture aspects of the time, cost, and effort associated with travel and transport that are likely to impact farmer decisions surrounding product sales and input purchases (Salonen et al. 2011). For each village, data on market access were collected through semi-structured interviews and were verified during our travel to each village. In all cases estimates were based on the most common mode of transport. The measures are summarized in Table 1.1 and in Chapter 3 are used to confirm the validity of our “highway” and “remote” categories, which were designed to capture a gradient in market access.

Sampling within villages

In each study village, I selected a random[4] sample of approximately 10 households with which to explore the management of the diversity of important food crops, agroforest species, and field types. The characteristics of the households surveyed in each village are summarized in Table 1.2. In addition to general socio-demographic descriptors, the Table 1.2 includes several proxies for "market participation," including: proportion of community members owning stoves, tin roofs, and motorized or electrical appliances, and time since last trip to the capital city. The first two proxies have previously been suggested as proxies for household wealth in the region (Velasquez Runk 2005). Both stoves and tin roofs must be purchased (as must propane for the stoves) and they are therefore indicators of market participation. The inclusion of motorized or electrical appliances as a proxy provides a further glimpse of household participation in the cash economy, and is likely a more accurate measure of market participation than roofing material for Kuna households, where the social norm even for those households most active in the cash economy is to maintain a thatched roof. The final proxy, time since last trip to the capital city, provides another indicator of participation in the cash economy as transport to Panama City requires cash payment, as does daily living in the city. Contrasting the values for these proxies among remote and highway villages reveals that our measures of market access were positively correlated with market participation. These data are formally analyzed in Chapter 3.

[4] I chose a random sampling strategy because we did not have a priori knowledge about how agrobiodiversity was distributed among households in the study villages. Work from other regions has reported contrasting relationships between variables such as household wealth and agrobiodiversity (e.g., Yongneng 2006; Perreault-Archambault and Coomes 2008; Isakson 2011), suggesting that such knowledge is a necessary prerequisite for the design of effective stratified sampling regimes.

Table 1.1 Summary of the characteristics of the thirteen study villages. Village IDs correspond to codes on the map of the study area (Fig. 1.8). Data on transport method, time and costs (in USD) are from interviews carried out in each village. Biophysical differences were taken into account in terms of their potential impact on agricultural practices. Rainfall data are from Hijmans et al. (2005) and elevation data from Bliss et al. (2006).

Village ID	**B1**	**B2**	**E1**	**E2**	**K1a**	**K1b**	**K2**	**B3**	**B4**	**E3**	**E4**	**K3**	**K4**
Cultural identity of majority of inhabitants	Black	Black	Emberá	Emberá	Kuna	Kuna	Kuna	Black	Black	Emberá	Emberá	Kuna	Kuna
"Remote" or "Highway" village (based on access to markets)	Highway	Highway	Highway	Highway	Highway	Highway	Highway	Remote	Remote	Remote	Remote	Remote	Remote
Measures of market access													
Estimated cost of transporting 20 quintales (2000 lbs) of agricultural goods to Panama City[1,2]	$66.00	$69.50	$60.00	$66.00	$53.00	$57.00	$60.00	$100.50	$218.50	$125.00	$159.00	$126.00	$181.00
Method - transport 20 qq agricultural goods[1]	T	T	T	T	T	T	T	OB	MD + T	D + T	MD + OB	MD + T	H + T
Time for personal trip to Panama City (hrs)[3]	5	6	4.5	5	2.5	2.75	3	12	16.5	9	15.5	6	12
Method - personal trip[1]	B	LB + B	W + B	B	B	B	B	MB + MB + LB + B	MD + MB + LB + B	D + LB + B	MD + OB	MD + B	W + LB + B
Availability of transport	Multiple daily (highway bus)	Multiple daily (highway bus)	Multiple daily (highway bus)	Multiple daily (highway bus)	Multiple daily (highway bus)	Multiple daily (highway bus)	Multiple daily (highway bus)	Must pre-arrange or own boat + motor	Must pre-arrange or own boat + motor	Must pre-arrange or own boat + motor	Must pre-arrange or own boat + motor	Must pre-arrange or own boat + motor	Multiple daily (hike to highway)
Biophysical characteristics of villages													
Annual rainfall (mm)	1760	1744	1930	1772	2309	2402	1861	1787	2686	2001	2680	2288	1844
Elevation (masl)	33.1	33.6	81.4	27.3	74.6	89.4	84.3	0	19.1	20.6	55.2	66.6	131.9

[1]During the rainy season, by most common (and often cheapest) method of transportation. Assume pay own passage (return) + $0.50 per quintal (100 lbs) on local vehicles + $2.50 per quintal on highway truck + full cost of gas for a motorized canoe trip (return) + $15 per horse carrying 3 quintales. In USD.

[2]W=Walk; LB=Local bus (vehicle providing local transport); B=Bus (regional bus, traveling to capital city); T=Truck (4x4 vehicle); D=dugout canoe; MD=Motorized dugout canoe (15 hpw-45 hpw motor); MB=Motor boat (>45 hpw motor); OB=Overnight houseboat.

[3]Allowing 1 hour for transfers between types of transport

Table 1.2 Summary of the characteristics of participating households in each village. Village IDs correspond to codes on the map of the study area (Fig. 1.8). Socio-economic data are based on the sample of approximately 10 households from each village that participated in the study. "Household heads" includes both male and female household heads.

Village ID	**B1**	**B2**	**E1**	**E2**	**K1a**	**K1b**	**K2**	**B3**	**B4**	**E3**	**E4**	**K3**	**K4**
Number household members (all ages)	6.2	4.6	5.1	6.3	7.4	7.1	10.1	4.7	3.6	6.2	6.8	8.3	10.6
Number of active adults per household	2.8	3.2	2.7	3.2	3.6	3.0	5.1	3.0	2.4	2.8	3.5	3.9	4.8
Average age of principal farmer(s)	44	46	44	45	43	42	36	47	46	41	46	54	35
Years of State education of most educated farmer in household	7.6	5.5	4.8	6.3	3.5	4.9	4.6	6.8	6.3	3.1	4.6	3.2	1.0
Percentage of adults who spoke Spanish	100%	100%	100%	100%	50%	60%	67%	100%	100%	97%	98%	50%	13%
Percentage of adults who spoke an indigenous language	0%	0%	91%	95%	100%	100%	100%	0%	2%	100%	100%	100%	100%
Proxies for market participation													
Percentage of household heads who had ever been to Panama City	100%	100%	95%	86%	86%	100%	76%	100%	100%	74%	88%	100%	45%
Weeks since last trip to Panama City (those who had ever been)	21.1	12.3	17.2	52.7	69.3	12.6	15.0	54.0	128.5	98.1	85.1	97.8	99.1
Proportion of households with metal roof	1.00	0.92	0.45	0.70	0.14	0.10	0.10	1.00	0.79	0.24	0.08	0.00	0.00
Proportion of households with a stove	1.00	1.00	0.45	0.80	0.71	0.50	0.70	1.00	0.86	0.14	0.00	0.30	0.00
Proportion of households with an appliance (outboard motor, chainsaw, television, washing machine, OR fridge)	0.90	0.77	0.55	0.36	0.67	0.20	0.73	0.64	0.57	0.10	0.07	0.30	0.07

Structure of dissertation

The remainder of this dissertation is structured as follows. Chapter 2 provides an overview of the history and cultural geography of the study region. In particular, the chapter addresses the origin of the ethnic groups that today make up Panama's Darien Region, factors that have contributed to the maintenance of ethnic boundaries through time, and the impacts of the highway on market access and on the socio-cultural structure of the region.

The primary research chapters (3-5) focus on relationships between markets, ethnicity and agrobiodiversity. In Chapter 3, I analyze relationships between market access, ethnicity, and landrace (variety) assemblages of six food crops: *Musa spp.* (bananas and plantains), maize, rice, taro, yams and cassava. I explore variation in both the richness and composition of these assemblages. In Chapter 4, I focus on explaining distributions of species predominantly cultivated in agroforests, including fruit trees, timber species and other useful shrubs and trees useful to local people. Chapter 5 explores whether ethnic identities and market access are also related to the types and spatial and temporal dynamics of the fields that farmers maintained. Each of these chapters includes a summary of the methods for the work presented therein; however, a more general overview of the methods used to establish the project, and of community responses to the project, is presented in Appendix 1.

Finally, in Chapter 6, I synthesize the findings of the previous chapters, and discuss the implications of my findings for efforts to maintain agrobiodiversity *in situ.*

Chapter 2: History of the study region

Political ecologists have long stressed the importance of looking beyond a single geographical scale of analysis (e.g., 'the village') and examining the larger, multi-scale political-economic, social and ecological processes in which rural livelihoods are embedded. (Colin 2010)

Historicity (i.e., historical change at various time scales) is a key to understanding globalization-related changes. (Zimmerer 2007)

In this chapter I provide an overview of the history and geography of the study region through a combination of written accounts of the region's history and 20th century census data. In some cases, I have supplemented information from secondary sources with accounts and perspectives of residents of the region, collected through interviews over the course of my research[5]. The chapter is divided into three parts. Part 1 focuses on the history of the region from pre-Columbian times to present. Part 2 explores the impacts of the highway on market access and on the socio-cultural structure of the region's population. Part 3 discusses some of the factors that have contributed to the maintenance of ethnic boundaries through time. My objective is to provide historical context for work presented in subsequent chapters. In particular, I highlight the long social, political, economic, and agricultural connections of Black, Emberá and Kuna communities in eastern Panama, and the transformative effect of the Pan-American Highway on land use and inter-cultural relations.

[5] Interviews in Spanish were recorded and later transcribed. Interviews in Kuna were recorded, transcribed and translated to Spanish by Domingo Diaz. I translated transcriptions from Spanish to English.

Part I – History of the Darien Region[6]

Pre-Hispanic history

For the last three million years, Panama has served as a narrow land bridge linking North and South America. As such, humans almost certainly passed through the region on their first southward migration through the Americas over 10,000 years ago (Dixon 2001). While relatively little is known of the pre-Hispanic populations of the Darien Region, existing archaeological evidence suggests that a single cultural province was formed by Eastern Panama and bordering areas of North-western Colombia from over 2000 years ago until the Spanish invasion in the 16th century (Bray 1984 in Peregrine 2001; Cooke and Sanchez Herrera 2004 in Velasquez Runk 2005:78). During this period, the human population of the region is thought to have been "dense," with settlements along both coasts and throughout the inland valley (Bray 1984:330 in Peregrine 2001:248).

The identity of the peoples living in Panama's Darien Region during this period remains uncertain. Most historians agree that the region was dominated by a group known as the Cueva, whose territory extended from Punta Chame, west of the Panama Canal, to the Atrato River in Northwestern Colombia (Fig. 2.1; Romoli 1987). Emberá and Wounaan groups, who speak Chocoan languages, are believed to have been concentrated in northwestern Colombia, between the Upper Atrato and San Juan Watersheds, but their territories may have extended into south-

---

[6] The "Darien Region" was defined in Chapter 1 and includes Darien Province, the Comarca Emberá-Drua, and the Districts of Chepo and Chiman in Panama Province. The region's history is closely tied to that of northwestern Colombia. In the text I refer to the Colombian *departamento* (province) of Chocó, which borders Darien Province and extends south along Colombia's Pacific Coast.

eastern Darién (Fig 2.1; Vargas 1991; Herlihy 1986:72). The Kuna, who speak a Chibchan language, are also thought to have been centered in Colombia, either on the middle Atrato River or on the east coast of the Gulf of Uraba (Fig. 2.1; Romoli 1953:104-6, 124-5, 380-1; Timborn 1949:50 and Rivet 1943; 1947; reviewed in Stier 1979:46). However, Kuna oral histories describe a long history of maritime travel and strong ties to the areas around Cerro Tacarcuna in northeastern Darién, suggesting a Kuna presence in eastern Panama long before the arrival of the Spanish (Helms 1979, 1988 in Langebaek 1991). Much uncertainty remains, as colonial accounts of the region often contradict one another, and the humid tropical environment has left scant archaeological evidence (Cooke and Sanchez 2004 in Velásquez Runk 2005:82-83).

While little is known of pre-Hispanic relations of Kuna and Emberá groups, oral histories of each group describe inter-group fighting (Howe 2002 in Velasquez Runk 2005:169; Vargas 1991). For example, Emberá oral histories describe wars with the Kuna along several rivers in the Colombian Chocó, including tributaries of the Sinu, Baudó, and Atrato (Fig. 2.1; Vargas 1991 citing Betania (1964:58) and Pardo (1984:205-217)). Similarly, Kuna legends describe fighting the "Chocó," a term used to refer to both Emberá and Wounaan[7] (Howe 2002 in Velasquez Runk 2005:169). These oral histories correspond well with early colonial descriptions of the Darién-Chocó as a contested territory in which many small chiefdoms were vying for control (Romoli 1976 in Velasquez Runk 2005:150; Pacheco and Velasquez 1993). Losonczy

[7] Emberá and Wounaan speak mutually unintelligible languages but recognize a common cultural heritage that separates them from the Kuna (Herlihy 1986:63). Perhaps because their material culture is similar (e.g., traditional house construction and dress), Panamanians long considered Emberá and Wounaan to be a single ethnic group, referred to as the "Chocó". See Velasquez Runk 2005:141-147 for discussion.

(2006:61) argues that it was in abandoning traditional inter-tribal wars and prioritizing resistance to the Spanish that the Kuna, Emberá and Wounaan were able to survive the Spanish invasion.

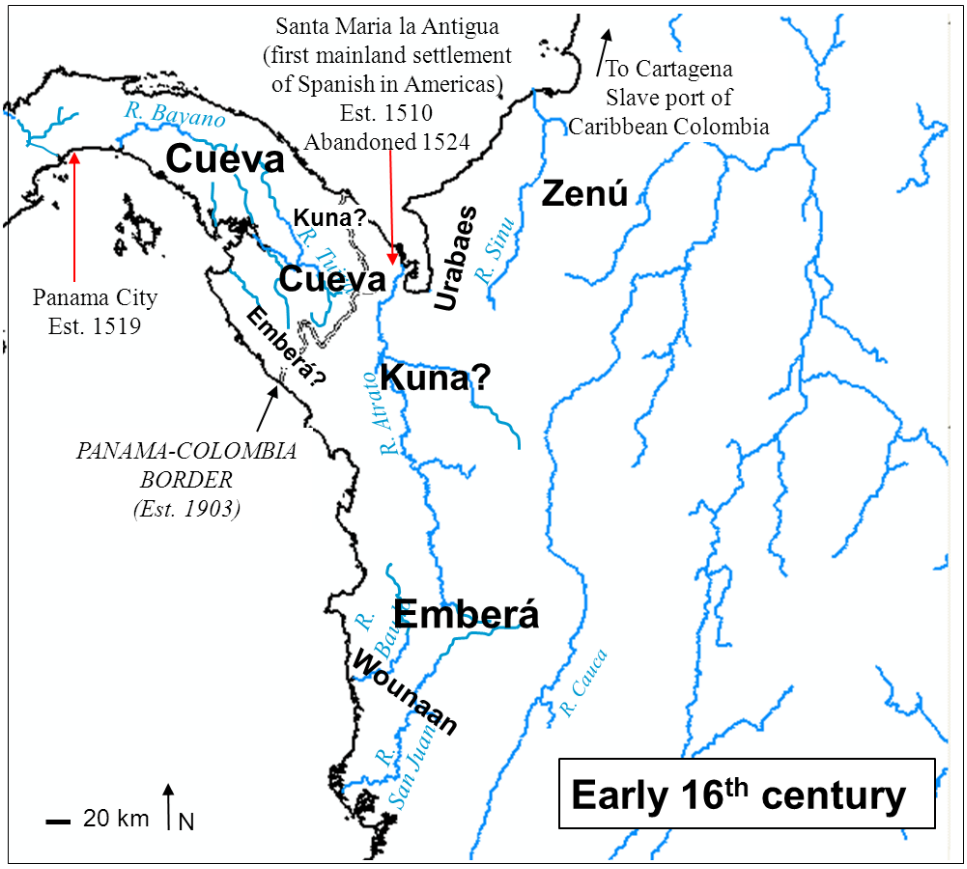


Figure 2.1 Location of early 16th century indigenous population centers discussed in the main text (Vargas 1991; Stier 1979:46; Herlihy 1986:70; Velasquez Runk 2005:151).

The Spanish invasion

Panama's Caribbean coast was first visited by Europeans in 1501, nine years after Columbus 'discovered' the Americas and established the first European settlement on the coast of present-day Haiti. Descriptions of the Darién-Chocó from 1501 include mentions of fertile fields around the mouth of the Atrato River, near the present-day Panama-Colombia border, and of two distinct groups of Natives: the poisoned-arrow wielding Urabaes, who occupied the areas

east of the Atrato river, and the more welcoming Cueva, who occupied the areas to the west of the Atrato river, including most of Eastern Panama (Anderson 1941:35; Vargas 1991; Fig. 2.1).

In 1510, the Spanish established their first mainland settlement in Cueva territory, just east of the present-day Panama-Colombia border (Anderson 1941; Velasquez Runk 2005). The settlement, Santa Maria la Antigua del Darién, served as a base of operations for the Spanish. It was also the site from which indigenous towns were looted for gold and slaves (Hoopes and Fonseca 2003).

The second governor of Darién, Pedro Arias de Ávila, oversaw a particularly violent period of indigenous-Spanish relations in the Darién-Chocó during his reign from 1513 to 1519. In his quest to subjugate the indigenous population and acquire gold, he carried out massacres of the indigenous population that were so horrific as to be referred to as "hallucinating" (Castillero Calvo 1994 in Velasquez Runk 2005:87). During this period Emberá, Wounaan and Kuna populations living along rivers in which the Spanish were active are said to have retreated to the isolated headwaters where they could avoid contact (Herlihy 1986:87). In 1519, de Avila moved his base of operations to a site near modern-day Panama City. By the time the settlement of Santa Maria la Antigua del Darién had been completely abandoned in 1524, violence, slavery and disease had decimated the indigenous peoples in closest contact with it, including the Cueva and Urabae.

By 1542, the decline in indigenous populations throughout the New World was such that the Spanish Crown acquiesced to pressure from missionaries and issued the "New Laws," exempting indigenous peoples from slavery (Losonczy 2006:52). However, the expansion of plantation agriculture and mining activities in the New World meant that labour was in high

demand. This demand was met by an increase in imports of African slaves, whose labour became the cornerstone of European economic success in the Americas.

African slaves

The first African captives were brought to the Americas in 1505, and their population steadily increased over the following centuries (Losonczy 2007:51). In the mid-16th century the Spanish established a slave port in Cartagena (Fig. 2.2), which received most of the Africans who ultimately were brought to the Darién-Chocó to work in gold mining. By the mid-18th century, 12-14 slave ships, each carrying 1000 slaves, were arriving at the Cartagena port each year (Graves and Shupe 1992; Losonczy 2006:53).

Little documentation of the origins of the slaves who arrived at the Cartagena port exists. However, most analyses suggest that slaves arriving in the region represented an array of language groups (see Losonczy 2006:55 for a review). For example, a combined ethnographic-linguistic study suggested that Africans who arrived in Cartagena before 1550 came mainly from Senegambia, and those who arrived over the next two centuries were mainly from the Congo-Angola region of Africa and, later, peoples from the central Guinea Coast (Friedemann and Arocha 1986 in Losonczy 2006:55).

From the outset, Spanish policy was designed to erase the diverse tribal and linguistic affiliations of African slaves, which the Spanish feared might foster a successful rebellion. To this end, the marriage of slaves from the same tribe was prohibited (Losonczy 2006:53). This policy accelerated the adoption of Spanish as a *lingua franca* and forced the emergence, early on, of a shared cultural identity among African slaves and their descendants (ibid).

Rules also governed interactions of Blacks and Natives. In particular, the Spanish instituted strict segregationist policies designed to ensure the continuity of the Black labour force. Under the New Laws of 1542, a child's status as indentured slave vs. free native was determined through the maternal line. As such, direct interaction between Blacks and Natives was prohibited, and unions of Black men with indigenous women were severely punished (Pacheco and Velasquez 1993). In addition, the Spanish are argued to have initiated an insidious effort to instill in each population (the indigenous and Black) a fear of the witchcraft of the other (Losonczy 2006; Pacheco and Velasquez 1993:276).

The contrasting approach of the Spanish with regard to the Black and indigenous populations was summed up by Jaramillo Uribe (1963:21) as follows: "While many of the colonial laws dealing with Indians aimed at protecting them from undue exploitation, there were no efforts to protect Blacks until the 18th century, and most laws dealing with slaves prescribed punishments for escape or rebellion."

Settlements of escaped African slaves ("*cimarrones*") were established in remote areas of the Darién-Chocó throughout the early colonial period (Losonczy 2007:56). Some of these settlements were well known to the Spanish and successfully defended their (often fortified) communities from repeated attempts at recapture or extermination. One of the most famous of these settlements was that of San Basilio near Cartagena, whose residents were granted their freedom in 1613 after years of resistance to the Spanish, on the condition that they did not accept more fugitives (ibid). The Blacks of San Basilio were said to speak a Spanish creole, and to have adopted a system of governance that fused diverse African and Spanish traditions (ibid).

Early agriculture

Analyses of two pollen cores from Eastern Darién province suggest that swidden agriculture centered around maize production was practiced in the Darien Region continuously from about 3800 years ago (Piperno 1994; Bush and Colinvaux 1994; in Velasquez Runk 2005:79). A dense human population subsisting on maize agriculture is suggested by early descriptions of the Darien Region by European chroniclers who described "extensive savannahs" (Sauer 1969:285-83; Gordon 1957:58-59 in Stier 1979:52; Velásquez Runk 2005:80). Trade networks are thought to have linked North and South America as early as the 13th century, and 16th century European explorers documented the cultivation by the indigenous population of agricultural crops with origins throughout the Americas, including maize (*Zea mays*), sweet potato (*Ipomoea batatas*), cassava (*Manihot esculenta*), New World yams (*Dioscorea trifida*), squash (*Cucurbita spp.*), peppers (*Capsicum spp.*), pineapples (*Ananas cosmosus*) and tree crops such as peach palm (*Bactris gasipaes*), avocado (*Persea americana*), guava (*Psidium guajava*) and mamey (*Pouteria sapota*) (Oviedo 1849, 1853, 1949, 1950 in Romoli 1987 and Cooke 1998)[8].

The arrival of the Spanish in the Americas initiated the "Columbian Exchange" (Crosby 1972), which, among other things, resulted in the introduction of an array of Old World crops to New World colonies. In Panama, banana[9] (*Musa spp.*) and sugar cane cultivation was well established among the Kuna by the 17th century (Wafer 1699 in Bennett 1962:46). Old World

---

[8] Oviedo, an early-16th century chronicler of Cueva material culture, noted that for each major food crop, 3-10 landraces were maintained. For example, Oviedo talks of black, yellow, '*aigarrado*,' white, soft, and hard maize (Romoli 1987:157).

[9] Interestingly, Kuna oral histories describe bananas as indigenous to the Americas, present before the Spanish invasion.

yams (*Dioscorea spp.*), which were a main source of food on transatlantic slave ships, were likely introduced with the first shipments of slaves in the early 16th century (Carney and Rosomoff 2009). The history of rice cultivation in the region is less clear; Emberá and Kuna oral histories describe at least several generations of rice cultivation. Mendez (2004:348) described rice as the "principal and primordial crop" of Darién Blacks, adding that it was grown by all households in the early 20th century. According to the Kuna of the San Blas islands on the Caribbean Coast, rice was never a major staple for the Kuna, but has long been planted in small quantities (Stier 1979:257). Both Stier (1979:257) and Mendez (2004:348) add that in the early 1900s local rice production was supplemented by imported rice, sold by the provisioning boats that plied the river ports of Darién and the islands of the Caribbean Coast. Several references describe the accelerating adoption of rice cultivation by Emberá and Kuna in the mid-20th century (Torres de Arauz 1966:27; 1970:49; Loewen 1972).

Indigenous swidden agriculture is described as being very similar during the early colonial period to what it is today (Patiño 1965:59 in Herlihy 1986:121). The major differences reflect the incorporation of Old World crops into local production systems (e.g., Bennett 1962). While some of these crops were almost certainly obtained by indigenous farmers directly from the Spanish, the proximity of Black and indigenous settlements may have been an important source of exchanges in agricultural technologies. African Americans are credited with introducing Europeans and Native Americans to the cultivation of a number of Old World crops, including yams and African rice (*Oryza glaberrima*; Littlefield 1981; Carney 2001; Carney and Rosomoff 2009). Accounts of the agriculture of *cimarrones* and African slaves in the Darien Region in the first centuries after the Spanish invasion are scarce; however, in other regions of the Americas, slaves cultivated provision gardens for subsistence purposes (e.g., Mintz 1985).

These gardens were often the sites of introduction of Old World crops to the Americas, as first generations of New World Africans obtained familiar planting material from incoming slave ships with excess provisions of yams and other Old World crops (Carney and Rosomoff 2009).

Territorial re-organization

By the mid-16th century the Cueva had been decimated by war, slavery and disease, and the Darien Region of Panama was open for colonization by other groups (Romoli 1987; Velásquez Runk 2005:87). By this time, the Spanish had moved their headquarters from the mouth of the Atrato River to a site near present-day Panama City, and Spanish presence in the region was more sporadic and focused almost entirely on gold mining.

The Kuna began to migrate west into Darién to areas once under Cueva control in the 16th century (Fig. 2.2). Some historians have argued that the Kuna were pushed into Darién by the northward migration of the Emberá, who themselves were reacting to the establishment of gold mining operations in the San Juan watershed between 1570 and 1600 (Vargas 1991:224; Romoli 1987:50; Fig. 2.2). These mining operations were powered by Black labour, and the first settlements of escaped and freed African slaves (known in Spanish as *cimarrones* and *libres*, respectively), were reported from the region in the late 16th century, including in Panama's Darién by 1575 (Heckadon Moreno 1997 in Velásquez Runk 2005:91).

By 1608, most of the Darien Region was occupied by the Kuna (Vargas 1991). The next two centuries were a period of intense conflict between the Kuna and Spanish. As Spanish mining activity in Panama's Darien Region increased, so too did Kuna attacks on Spanish forts and mines. The conflict was punctuated by several short-lived peace treaties, some of which reveal that Kuna attempts to defend their territories against outsiders included attempts to

exclude Blacks, whose population was increasing in step with gold mining activity (and whose presence was probably often a sign of Spanish extractive activity; West 1957:100). For example, a 1738 peace treaty between the Kuna and the Spanish included the stipulation, demanded by the Kuna, that "no Negroes, mulattoes or zambos were to live in, or pass through, their territory" (Nordenskiold 1938:4; Stier 1979:80).

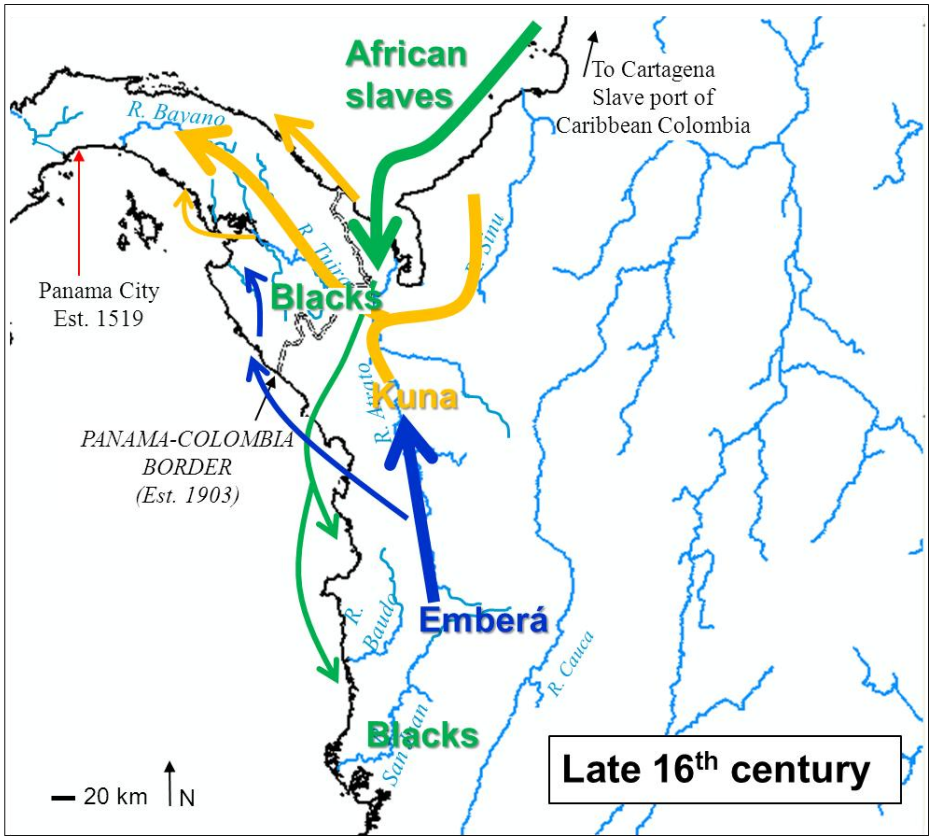


Figure 2.2 Following the decimation of the Cueva, larger numbers of Kuna, Emberá and Blacks began to move into eastern Panama. The map shows approximate population centers and main migration routes of each group in the late 16th century (West 1957:100; Herlihy 1986:70-72; Stier 1979; Heckadon Moreno 1997; Velásquez Runk 2005:166; UNESCO 2006). "Blacks" refers to slaves, cimarrones (escaped slaves) and libres (freed slaves) of African descent, here centered on important gold-mining sites. Today their descendants identify as belonging to la *etnia negra* (the Black ethnicity). For a description of Wounaan migration routes into Panama see Velásquez Runk (2005:172).

The 17th century was also a period of conflict along the Pacific coast of the Colombian Chocó. During this period, gold mining in the Upper San Juan and Atrato river basins was increasing. In some cases, Emberá and Wounaan farmers supplied mining operations with maize and other agricultural goods needed to sustain their labour forces (Hansen 1999 in Velásquez Runk 2005:159). Missionary activity in the region was also increasing, with a view to pacifying Emberá and Wounaan, whose hostility toward the Spanish was revealed by attacks on mining parties that strayed into tributaries of the Upper San Juan and Atrato Rivers. In 1684, Emberá across the region coordinated an uprising against the Spanish, in which they targeted and killed Spanish, Mestizos, Black slaves and indigenous assistants of the Spanish (Hansen 1991 in Velásquez Runk 2005:161). Spanish reprisals following this uprising forced the Emberá and Wounaan population to retreat to more remote areas (ibid).

While the attitudes of the Kuna and Emberá towards Blacks appear to have been hostile in the 17th and 18th centuries, the attitudes of *libres* towards the indigenous population of the Chocó, (mainly Emberá and Wounaan), appears to have undergone a shift in the 18th century. Losonczy (2006:57) describes a conscious effort by communities of escaped and freed slaves to overcome two centuries of violence and mistrust in order to gain allies who would help them to maintain their freedom. Certainly, centuries-old alliances between Blacks and Emberá are supported by oral histories (Pacheco and Velásquez 1993:274).

One of the outcomes of Black-Emberá alliances has been the ritualized practice of "*compadrazgo*," whereby Emberá families seek Black god-parents for their children (Stipek 1974; Pacheco and Velásquez 1993; Losonczy 2006). The *compadrazgo* system affords both Emberá parents and Black god-parents protection from the other group's witchcraft (through access to a shaman of the other group; Stipek 1974; Pacheco and Velásquez 1993; Losonczy

2006). In addition, ritualized interactions between parents and god-parents (including preferential trades, and hospitality upon the arrival of one family at the home of the other), may have served to de-fuse tensions among the two groups that otherwise could have been an important source of conflict over this period (ibid).

Kuna retreat and Spanish withdrawal

In 1783, after decades of attacks by Kuna armies on Spanish forts and mines (sometimes in the company of English, Scottish, and French pirates), the Spanish Crown issued a Royal Decree calling for the extermination of the Kuna (Nordenskiold 1938:3; Arosemena 1972:228 in Herlihy 1986:77). Several sources suggest that during the ensuing battles, the Spanish employed Black and Emberá soldiers in their effort to conquer the Kuna (Arosemena 1972:230 in Herlihy 1986:77). By 1789, the Spanish Crown was so frustrated by the repeated losses they had suffered in Darién, particularly in relation to other New World regions, that the region was ordered abandoned and Spanish forts dismantled (Mendez 1979:122 in Herlihy 1986:78). Although the Kuna had not been defeated, their numbers were reduced and by the late 1700s the majority of the Kuna population had migrated out of Darién to the Caribbean coast. Those Kuna that stayed in Darién were settled along the upper reaches of a handful of rivers.

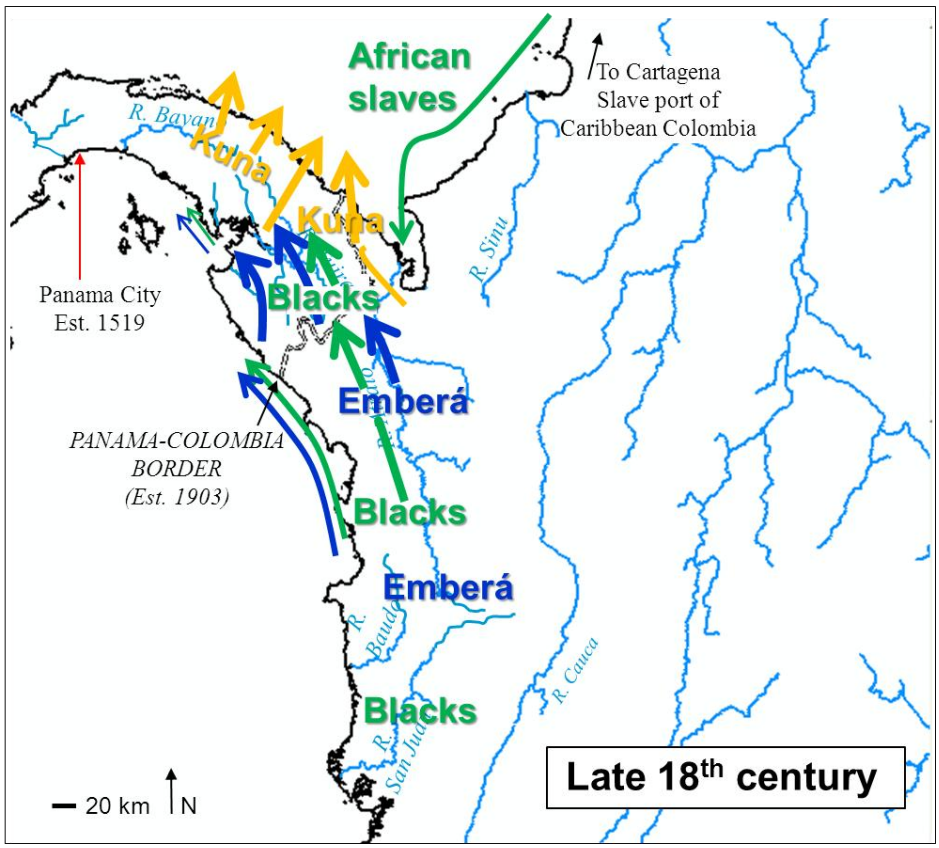


Figure 2.3 Approximation of the population centers and main migration routes of Emberá, Blacks and Kuna in the Darién-Chocó region towards the end of the 18th century (Herlihy 1986:78-80; Velásquez Runk 2005).

In the wake of the retreat of many Kuna to the Caribbean coast, the Emberá and Wounaan gradually expanded their presence in eastern Panama, and by 1850 Emberá families had occupied most of the region's watersheds (Herlihy 1986:75). Groups of Black cimarrones, runaways from Chocó mining camps, had settled along tributaries of the region's rivers throughout the 18th century, and their numbers were buoyed by the immigration of many Blacks to Darién following the 1851 enactment of the law abolishing slavery (West 1957:100, 103).

Over the next century and a half, Black, Emberá, Wounaan and Kuna communities were the primary managers of the landscapes of Darién, and relations during this period appear to have been relatively peaceful. Entrepreneurs from central and western Panama, North America,

Europe, China, and the Antilles came to the region to explore and extract, but only occasionally settled there permanently. Black, Emberá, Wounaan and Kuna communities were often engaged in extractive activities, earning cash to supplement subsistence agriculture and fishing. Extraction focused variously on gold mining, timber, ivory nuts, rubber, mangrove bark, ipecac, caiman and conch shells (Pagnini 1970; Velásquez Runk 2005:104; Perafan and Nessim 2002). During this period, conflicts over land and resources are not reported as being important.

20th century Darién: ethnic identities and land rights

The separation of Panama from Colombia in 1903 was followed by a renewed interest by the State in indigenous affairs, an interest that had been nearly absent since the end of the Spanish-Kuna war in 1789 (Stier 1979). In 1925, the Kuna living on the San Blas islands of the Caribbean coast revolted against the increasing presence on the islands of government officials and police and their attempts to regulate Kuna behaviour (Howe 1998). Kuna demands for autonomy came as a wave of populist *indigenismo* was sweeping Latin America, which saw nascent nation-states promoting the cultures and histories of indigenous peoples as a source of national identity (De la Peña 2005; Jackson and Warren 2005). The outcome of the Kuna uprising was the formal recognition of the Comarca San Blas (now the Comarca Kuna Yala, Fig. 1.6), a semi-autonomous reserve that is governed as collective lands by the Kuna. The establishment of the Comarca ushered in a new era of cultural politics in Panama, in which ethnic identities served as a basis for negotiating land rights.

The success of the revolution of the coastal Kuna did not immediately affect the indigenous communities of the Darien Region. However, in 1938, efforts of Kuna communities in the Bayano River watershed to secure title to their collective lands succeeded with the formal

recognition of the Comarca Kuna de Madungandí, the first *comarca* in the Darien Region. It would be 45 years before another *comarca* was recognized in the region.

Two important events of the 1950s and 1960s would have significant implications for intercultural relations in the Darien Region. First, the Emberá and Wounaan broke their tradition of settling in dispersed family units, settling instead in villages where their children would have access to education and other basic services (Herlihy 1986:173). In addition, with the support of the populist government of Omar Torrijos, the Emberá adopted a political system that was modeled after that of the Kuna. Whereas leadership among Emberá and Wounaan was historically diffuse, with family patriarchs intervening on behalf of their families when necessary, the new system included a hierarchy of regional and local chiefs (Velásquez Runk 2005:118). The concentration of the Emberá and Wounaan populations in settlements, and their adoption of a hierarchical political structure, would ultimately help these groups to negotiate for rights over the coming decades (Herlihy 1986).

The second event of the mid-20th century that would heighten cultural politics was the establishment in the Bayano region and, later, Darién Province, of the first settlements of Latino colonists from Panama's central and western provinces (Wali 1993; Herlihy 2003:318). The cattle ranching tradition of these settlers, who until the 1970s would occupy only a handful of settlements in Darién Province, would ultimately transform land cover in the region and initiate an era of land conflicts that continues to this day (Herlihy 2003:318; Heckadon et al. 1984:97). A fundamental difference in the ways land is processed by cattle ranchers vs. swidden agriculturalists underlies much of this conflict. Whereas groups historically occupying Darién processed land in a cyclical fashion (forest > crop > fallow > forest), new colonists processed

land with an end to establishing cattle pasture (forest > crop > pasture), inevitably creating a shortage of forested land (Velásquez Runk 2005; Sloan 2007).

Agricultural booms and busts of the 20th century

> *When I first arrived [in Tucutí] from the San Juan River [Colombia], everyone was selling bananas. After that, it was ipecac*[10] *and plantains. Then, when the government established the buying post [just downriver] in Camogantí, people started to plant large quantities of rice and maize. Then came logging. Today, it's gold that everyone is after.*
>
> - Juan[11], 70, Tucutí

The first agriculture-related boom of 20th century Darién began during the Second World War, and saw bananas shipped out of the major rivers of the region by boat on a weekly basis (Herlihy 1986:149). Unlike the corporate "banana republics" that dominated western Panama, the plantations of Darién were owned mainly by local families (of all ethnicities), and the prosperity experienced by these smallholders earned bananas the moniker of *el oro verde*, or "the green gold" (Mendez 2004:358). The riparian areas of the region were said to be "pure banana" during this period (ibid). Banana boats arriving at the region's river ports were met by farmers from upriver villages in dugout canoes overflowing with bananas.

The people I worked with often reminisced about this era ("ah, that was a time of money"). In the community of Condoto, where in 2007-2008 all of the community's residents

---

[10] The dried rhizome and roots of *raicilla (Carapichea ipecacuanha)* was used to produce syrup of ipecac, an emetic. The plant grows in the forest understory.
[11] Names have been changed

shared two outboard motors, a woman described how her father alone had had three outboard motors during the banana boom. A number of the older people with whom I worked who had been born in Colombia and migrated to Darién during the banana boom to work as labourers in banana plantations. At the time, it was not uncommon for recently immigrated Blacks to work for established plantation owners who were Emberá, and vice versa (Heckadon et al. 1984:86).

The boom was short-lived, however: in the 1950s demand for bananas began to fall as the market became flooded with bananas from other regions. Plantations were struck by Panama Disease (caused by the fungus *Fusarium oxysporum*), and this had a devastating impact on production (Fig. 2.4; F. Herrera, Pers. Comm.). In 1962, refrigerated banana boats from North America stopped coming to the ports of Darién (Herlihy 1986:150) and, according to Mendez (2004:358), the region fell into a depression.

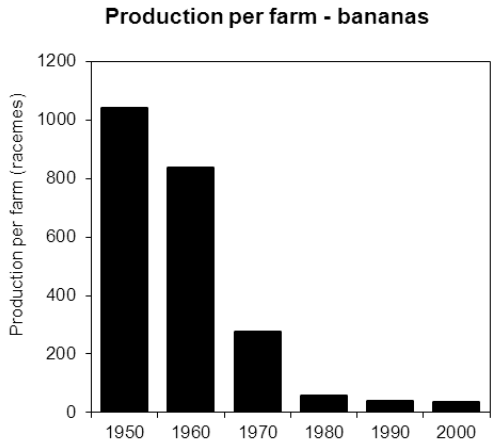


Figure 2.4. Production of bananas per farm from 1950 to 2000 for Darién Province. The decline in bananas after the 1950s reflects the infection of many plantations with Panama Disease (caused by the fungus *Fusarium oxysporum*), combined with falling demand for bananas. Data are from the decadal National Agricultural Census (Contraloría de Panama 1951, 1961, 1971, 1981, 1991, 2001).

In the years after the banana crash, cash cropping of plantains became more important, as did extraction of ipecac, timber, and gold. Slowly, rice cultivation was adopted by Black and

Emberá farmers, encouraged by new market opportunities surrounding its sale (Torres de Arauz 1970:49). The adoption of rice accelerated with the opening in the late 1960s of a series of subsidized buying stations at major river ports in the region (Pagnini 1970:201). There, farmers were guaranteed a price for rice, maize, and, in some cases, yams. This led to a major increase in cash cropping throughout the region.

Blacks featured prominently in their role as intermediaries during the various booms in extractive activities, in part because they faced no language barrier in communicating with Spanish-speaking Panamanians (Perafan and Nessim 2002). However, already by the 1970s an estimated 75% of Emberá men spoke Spanish, having learned the language in order to participate in banana and plantain markets (Heckadon et al. 1984:90). My interviews in Kuna communities suggest that this was also the case for Kuna farmers transporting bananas, plantains and other goods to the port of La Capitana on the Bayano River.

Darién as the country's agricultural frontier

In 1971, the Panamanian government officially launched the "Conquest of Darién" as part of a national development strategy that aimed to reduce the country's reliance on income from the canal-centered service sector (Colin 2010). Instead, foreign currency would be obtained through increased exports of natural resources and agricultural goods. The Darien Region was to fulfill a number of roles in the development strategy. In particular, it would allow for the expansion of the country's agricultural frontier by a planned 26,000 hectares by 1985, and by another 45,000 hectares by 2000 (OAS 1978:7 in Colin 2010:156). It would also absorb marginalized and landless farmers from Central and Western Panama, whose establishment in the region would power the expansion of the agricultural frontier. Again, targets were set:

immigration would boost the local population from 22,750 in 1975 to 38,000 by 1985, and to 105,000 by the year 2000 (ibid).

Figure 2.5 Opening of the Pan-American Highway extension to Darién in 1980. The sign reads: "More than one million hectares of fertile land incorporated into the country's development." (Photograph by Stanley Heckadon Moreno, published in Heckadon Moreno and McKay 1984).

The extension of the Pan-American Highway into Darién was key to the new development strategy and would provide a focal point for settlement and development activities (Fig. 2.5). Prior to 1971, the Pan-American Highway ended at the town of Chepo (Fig. 1.5). By 1984 it had reached its current endpoint in the town of Yaviza. Even before the highway opened, Latino settlers from Central and Western Panama began to claim farmland along its length. Settlers were drawn to the region by government advertising and pushed from their home provinces by land degradation and shortages (Heckadon 1984:23). In areas in which new immigrants settled, pasture quickly replaced forests. The rate at which land was claimed and

cleared was augmented by laws surrounding land titling. The National Agrarian Code of 1962 required farmers to prove the "social function" of their land in order to receive titles to it (Law No. 37 of 1962; Perafan and Nessim 2002:5). This could be achieved by planting crops and establishing pastures on over two-thirds of the area sought (ibid).

Another project key to the new development strategy was a massive hydroelectric dam in the Bayano watershed, at the heart of the Comarca Kuna de Madungandí (Wali 1989). Work on both the highway and dam began in the early 1970s. In 1976, the Bayano Dam was completed and 300 km^2 of fertile farm land were flooded. Over 4,500 Kuna, Emberá, and Latino individuals were displaced[12] (Wali 1993). Preference was given to the Kuna when deciding which of the region's residents would be resettled in the areas immediately around the new reservoir, as the Kuna were seen as the group least likely to replace the forests of the Bayano watershed with pasture, thereby protecting the flow of water to the reservoir (Wali 1989). Emberá families were also resettled in the area, but colonist Latino farmers were resettled out of the region (ibid).

The country's new development strategy also included the establishment of protected areas in which natural resources would be maintained for future use. In 1972, Darien National Park was established near the Panama-Colombia border (at the time it was called Alto Darién Protection Forest; Velásquez Runk 2005:126). The park boundaries were officially delimited in 2001, and the park today encompasses a number of Emberá and Kuna communities. It remains one of the largest national parks in Central America (ibid).

---

[12] Little information is available on the impacts of the dam on Black families who historically occupied the Bayano watershed and were known as "Bayaneros" (see Wali 1993).

Post-highway events

Shortly after the opening of the highway, in 1983, the Comarca Emberá-Wounaan was formally recognized by the Panamanian State (Fig. 1.5). The Comarca included two disjoint areas (the district of Cemaco in the North-East and Sambú in the South-East), which together encompassed almost a quarter of the area of Darien Province. However, about half of the region's Emberá and Wounaan communities did not fall within the Comarca limits and their lands were therefore afforded no protection. In 2000, the Comarca Kuna de Wargandí was recognized. Around the same time, with their lands increasingly being encroached upon, the Emberá-Wounaan communities of Darién Province not encompassed by the Comarca stepped up their campaign for collective titles to their lands (see Fig. 2.10).

While Black communities are said to have launched their own campaign for collective land rights (Perafán and Nessim 2002; Velásquez Runk 2005), the campaign appears to have been abandoned in the mid-2000s. I did not encounter information on why this occurred. However, a report by Hvalkof and Saavedra (2007) described how employees of the land-titling arm of the Programa de Desarollo Sostenible de Darién (PDSD) convinced a number of Emberá and Wounaan communities to abandon their plans to collectively title their lands at the risk of losing them altogether; instead, these communities were convinced to privately title their lands. While the message spread by this group of employees was not the official position of the PDSD, the group travelled throughout Darién in the 2000s to help landholders initiate the land-titling process, and may have had an important influence on decision-making in other communities (for further discussion of PDSD see Velásquez Runk 2005:416). In contrast to Panama, Colombia awarded Black communities in the Colombian Chocó the right to title lands collectively in 1993 (Velez 2011).

The extension of the Pan-American Highway into Darién was paved beginning in 2001, and the paving was completed in 2009. This has further improved access to Panama City for communities along its length. Secondary roads have proliferated as a result of logging activities, and have themselves become focal points for settlement by new colonists. While most of these secondary roads remain impassable during the rainy season, a handful of secondary roads have been paved and provide all-season access to the highway.

Part II – Impacts of the highway

The previous sections highlighted some of the market activities of residents of the region prior to the construction of the Highway. In this section, I explore the extent to which the highway has differentially impacted communities with direct vs. indirect access to it. I focus in particular on the impacts of the highway on market access.

Impacts of the highway on communities without direct access to it

Riverine communities with indirect access to the highway quickly saw markets for agricultural products re-orient to the highway (Fig. 2.8; Herlihy 1986:153). The impacts of this re-orientation were compounded by two other events that took place in the early 1980s. The first was the closure of the government-sponsored guaranteed buying stations for agricultural goods (Perafan and Nessim 2002). The second was the infection of the region's plantain plantations with Sigatoka Disease, greatly reducing production (ibid). Combined, these events resulted in a sharp decline in market opportunities for farmers in riverine communities, even while opportunities for farmers along the highway increased. Shortly after the highway opened in the

1980s, farmers along the highway were already receiving higher prices for their goods than were farmers selling and riverine posts (Herlihy 1986:155,239).

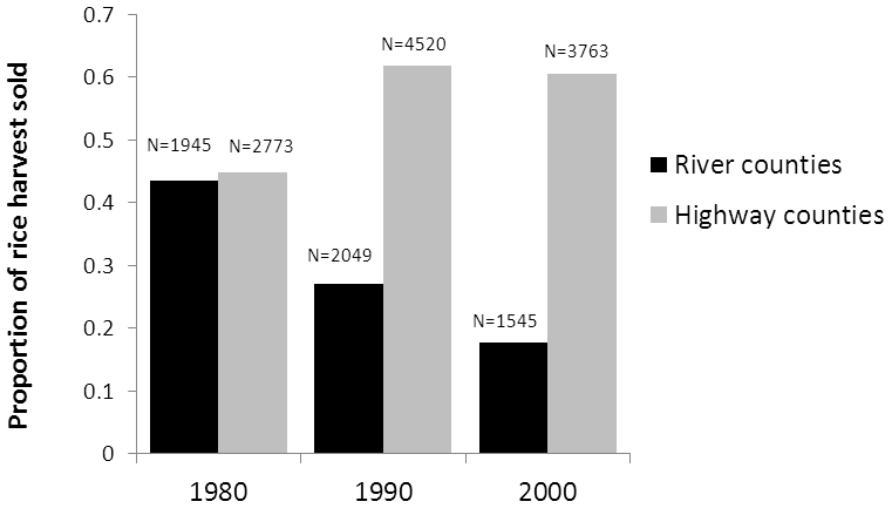


Figure 2.6 Before and after the highway: Proportion of rice harvest sold by farmers in *corregimientos* (counties) with direct vs. indirect highway access. *N* indicates the number of farms contributing data (these data are aggregated by *corregimiento* in Census publications). Note that in 1980 the government had a subsidized buying program that was active throughout Darién, and particularly along major rivers. The program was eliminated in the early 1980s, reducing existing market opportunities for communities with little highway access. Data are from the Decadal National Agricultural Census (Contraloría de Panama 1981, 1991, 2001). See Appendix 2.2 for details, including *corregimientos* included in "highway" and "river" categories.

In interviews, farmers in remote villages were matter-of-fact about the lack of agricultural market opportunities in recent times: "Nowadays, people just plant for the family. Any products that are sold in La Palma [the nearest large town] are sold at a low price to offset the costs of the trip downriver" *(Alicia, 50, Tucutí).*

Those who do venture to transport their goods to markets – for example, by transporting their harvest to the edge of the highway, where it can be sold to an intermediary, face many risks.

In communities with river access to the highway, many families described the horror of a trip to sell a season's harvest in which their dugout overturned as they reached the river mouth, resulting in the loss of the entire harvest. In communities where products are hiked out to roads, farmers are vulnerable to the vagaries of intermediaries, with whom they often have only sporadic contact. Appendix 2.1 includes an excerpt from my field notes which describes an unsuccessful effort by farmers in the community of Nurra to meet an intermediary in order to sell their coffee harvest.

While many families in remote areas have turned to alternative sources of income, such as gold mining and fishing, the economic well-being of families in areas with poor access to the highway is on average worse than of families in areas adjacent to the highway (Fig. 2.9).

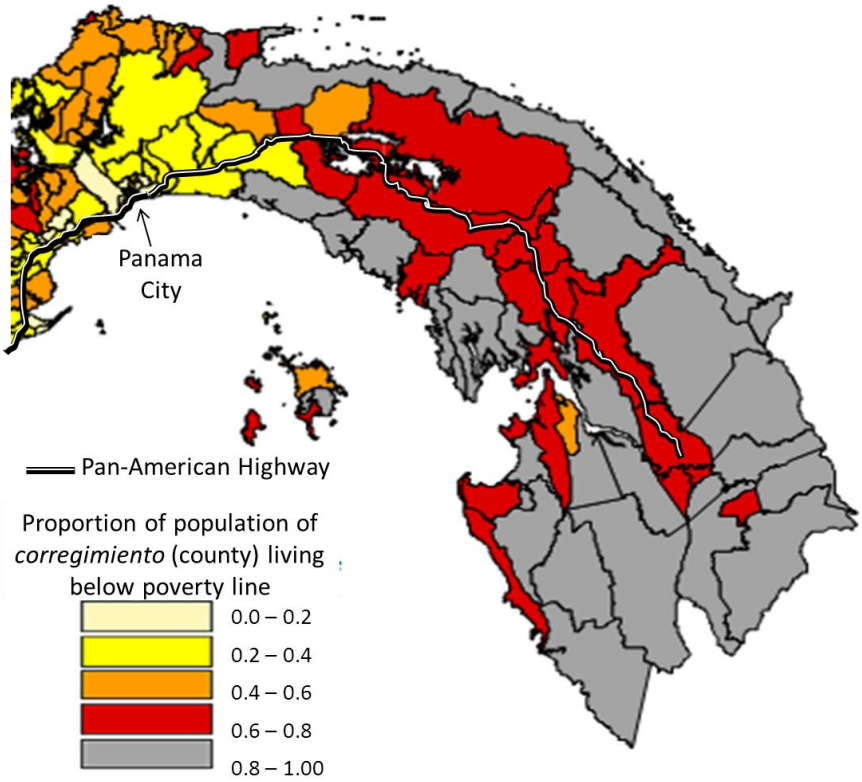


Figure 2.7 Proportion of population below the poverty line by *corregimiento* (county) in 2003. The distribution of red and gray *corregimientos* in the Darien Region highlights the impacts of the highway on economic wellbeing. Persons below the poverty line were those living on less than $ 953 USD annually (Ministerio de Economía y Finanzas, Dirección de Políticas Sociales, 2005). Note that in many of the *corregimientos* without highway access, more than 80% of people were considered to live in extreme poverty (living on less than $534 annually in 2003; ibid).

One of the consequences of the crisis in the agricultural markets following the opening of the highway was the emigration of many families and young people to Panama City. This pattern of emigration was particularly strong in Black communities (Heckadon et al. 1984:86; Perafan and Nessim 2002). One woman in a remote Black community described the pattern:

> *Many have gone to the city. Sometimes they go to accompany someone who is sick to the hospital, but then they decide to stay. They still keep their houses here, and sometimes the mother [i.e., the family matriarch, usually the grandmother] stays.*

But I don't know why they go, especially the ones without work. They leave their montes *[land] here, where they could harvest plantain, cassava,* ñampi *[yam],* otoe *[taro], maybe not in huge quantities but one always has something to eat. But in the city, where can they get plantain? Who is going to give them a plantain, or a pound of rice?*

Impacts of the highway on communities adjacent to it

Shortly after plans for the highway were announced, the Kuna community of Ipetí relocated itself to the edge of the highway, where they felt they would better be able to protect their lands from encroachment. This was a prescient move, as immigration by landless settlers skyrocketed with the opening of the highway. Communities such as Arimae (an Emberá community about halfway between Chepo and Yaviza, Fig. 1.6), which did not have any government recognition of their land rights, were less successful in maintaining their territories. The sequence of events in Arimae was described to me as follows by an elder from the village who has long been active local politics:

In 1971, knowing the highway was coming, we cut the first trocha [boundary line] *around our lands. It passed through Agua Fría No. 1* [today a highway town] *and stretched into the hills to the South, encompassing 72,000 ha. To the North, the land of the Kuna of the Chucunaque River provided a boundary. At that time there was only one* interiorano[13] *with land in the area. There were always* darienitas[14] *around, but they were constantly moving, working in gold or logging. They weren't worried about claiming land, they didn't realize its value. Even we didn't realize how valuable the land was. In 1972 we petitioned the government*

[13] An 'interiorano' is a person from Panama's 'interior' (central or western provinces).
[14] '*Darienita*' was traditionally used to refer to Blacks in Darién

for a collective title to the 72,000 ha, but we didn't get anywhere. Things were quiet for a few years. But then, in 1977, like a pest outbreak, the colonists began to arrive. They moved into our lands, into areas we had delimited, they even claimed 200 ha of rastrojo *[fallow land] near Agua Fría. When we complained to the government, the government told us they would recognize claims to land under pasture, but not to land under* rastrojo. *But we did not want to convert our lands to pasture. The colonists were so aggressive that in 1979 we agreed to reduce the area of our land claim. We thought that we had a final agreement with the government. But then, in 1980, the government asked us to make it smaller again. This happened again in the 1990s. Today our* trocha *encompasses only 8,000 ha, and even now our lands are being invaded. The government still has not issued our collective title, and we are financing our legal fight by logging the forests we have left.*

Even the community of Ipeti-Kuna, which was within a legally demarcated *comarca* and which preemptively relocated to the highway edge to be able to better control invasions, faced land encroachment. These invasions continue to this day. One resident of Ipetí-Kuna summed it up this way:

The highway has its advantages. We can more easily sell our agricultural products. But the disadvantage is that it has facilitated the colonization of our lands by **wagas**[K,15]*. It is fine that the government has facilitated access to land for other social groups. But it is not fine that those groups are now trying to take what is ours.*

---

[15] Here used to refer to *latino* colonists. Throughout the text, words in the Kuna language (Dulegaya) are indicated using a "K" superscript and underlining.

Another was more negative:

> *Today we are seeing and savouring the results of the opening of the highway [...]. The invasion of our lands by colonists is now uncontrollable. They don't respect our legalized lands, they are raping them. Even the State is not protecting or supporting us. We are now surrounded by* **wagas**[K]*, our lands are being filled with pastures, and [escaped] cows are eating and destroying our crops. We have serious problems.*

Some of the changes in land use alluded to in this last quote are illustrated in Fig. 2.8, which highlights changes in land cover between 1990 and 2008. By 2008, almost a third of the forests of the Darien Region had been converted to crop and pasture land, with pasture concentrated along the highway and outside of indigenous *comarcas* and collective lands (Nelson et al. 2001; Velásquez Runk 2005, 2010; ANAM 2009). Many of the remaining forested areas in the region have been selectively logged by logging companies.

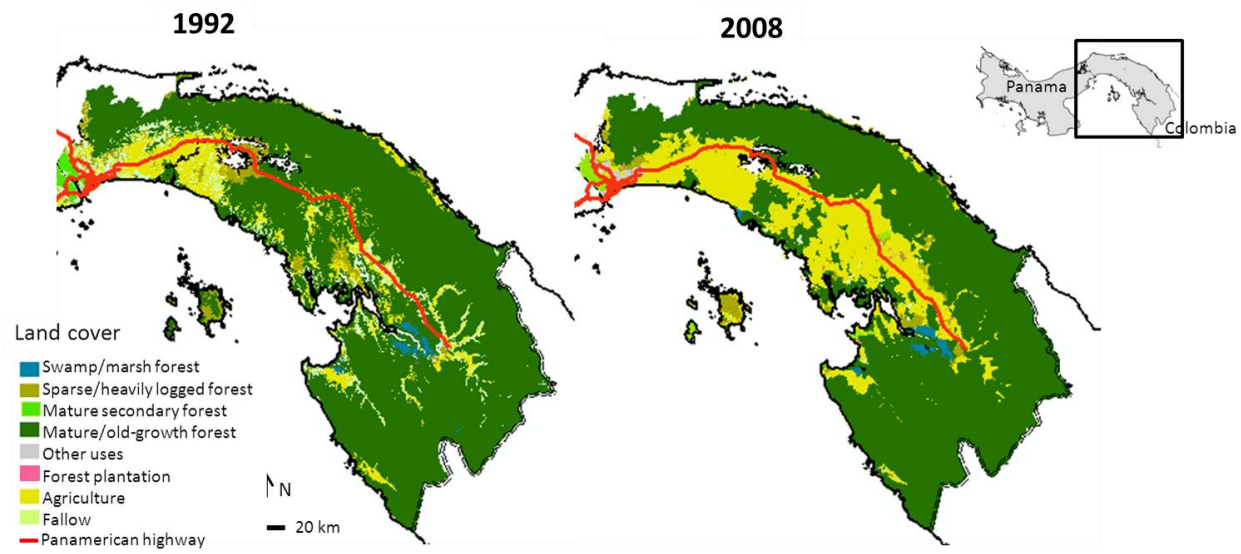


Figure 2.8 Land cover of Eastern Panama in 1992 and 2008. Note the large-scale conversion over this time period of forest to agricultural land (mainly pasture) in areas most easily accessed by the highway (Land-cover data obtained from Panama's National Environmental Authority (ANAM) in 2009).

Population structure and territorial divisions today

In 2010, approximately 10.7% of the population of the Darien Region identified as Black, 18.5% as Emberá, and 6.9% as Kuna. Another 4.8% of the region's population identified as Wounaan, and 2.7% as belonging to another indigenous group (Contraloría de Panama 2010a, b). The remaining 56.4% identify as ethnic Panamanians; in Darién, these people are generally known as "*colonos*" (colonists) or "*interioranos*" (because of their origin in the "interior" or central provinces of Panama) (ibid; Fig. 2.9; please see Appendix 2.3 for details on estimates).

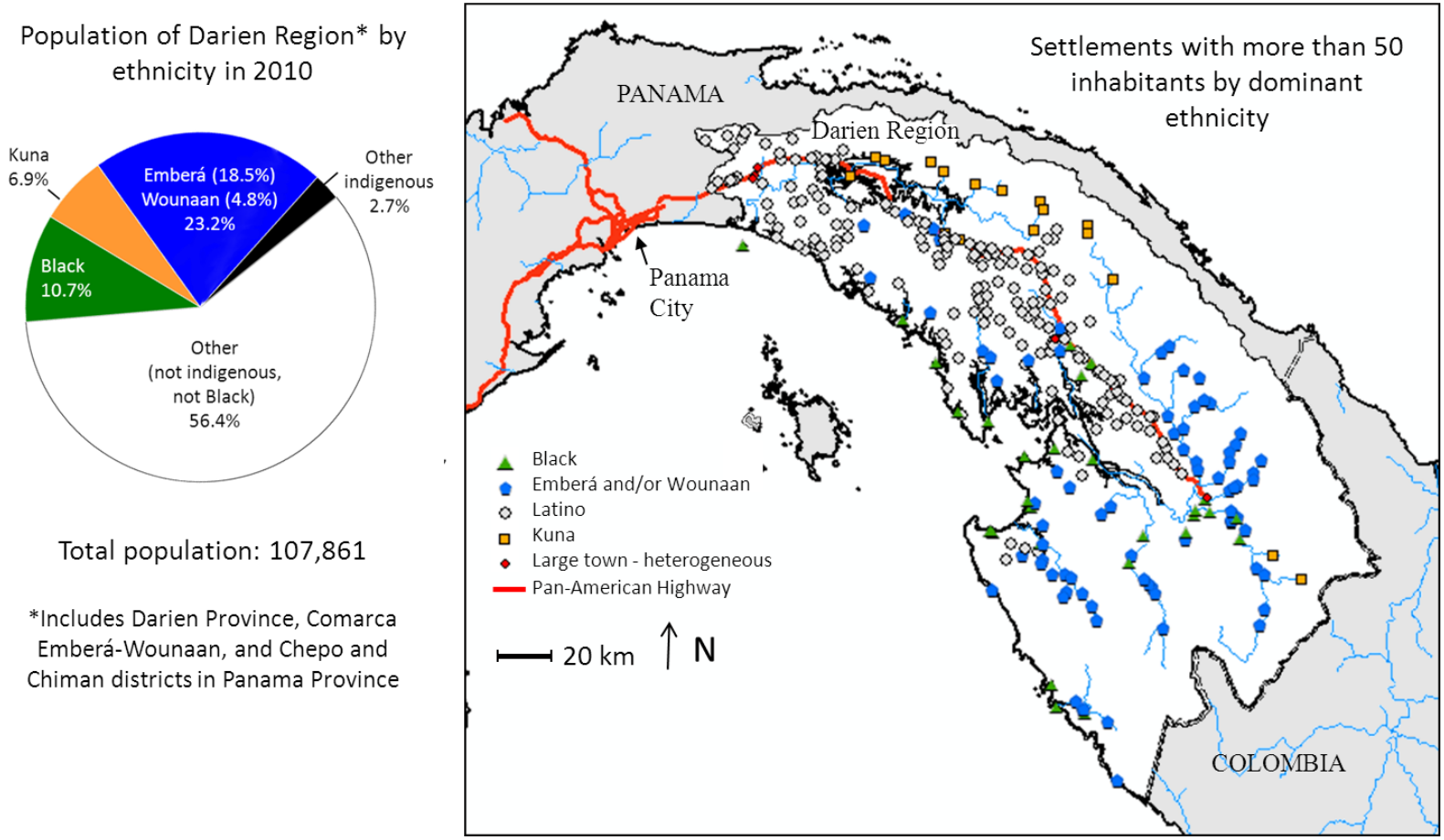


Figure 2.9 Population of the Darien Region by declared ethnicity in 2010, and map of settlements with greater than 50 inhabitants by dominant ethnicity. Population data are from the 2010 National Population Census (with a few exceptions; see Appendix 2.3). Data on location of settlements were obtained from the National Environmental Authority (ANAM) in 2006. Data on ethnicity of settlements are from Herlihy 1989:8; Dames and Moore 2001; PRONAT 2008; Ventocilla 2004. Please see Appendix 2.3 for detailed discussion.

Management of land by different ethnic groups

While the huge influx of migrants into the region following the opening of the Highway might suggest that the Black, Emberá, Wounaan and Kuna population of the Darien Region now have only a minor influence on the region's landscape, this is not the case. Indeed, summing the areas of (1) indigenous *comarcas*, (2) indigenous collective lands under consideration by the National Program for Land Administration (PRONAT), and (3) a population-proportional estimate of the areas managed by the Black population of Darién suggests that these groups are the primary users of approximately two-thirds (61%) of the land base of the Darien Region (Appendix 2.3). While there are many caveats associated with this estimate (discussed in Appendix 2.3), and it is more conservative than previous estimates which identified the majority of the Province of Darién as Emberá, Wounaan or Kuna subsistence zones (Chapin and Threkeld 2001 in Velásquez Runk 2007), it provides a starting point from which to consider the important role of these communities in managing the landscape of Panama's Darien Region.

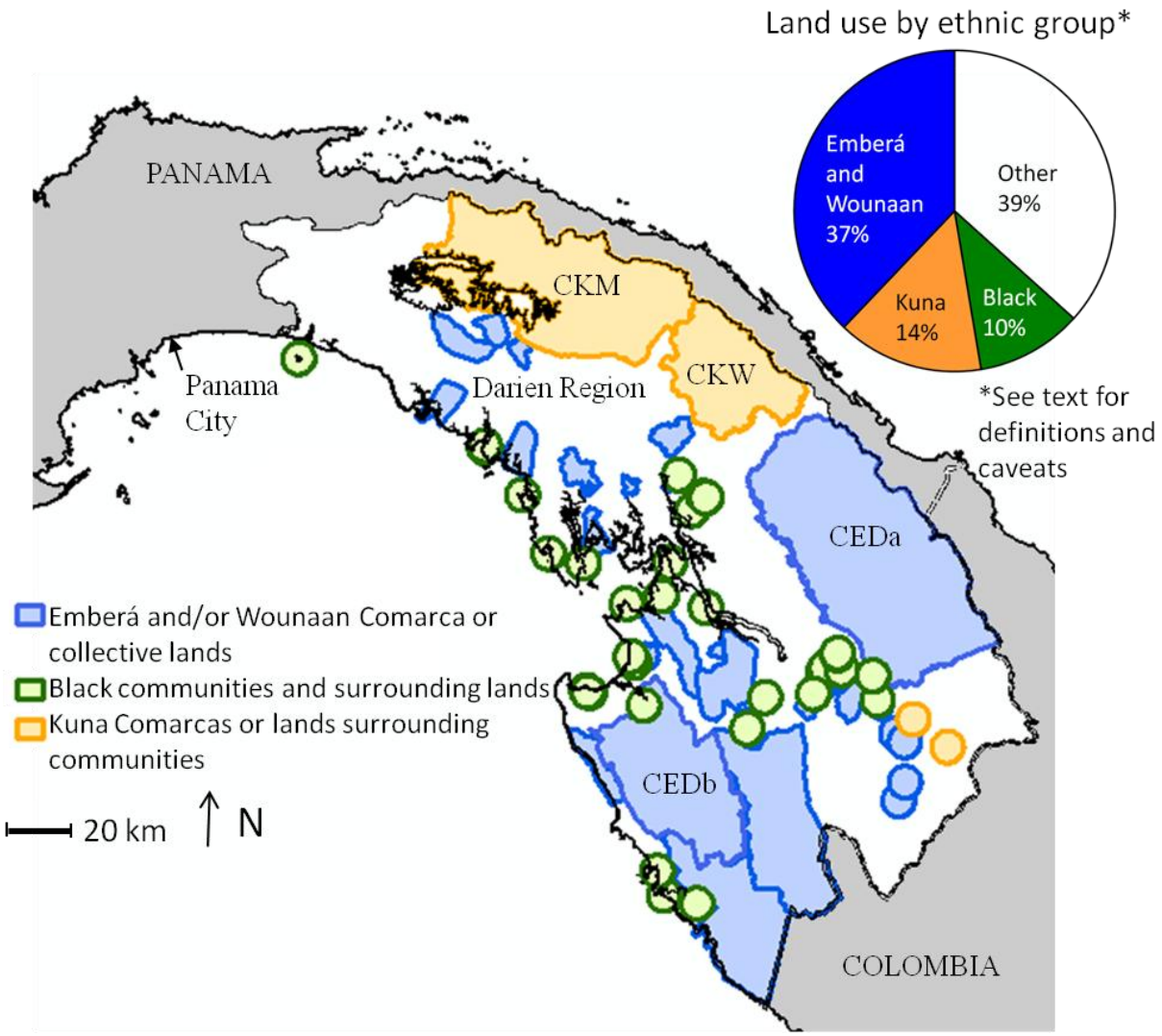


Figure 2.10 Areas titled, claimed or surrounding Emberá-Wounaan, Kuna and Black communities in the Darien Region. Note that the only officially demarcated areas are the Comarca Emberá-Drua (CEDa and b), Comarca Kuna de Madungandí (CKM), and Comarca Kuna de Wargandí (CKW). Other blue- and orange-coloured areas include those claimed as collective lands by Emberá-Wounaan communities not encompassed by the Comarcas, and land surrounding Emberá and Kuna communities in the *corregimientos* of Pucuro and Paya in the Northeast corner of the region. As no data were available on areas claimed as collective lands by Black communities, or areas privately titled by members of communities that are predominantly Black, a circular zone around each of these communities is indicated, and an assumption made for area estimates that the area managed by these communities would be at least proportional to population (10%). Appendix 2.3 describes in detail the methods used to produce the map and the caveats associated with these methods.

Part III - Maintenance of ethnic boundaries

The fact that ethnic boundaries have been maintained among Kuna, Emberá and Black communities in the absence of geographical barriers among the groups has been highlighted by a number of scholars as remarkable (e.g. Stipek 1974; Losonczy 2006). For the purposes of this study, ethnic boundaries among groups are relevant in that they may also represent boundaries among knowledge and belief systems, and hence among practices related to agriculture. Here, I summarize some of the historical and current-day factors that may have contributed to the maintenance of inter-ethnic boundaries in the Darien Region.

A major force in the maintenance of ethnic boundaries among Kuna, Emberá and Blacks has been the practice of ethnic endogamy[16], which has been adhered to more or less strictly by each group at different points in history (Howe 1974a:21 in Stier 1979:82; Bennett 1962:46; Torres de Araúz 1980; Kane 1986: 287). While each group might have been endogamous even in the absence of external intervention (i.e., because of language differences, and/or fundamental differences in world views and belief systems), efforts by the ruling elite to exploit differences among the groups as a means to maintaining or maximizing power almost certainly contributed to feelings of mistrust among the groups[17]. Examples of this exploitation include early colonial policies designed to segregate Blacks and Natives, and the role of the Spanish in pitting Blacks and Emberá against Kuna in the 18th century. Please see Part 1 for further discussion.

---

[16] The practice of marrying within a specific ethnic group,

[17] Though see interesting note in Kane 1986:284 which describes efforts by Catholic curates from Spain, working in Darién, to reverse "racial asymmetry" in the choice of godparents by Emberá. The curates banned the choice of Black godparents by the Emberá, as they thought that this was a sign of the poor self-image of the Emberá, rather than a means to negotiating the economic, spiritual landscape of Darién (see description of compadrazgo system on p. 32).

Spanish policy also may have fostered attitudes of cultural superiority among the groups, and have contributed to the fears of some groups of the magico-religious powers of others. These factors remained important determinants of Black-Emberá relations at the close of the 20th century in both Panama and north-western Colombia (e.g., Stipek 1974; Pacheco and Velásquez 1993; Mortensen in Velásquez Runk 2005:144; Losonzcy 2006; Kane 1986:278-285), and of Emberá-Kuna relations in Panama (Kane 1990).

More recent analyses of boundary maintenance among these groups highlight the roles of identity politics in conflicts over land and resources, and the role of State policies in shaping minority identities (Wali 1989; Velásquez Runk 2005; Colin 2010). For example, in her dissertation on the impacts of the Bayano dam and highway on communities in the vicinity of the dam, Wali (1989: 150, 159) argued:

> *I would claim that before the late 1960s, (when there was no significant colonist migration into the region and no development projects), the Bayano population, while aware of differences between [ethnic] groups, did not actively maintain or exploit separate identities as a political strategy […] Inter-group conflict increased in the years after the construction of the dam, as each group solidified boundaries in order to preserve their access to land. The Kuna and Emberá used their ethnic identity as political "bargaining chips" to negotiate rights to resources.*

More recently, the concept of indigeneity has proved to be a source of tension in the region, particularly with respect to Black communities, who are not considered indigenous by the State and have been afforded no collective land rights despite their history in the region (e.g., POTLATCH 1998). Appendix 2.4 presents the perspectives of members of one Black community with which I worked on ethnic identities and inter-ethnic relations.

Summary and conclusion

In this chapter I have introduced the origins and histories of the Black, Kuna and Emberá communities of Panama's Darien Region[18]. In the absence of geographical barriers among groups, a combination of political, economic and social factors has contributed to the maintenance and evolution of the groups' distinct identities over the last five centuries. Today, these three groups are the primary users of approximately 2/3 of the landscape of eastern Panama, and each group has communities and territories throughout the region, creating a complex cultural territorial mosaic.

While communities in eastern Panama have historically participated in commodity markets (e.g., gold, bananas, timber), the extension of the Pan-American Highway into Darién in the 1970s created a new, more reliable market connection. The paving of the highway between 2001 and 2009 has further reduced travel times and risk surrounding the transportation of agricultural goods to markets. For highway communities, the reliability of the highway as a transportation corridor has made it feasible for farming households to rely entirely on income from cash crops and other market activities for the procurement of food (i.e., rather than growing some portion of it). This is much rarer in more remote communities, where high transportation costs result in lower profits and where farmers are vulnerable to the vagaries of intermediaries.

---

[18] My focus on topics most relevant to my dissertation research has forced me to omit much of the region's rich history from the 18th century onward. I also have not touched on some of the topics that keep the Darien Region in national and international news – from the role of the region as a refuge for Colombian guerillas and paramilitaries, to ongoing discussions surrounding the closing of the 'Darien Gap' via a final extension of the Pan-American Highway to Colombia. A more in-depth discussion of the region's history and current events is presented by Velásquez Runk (2005).

As a result, a sharp gradient exists in terms of farmers' access to markets, largely reflecting their location relative to the highway.

Together, the cultural territorial mosaic of the Darien Region and the sharp gradient in market access that is centered on the Pan-American Highway provide an opportunity to explore the relative influence of cultural vs. market-related factors on distributions of agrobiodiversity. In the next three chapters, I explore this topic with respect to three different forms of agrobiodiversity that are particularly relevant to the agricultural systems of shifting cultivators in eastern Panama: annual crop landraces (Chapter 3), agroforest species (Chapter 4), and fields (Chapter 5).

Chapter 3: Cultural diversity is essential to agricultural biodiversity in a tropical frontier

Introduction

Access to crops adapted to a broad range of environmental conditions is expected to be particularly critical over the coming century as farmers contend with climate change, water scarcity, agricultural land degradation, and the increasing costs of petroleum-based fertilizers and pesticides (IAASTD 2008; FAO 2010). Over the last century, 75% of crop genetic diversity has been lost globally (Pretty et al. 1995; FAO 2010). These losses have motivated a global effort to conserve crop diversity *ex situ* in seed banks and botanical gardens (Frankel 1970). However, *ex situ* conservation efforts are limited in their ability to provide continued and easy access to crop diversity for farmers and plant breeders in need (Altieri and Merrick 1987; Oldfield and Alcorn 1987).

In situ, or "on-farm," conservation overcomes many of the limitations of *ex situ* conservation. As such, it is widely recognized as necessary and complementary to *ex situ* conservation (Brush 2004; Hodgkin et al. 2007). Partnerships with small-scale farmers provide one of the most promising approaches to maintaining crop diversity *in situ.* However, many small farms are located in areas where the expansion of rural infrastructure and global trade is transforming local economies and cultures at an accelerated rate (Kramer et al. 2009).

---

[19] Co-authors: Kathryn R. Kirby, Sarah E. Gergel, and Domingo Diaz

Understanding how these transformations affect crop diversity will be critical to successful *in situ* conservation.

Traditionally, economic incentives and constraints have been considered paramount in explaining losses of crop diversity (Harlan 1975). Spatial economic models predict that farmers will specialize in commercially valuable crops as they become more integrated to markets, with a resultant loss of crop diversity (Von Thünen 1966). While such models have been validated in many settings (Zimmerer 1991; Humphries 1993; Heinrich 1997; Bellon 1996; Peroni and Hanazaki 2002), field studies have also revealed cases where crop diversity increases with increasing market access (Vadez et al. 2004; Perrault-Archambault and Coomes 2008). Other cases demonstrate, despite some losses, persistence of local landraces and crops within modernized production systems (Brush 1995). Market-based explanations for these contrary findings are diverse, and include the role of markets as sources of novel crops (thus offsetting local losses), and opportunities for farmers who have good access to markets to commercialize rare or underutilized crops (Dennis et al. 2005; King and Smale 2005).

Non-market values of crops provide alternative explanations for farmers' decisions to maintain crops with little or no commercial value (Boster 1986; Benz et al. 2007). These values may be strongly linked to farmers' cultural identities and to the belief- and knowledge-systems they embody (Atran et al. 1999; Benz et al. 2007). Many small-scale farming landscapes are mosaics of land managed by different ethno-linguistic groups, with ethnicity, language and place-based experience providing powerful sources of cultural identity. Previous work exploring relationships between cultural identities and crop diversity has often used ethnicity as a proxy for culture, but has failed to decouple the influence of cultural, biophysical and economic factors on crop diversity (but see Perales et al. 2005). In part this failure reflects the fact that different

cultural groups often occupy ecologically and economically distinct areas, such as discrete altitudinal zones or areas with differing access to markets.

Here, we examine the relationship between ethnicity, market access and crop diversity in Panama's Darien region, while controlling for the effects of biophysical factors known to influence agriculture. Working with Black, Emberá and Kuna farmers in villages with contrasting access to markets, we addressed the following questions: (1) Do farmers of different cultural identities maintain different total numbers and distinct assemblages of crop landraces? (2) How is market access related to the richness and composition of farmers' landrace assemblages? (3) What is the relative importance of cultural vs. economic factors in explaining the distribution of crop diversity among villages in the region?

Methods

Study region. The Darien Region provides an exceptional landscape in which to examine the relative influence of markets and cultural identities on agrobiodiversity (Fig. 1.6). In the 1980s, the region was first bisected by the Pan-American Highway, which remains the only road connecting the region to Panama City (Heckadon Moreno and McKay 1984). Paving of the highway began in 2001 and was completed in 2009, dramatically reducing travel times to Panama City for villages on the highway. Because there are few agricultural markets outside of the capital, farmers must either take their harvest directly to Panama City, or sell it at a lower price to an intermediary. The presence of intermediaries is extremely unpredictable except along the highway. These factors result in a sharp gradient of access to markets by villages depending on a village's position relative to the highway.

The Darién represents the northern limit of the Chocó bioregion, an internationally recognized biodiversity hotspot (Conservation International 2005). It extends east from the town of Chepo in Panama Province to the Colombian border and is bounded to the south by the Pacific Ocean and to the north by the San Blas range. Elevation in the region ranges from 0-1,875 masl. Average temperatures in the lowlands range from 25-27°C and rainfall from 1600-4500 mm annually, with a marked dry season from January through April (Hijmans et al. 2005). Shifting cultivation is the dominant agricultural system. The region's native races of maize (*Zea mays*) are part of the Lowland Tropical American Cluster, which is second only to the Highland Mexico Cluster in terms of its genetic diversity (Roberts 1957; Vigouroux et al. 2008). Other staple crops native to the region include cassava (*Manihot esculenta*), New World yams (*Dioscorea trifida*), and taro (Xanthosoma spp.). Because the Darien Region was one of the first sites of European settlement in the Americas, Old World crops such as upland rice (*Oryza sativa*), bananas and plantains (*Musa spp.*), yams (Dioscorea spp.) and taro (*Colocasia spp.*) were incorporated into indigenous cropping systems relatively early in this region. For example, bananas and plantains are thought to have been incorporated into Kuna agriculture in the second half of the 16th century; by 1681 they were "an important food item" in the Kuna diet (Wafer 1934).

We worked with farmers of three ethno-linguistic groups: Kuna, Emberá, and Black. The Kuna and Emberá are indigenous to the region and belong to the Chibchan and Choco language groups, respectively (Lewis 2009). The Black population of Darien is descended from Africans who arrived in the Americas as slaves beginning in the early 1500s (West 1957; Losonczy 1997). Despite their diverse origins in Africa, colonial laws forbidding the marriage of slaves of the same tribal group forced the emergence of a shared identity over the course of the colonial period

(Losonczy 1997). The three groups have maintained long-standing exchange networks for goods, labour, and healing services (Vargas 1991; Losonczy 1997). However, the majority of the region's settlements remain segregated along ethnic lines, a fact that has not changed with the arrival in the region over the last century of *Latino* settlers from western Panama (Hernandez 1970).

Study design. Working with regional indigenous congresses and institutions, we selected twelve villages with varying access to markets (Chapter 1, Appendix 1). Each cultural group was represented by four villages, two located on the Pan-American Highway (or just off it, with all-season road access; hereafter referred to as "highway villages") and two villages with more difficult access to the highway ("remote villages") (Fig. 1.8; village K1b was not included in this study). Because surplus agricultural products are generally sold in Panama City markets or to an intermediary on the highway, village position relative to the highway has an important influence on market access. In each village, we selected a random[20] sample of approximately 10 households (range 8-15) growing at least one of the region's staple crops[21]. We considered a household to be a family unit sharing agricultural fields, seeds, and labor. Only data from households where the farmer(s) self-identified as being part of the dominant cultural group of the village were analyzed (123 of 125 households).

---

[20] We chose a random sampling strategy because we did not have a priori knowledge about how agrobiodiversity was distributed among households in the study villages. Work from other regions has reported contrasting relationships between variables such as household wealth and agrobiodiversity (e.g., Yongneng 2006; Perreault-Archambault and Coomes 2008; Isakson 2011), suggesting that such knowledge is a necessary prerequisite for the design of effective stratified sampling regimes.

[21] We sometimes were unable to work with ten households during the period we had reserved for work in each village (e.g., because of community-wide congresses and other events, or because of medical or transportation problems), and in some cases found ourselves with additional time and therefore worked with additional households.

We controlled for the impact of several biophysical variables known to influence agriculture in the region by selecting villages in lowland areas (<135 meters above sea level) and in such a way as to avoid systematic differences in annual precipitation among villages of particular cultural groups and among remote vs. highway areas (Hijmans et al. 2005). We used ANOVA to test whether this aspect of our study design was successful. We could not control for differences in soil characteristics *a priori* because of a lack of data (IDIAP 2006). We therefore collected composite soil samples from a rice or maize field of each participating household as part of our research in each village. Soil samples were analyzed at the Instituto de Investigación Agropecuario de Panamá for pH, organic matter, and the following nutrients: P, K, Mg, Ca, Al, Mn, Zn, Fe, Cu. The median level of each soil variable was calculated for each village and used to test for a significant difference among villages of different cultural groups or at different distances to the highway.

We also used ANOVA to confirm that our categories ("remote" vs. "highway") reflected differences in market access (measured as time for trip to Panama City market and cost to transport 20 *quintales* (approximately 2000 lbs) of goods to Panama City market; Table 1.1). The independent variables in the ANOVA were village position (remote or highway) and ethnicity (Black, Emberá or Kuna). We further used ANOVA to test proxies for participation in markets, including: proportion of community members owning stoves, tin roofs, and motorized or electrical appliances, and time since last trip to the capital city (Table 1.2).

Measuring crop diversity. We assessed two key components of crop diversity: richness (total number of landraces) and composition (differences in landraces) for six principal food crops providing important sources of carbohydrates in the region: rice, *Musa spp.*, maize, yams,

cassava, and taro (hereafter, staple crops; Duke 1968, 1970, 1975; Torres de Arauz 1970; Pagnini 1970; Howe and Chapin 1975; Stier 1976; Stier 1982). In defining the six staple crops, some closely related biological species were grouped as a single crop. In particular, all landraces of the species *Musa paradisiaca*, *Musa acumens* and their crosses were classified as "*Musa spp.*" (banana and plantain group). "Yams" consisted of all landraces of *Dioscorea spp*., including old world yams (known by the Spanish name *ñame*) and the new world yam *Dioscorea trifida (ñampi*). "Taro" included *Xanthosoma spp.* (*otoe*) and *Colocasia spp.* (*papa china*). Maize, rice and cassava were each represented by landraces of a single biological species (*Zea mays (maíz)*, *Oryza sativa (arroz)*, and *Manihot esculenta (yuca)*, respectively). Landraces were defined as farmer-differentiated varieties (Jarvis et al. 2000; Gibson 2009).

Richness and composition were assessed through a combination of field inventories and follow-up questionnaires. In 2008 we visited a subset of each household's fields and documented all of the landraces of each staple crop being cultivated. In total, we inventoried 447 fields belonging to 123 households across the twelve villages. In early 2009, we returned to the same households to verify our 2008 inventories by reviewing the list and descriptions of landraces encountered in 2008. We then asked whether in 2008 the household had planted any of the other landraces we had documented in the region. This provided reliable data on the total number of landraces of each staple crop that each household maintained in 2008 (richness data).

Standardization of landrace names across households and villages was necessary for evaluating the distinctness of the landraces maintained (differences in composition). Because the standardization process was iterative and therefore time intensive, we focused on standardizing landrace names for three of the six crops (maize, rice, and *Musa spp*.). Standardization of landrace names was based on researchers' documentation of landrace phenotypes during field

inventories, farmers' descriptions of landrace characteristics (appearance, time-to-maturity, ecological sensitivities), and individual and community-level discussions of photographs and a travelling set of voucher specimens. In a few cases where a subset of farmers distinguished between several landraces that other farmers considered a single landrace (Jarvis et al. 2008), we used a conservative approach and distinguished only a single landrace. This was necessary only for a few *Musa spp*. Voucher specimens of maize and rice landraces were deposited at the herbarium of the Universidad Nacional de Panama.

Statistical analyses of crop diversity. We used three types of analyses (mixed models, multivariate analyses, and correlation analyses) to address each of our research questions as different analyses were best suited to exploring trends in crop richness vs. crop composition. For analyses of richness, count data corresponding to the number of landraces of each staple crop maintained by each household were averaged and analyzed using ANOVA[22]. For two crops (maize and yam) we observed an increasing variance at higher mean values and therefore log transformed the data. Treatment variables were cultural identity and highway access (as a proxy for market access). Analyses were performed in SAS v9.2 (SAS Institute Inc. 2008).

Compositional data for maize, rice and *Musa spp.* were summarized in village-by-landrace matrices (one matrix per crop, 3 in total) as the proportion of households in a village maintaining each landrace. These matrices were converted to village-by-village dissimilarity matrices using the Bray-Curtis distance measure. We then used a permutational multivariate

[22] We also tried analyzing this data using mixed models with a Poisson distribution, with households nested within villages. This gave qualitatively similar results, but the assumptions of the linear model were better met by our data and so we report those results here.

analysis of variance (PERMANOVA; Anderson 2001; Fig. 3.2) with 9,999 permutations per analysis to test whether cultural group or highway access explained a significant proportion of the dissimilarity between villages. Analyses were performed in R using the adonis function of the vegan package (Oksanen et al. 2008). Upon finding significant differences in crop similarity among cultural groups and/or with distance to the highway ($p<0.05$), we performed additional analyses to identify the individual landraces that differed. In particular, we determined the Pearson correlation between each landrace and each predictor variable. Although the statistical significance of the Pearson correlations should be viewed with caution because of a large number of comparisons, the value of the correlation coefficient gives an indication of a landrace's tendency to be planted by a specific cultural group or in remote vs. highway villages.

Mechanisms underlying patterns of crop diversity. We hypothesized that patterns of crop diversity might be influenced by the dietary importance of different crops and (2) seed exchange networks, which themselves might be related to ethnicity. To explore correlations between landrace richness and dietary importance, we asked households to rank staple crops in terms of their dietary importance (see Appendix 3.4 for details). We used a random coefficient regression (RCR) model to test whether there was a common correlation between richness and dietary importance across crops. RCR models allow the slope and intercept to vary between subjects (in this case crops), and tests whether there is a significant, common trend among subjects. Richness and rank data for each crop were standardized because of their different ranges. To explore seed exchange networks, we asked households where and from whom they had acquired seed maize and rice landraces planted in 2008. If obtained from a specific person, we asked about that person's ethnicity. We then calculated the proportion of landraces found in each village that were

acquired from farmers of the same ethnicity, different ethnicity, from government donation programs, or from stores.

Results

Validation of study design. Selected villages were distributed throughout the region to avoid a correlation between cultural group, highway access and the biophysical environment: the altitude of all villages was less than 135 meters above sea level, and annual precipitation did not differ significantly by cultural group or between remote vs. highway villages (ANOVA $F_{5,7}$=0.83, p=0.57; Table 1.1). A global test of median soil values for the variables pH, organic matter, P, K, Mg, Ca, Al, Mn, Zn, Fe, and Cu was conducted using a multivariate comparison, ADONIS, in R. The test revealed differences in soil characteristics with village location relative to the highway (R^2=0.22, p=0.04), but not with village cultural identity (R^2=0.10, p=0.85; Appendix 3.1). In view of this result, each soil variable was compared by village location relative to the highway using a two-sample t-test. Two nutrients differed: phosphorus was significantly higher in highway village soils ($t_{6.021}$= 2.930, p = 0.03), and zinc was significantly higher in remote village soils ($t_{9.943}$= 2.284, p = 0.04).

Our measures of market access differed significantly between remote and highway villages. That is, average travel time to Panama City was significantly longer for remote compared to highway communities (12 hours vs. 4 hours; $F_{2,6access}$=33.43, p<0.01) and average transport costs for 20 *quintales* of agricultural goods were significantly higher for remote compared to highway communities ($152 vs. $62; $F_{2,6access}$ =31.95, p<0.01; Table 1.1). Neither travel time nor transport costs differed significantly with village ethnicity, though the average travel time to Panama City was marginally shorter for Kuna communities than for Black or

Emberá communities (6 hours vs. 9 hours; F_{group}=3.73; p=0.09; Table 1.1). Household-level proxies for participation in markets confirmed that our measures of "market access" also reflected household participation in markets: across all cultural groups, a greater percentage of households in highway villages compared to remote villages owned gas stoves (74% vs. 38%; $F_{2,6access}$=86.64, p<0.01), tin roofs (54% vs. 35%; $F_{2,6access}$=100.76, p<0.01), and an appliance (58% vs. 29%; $F_{2,6access}$=39.92, p<0.01). In addition, a much shorter time period had passed since members of highway households had visited the capital city (5 months vs. 22 months since last visit; $F_{2,6access}$=26.35, p<0.01). However, for all of these variables except the latter, there were also significant differences among cultural groups. On average, a greater proportion of Black households owned stoves, tin roofs, and an appliance than Emberá or Kuna households (Stoves: $F_{2,6group}$=15.43, p<0.01; Roof: $F_{2,6group}$=9.08, p<0.01; Appliance: $F_{2,6group}$=12.09, p<0.01; Table 1.2).

Richness of landrace assemblages. On average, across all villages, households maintained 2.2 landraces of rice (range 0-10), 1.4 landraces of maize (0-5), 8.6 landraces of *Musa spp*. (1-21), 2.2 landraces of yam (0-8), 1.3 landraces of cassava (0-5) and 0.6 landraces of taro (0-3). Cultural identity of the household was a significant predictor of landrace richness for all staple crops except taro. Importantly, the cultural identity of villages in which households maintained the highest number of landraces differed by crop (Fig 3.1 a-f). Black farmers maintained the highest diversity of yams (mean 3.2 (±0.4 SE) landraces per household). Emberá farmers maintained the highest diversity of rice (mean 3.1 (±0.4) landraces per household). Kuna farmers maintained the highest diversity of maize and *Musa spp.* (mean 2.2 (±0.4) maize landraces and

12.9 (±0.7) *Musa spp.* landraces per household). Black and Kuna farmers both maintained relatively high numbers of cassava landraces (1.6 (±0.1) and 1.3 (±0.1) landraces, respectively).

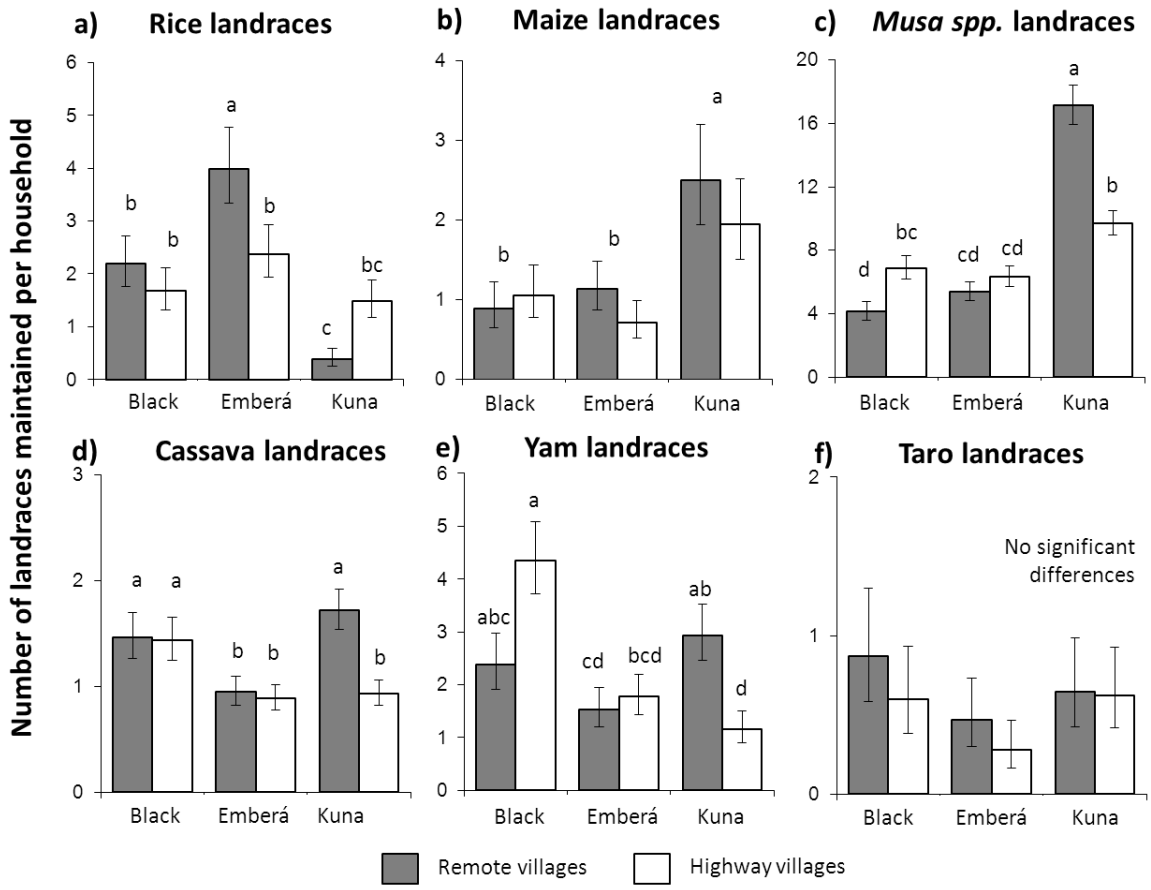


Figure 3.1 Number of landraces of each staple crop maintained by households of different cultural groups in remote vs. highway villages. Each bar represents the average (±SE) of approximately 10 households in each of two villages. Different letters indicate significant differences (α=0.05) based on uncorrected contrasts of least squares means.

The relationship between highway access and landrace richness differed by crop (Fig. 3.1). For maize and taro, we found no significant relationship between highway access and the number of landraces maintained per household. In contrast, for *Musa spp.*, rice, and cassava, households of one cultural group in remote villages maintained significantly more landraces than households on the highway: Kuna households in remote villages maintained an average of 16.9

(±1.6) landraces of *Musa spp.* and 1.7 (±0.2) landraces of cassava compared to the 9.0 (±0.8) landraces of Musa spp. and 0.9 (±0.1) landraces of cassava maintained by Kuna households in highway villages. Similarly, Emberá farmers in remote village maintained an average of 3.6 (±0.7) landraces per household of rice compared to the 1.6 (±0.2) landraces maintained per household in highway villages. In the case of *Musa spp*., the cultural group maintaining very low diversity in remote villages maintained higher diversity in highway villages: Black households in highway villages maintained more landraces of *Musa spp.* than Black households in remote village (6.4 (±0.7) vs. 3.7 (±0.5) landraces). Black households on the highway also maintained the highest number of yam landraces, but only marginally more than the number maintained by Black households in remote villages (p=0.06).

Distinctness of landrace assemblages. Farmers of different cultural groups not only maintained different total numbers of landraces, but also *distinct* landrace assemblages, as demonstrated by the multivariate dissimilarity analyses. Examples of pairwise dissimilarity comparisons are given in Figure 3.2 for four villages. When considered across all villages, cultural identities explained 51% of the variation in maize assemblages (11 common landraces analyzed; p<0.001), 30% of the variation in rice assemblages (19 landraces; p=0.002), and 55% of the variation in Musa spp. assemblages (24 landraces; p=0.002; Table 3.1). In the case of maize, the ‘typical’ landrace assemblage of each cultural group was distinct from other cultural groups. For *Musa spp*. and rice, the assemblages of Black and Emberá villages were distinct from the assemblages of Kuna villages but not from each other. Highway position explained a significant portion of the variation in rice assemblages (12%, p=0.051) but not of maize or *Musa spp*. assemblages.

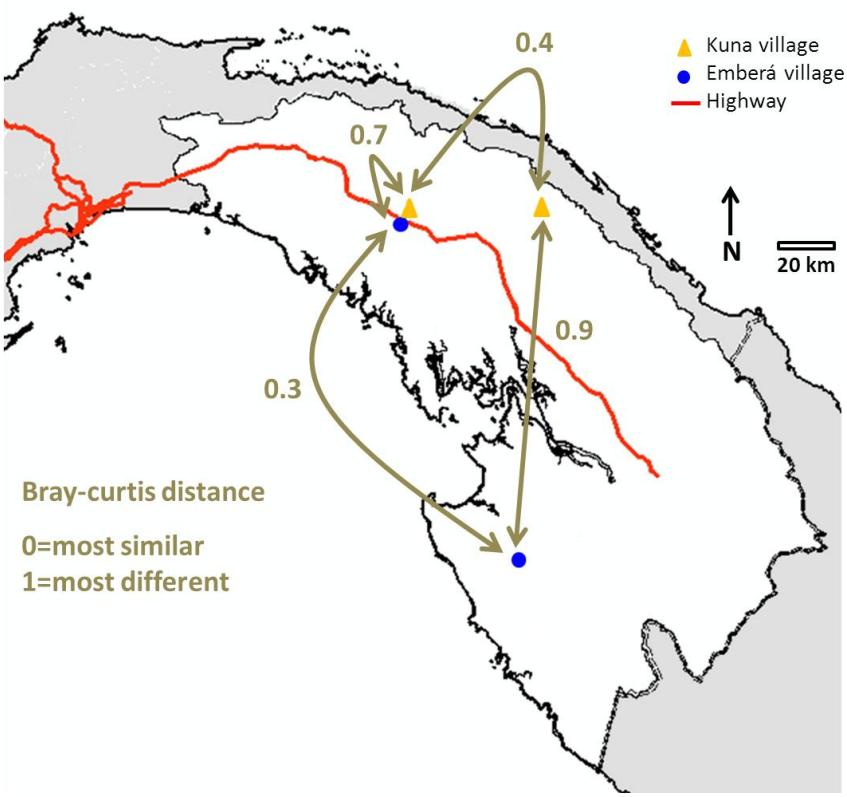


Figure 3.2 Pairwise dissimilarity analyses of maize assemblages in four villages. In this example, the maize assemblages in a Kuna village and Emberá village right across the highway from one another are much more dissimilar (0.7) than assemblages maintained in the two Emberá villages (0.3) or the two Kuna villages (0.4) separated by a day's travel. Village assemblages were described based on the proportion of households in a village maintaining a given landrace. For each pair of villages, the dissimilarity in the proportion of households maintaining each landrace was taken into account using the Bray-Curtis distance index. The extent to which ethnicity and highway access explained the variation in Bray-Curtis distances between all pairs of villages are presented in Table 3.1.

Table 3.1 Distinctness of landrace assemblages. For maize, rice and Musa spp., cultural identity and highway access explained 56%, 42% and 64% of the variation among villages in landrace assemblages, respectively. In all cases, cultural identity was a stronger predictor of the composition of landrace assemblages than highway access, explaining 2.5 to 8.5 times more variation in landrace assemblages as determined by PERMANOVA. P-values are based on 9,999 permutations. Bolded p-values are significant. Landraces included in the analyses are listed in Appendix 3.2.

	Cultural identity				Access to markets		
	Variance explained (R^2)	P	Differences		Variance explained (R^2)	P	Differences
Maize landraces	0.51	**0.000**	K ≠ B ≠ E		0.06	0.332	NS
Rice landraces	0.30	**0.002**	K ≠ B, E		0.12	**0.051**	R ≠ H
Musa landraces	0.55	**0.002**	K ≠ B, E		0.09	0.120	NS

Pearson correlations of individual landraces of maize, rice and *Musa spp*. to cultural identity and highway access suggest that a number of landraces are strongly associated with particular cultural groups or with highway or remote villages (Appendix 3, Tables A3.3-A3.5). For example, five landraces of floury maize, ***dule ob coroguat***^{K,23}, ***dule ob sichit***^{K}, ***dule ob sipuguat***^{K}, ***purwa ob***^{K} and ***ob nunut***^{K}, were strongly associated with Kuna identities. Similarly, in the case of rice, the landraces *rexoro blanco* and *MIDA* were most strongly associated with highway villages. Complete results for the correlation analyses are presented in Appendix 3.2.

Dietary importance of staple crops by cultural group and distance to the highway. Dietary importance was positively correlated with number of landraces maintained per household for all crops. Results from the RCR indicated that this correlation was significant (t=3.79, df=65,

[23]The language in which species names are given is indicated as follows. English names are in plain text, *Latin names* and local *Spanish names* are in *italic text*, and local ***Kuna names***^{K} and ***Emberá names***^{E} are in ***bold italic*** text, with the addition of the superscripts 'K' or 'E' to differentiate between the two.

p=0.0003). The overall correlation between dietary importance and number of landraces was moderate (Pearson's r=0.4), and this ranged for individual crops from low (Pearson's r=0.22 for yams) to fairly high (Pearson's r=0.70 for *Musa spp.*). Overall, Kuna households ranked *Musa spp.*, maize and cassava as being more important in their household diet, and rice as being less important, than Emberá or Black households. Regardless of ethnicity, highway households ranked rice and cassava as more important, and maize as less important, than did remote households (Appendix 3.3). Yams and taro were ranked as the least important components of the diet across all cultural groups.

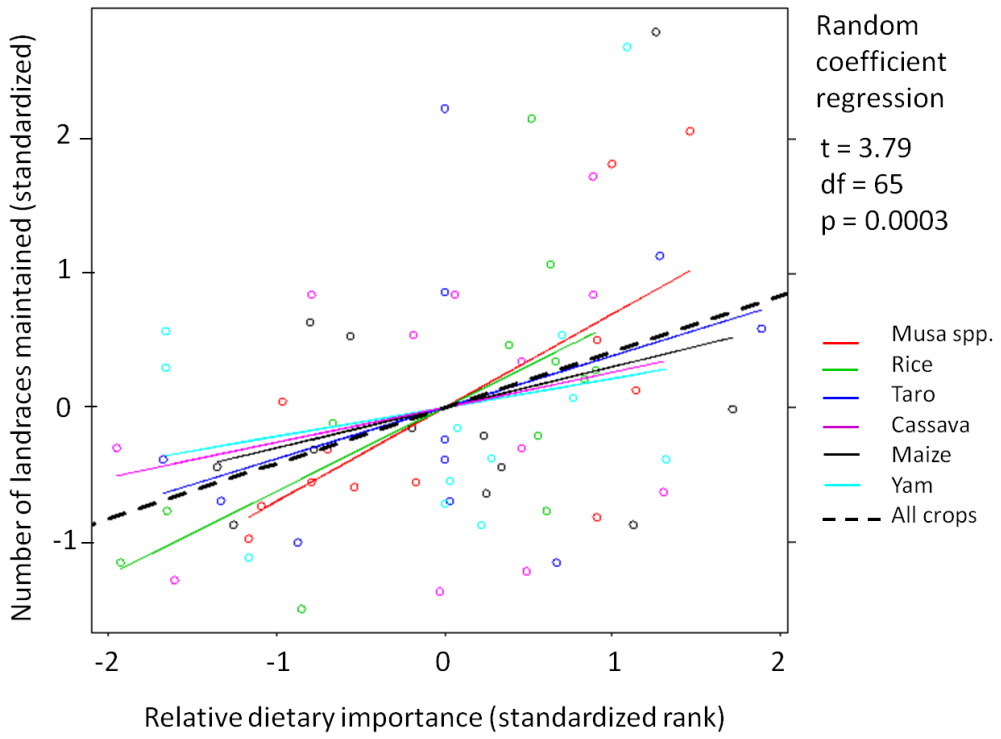


Figure 3.3 Landrace richness was positively correlated with dietary importance for the six crops we studied. We tested this relationship using a general (across-crop) test that required the standardization of richness and ranking data based on maximum and minimum values for each crop. The strongest relationship between richness and dietary importance was for *Musa spp*., while the weakest relationship was for yam.

Seed acquisition networks. In all villages, farmers acquired the majority (mean = 74%) of their maize and rice seed from farmers of their own ethnic group, measured in terms of number of acquisition events rather than amount of seed acquired (Fig. 3.4). Black farmers' seed acquisition networks were the least constrained by cultural group (31% acquired from individuals of other ethnicities), followed by Emberá farmers (18%) and Kuna farmers (7%). Highway access was positively correlated with the proportion of seed obtained from individuals of other ethnicities for Kuna (13% in highway villages vs. 0% in remote villages) and Emberá farmers (27% in highway villages vs. 9% in remote villages) but barely differed for Black farmers (33% in highway villages vs. 29% in remote villages; Fig. 3). The government was a significant source of seed for Emberá and Kuna farmers in highway villages, providing 10% and 26% of the landraces planted in those villages in 2008, respectively. Less than 2% of landraces in any village had been purchased from stores.

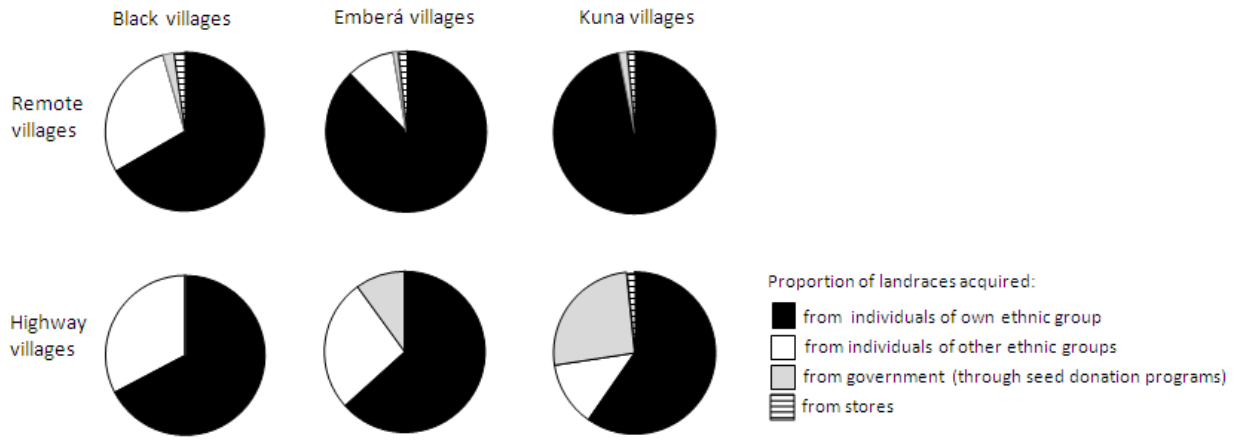


Figure 3.4 Original source of rice and maize landraces being planted in 2008, arranged by the ethnicity and highway access of the village they were planted in. On average, 74% of landraces were obtained from another individual of a farmer's own ethnic group. Landrace acquisitions by Black farmers were least constrained by ethnicity, with little difference between remote and highway villages. Landrace acquisitions by Emberá and Kuna farmers were significantly less constrained by ethnicity in highway villages compared to remote villages. Government donations were an important source of landraces for Kuna and Emberá farmers in highway villages.

Discussion

Cultural identity strongly influences crop diversity. Overall, our findings reveal strong relationships between ethnicity and the richness and composition of landrace assemblages. Cultural identities were significant predictors of landrace richness for five of the six staple crops we studied, and of landrace composition for the three crops for which landrace names were standardized across villages (maize, *Musa spp.* and rice). Analyses of annual rainfall and soils, two environmental variables with important impacts on agriculture in the study region, revealed that differences in crop assemblages among groups did not reflect systematic differences in the soils or rainfall of villages of each ethnic group. Previous studies of one focal crop, within its center of diversity, have demonstrated a link between ethno-linguistic identities and landrace richness (Stromberg et al. 2010; Nasser-Baco et al. 2007) and landrace composition (Perales et al. 2005; Benz et al. 2007; Nasser-Baco et al. 2007). However, to our knowledge, our work is the first to establish quantitative patterns for several different staple food crops in the same region. In examining multiple crop types sympatrically, we were able to determine whether relationships between cultural identities and landrace diversity differed by crop. We found that they did: farmers of different cultural groups maintained both *different numbers of landraces of different crops* and *distinct landraces* of each crop. Thus, the crop assemblages of farmers of different cultural identities were complementary, and combined to bolster levels of crop diversity in a broader region.

What mechanisms underlie the strong relationships we observed between cultural identities and crop diversity? The three cultural groups have been sharing the agricultural landscape of the Chocó bioregion since the early 16th century (West 1957; Vargas 1991). Thus,

differences in arrival times to the region are unlikely to explain differences in crop assemblages as they have been argued to in other regions (e.g. Nasser-Baco et al. 2007)[24]. However, a number of other mechanisms have been evoked by previous studies including the dietary and ritual uses of particular crops (Soleri and Cleveland 1993; Brush 1995; Salick et al. 1997), culturally bounded exchange networks (Boster 1986; Louette et al. 1997; Benz et al. 2007; Van Etten and de Bruin 2007), and non-utilitarian valuation of crop diversity (Boster 1985; Salick et al. 1997; Ban and Coomes 2004; Benz et al. 2007). In the following sections, we provide brief examples of how each of these forces may have contributed to the patterns in crop diversity that we documented.

We found that differences in diet among the three cultural groups were reflected in patterns of landrace richness, as demonstrated elsewhere (Brush 1991; Reyes Garcia et al. 2008). Landrace diversity can assist in maximizing yields, a likely priority for those crops of greatest dietary importance. Varietal diversity buffers harvests from environmental shocks, enables farming in diverse terrain, and can provide more than one harvest of a crop per year (e.g., because of different maturation times) (Clawson 1985; Smithson and Lenné 1996; Ceccarelli 1994; Bellon 1996; Defoer et al. 1997; Louette et al. 1997). Where farmers have little access to pesticides and fertilizers, as in our study villages, such benefits of crop diversity are especially important.

---

[24] Though differences in origin could explain differences in crop composition, something that would be interesting to explore in future chapters. For example, Judith Carney's work has documented the role of Africans in bringing old world domesticates to the Americas, and has shown that modern-day Afro-American communities sometimes harbor African crops not widely dispersed in the Americas, such as African rice (*Oryza glaberrima*).

An alternative (and not mutually exclusive) explanation relates to the importance of landrace diversity in providing culinary diversity, also likely a priority for foods dominating the household diet. For example, Emberá and Black families reserved particular rice varieties for particular dishes. Rice landraces said to have "their own oil" (and thus particularly flavorful) were reserved for special occasions. Other, short-grained landraces were saved to make special puddings, and still others were preferred for making steamed rice cakes ("bollos"). Similarly, soups containing boiled bananas and plantains often included many different varieties of each, such that each bite contained a different flavor and texture. Different culinary traditions also help to explain the identity of landraces maintained for a several crop. For example, rice is a less important food in Kuna households, and we encountered few of the 'specialty' rice varieties in Kuna households. In contrast, a common beverage in Kuna homes (but not Emberá or Black homes) uses the varieties of floury maize associated with Kuna villages. These landraces can be ground into a maize flour while dry and produce an unfermented beverage with superior texture and flavor compared to hard-grained varieties of maize. Floury maize has no commercial value, and it was cultivated by less than 5% of non-Kuna households.

Our data also suggest that culturally bounded exchange networks may reinforce differences in the landrace assemblages (Louette et al. 1997; Benz et al. 2007; Van Etten 2007). Kuna farmers reported the fewest seed acquisitions from other ethnic groups, while Black farmers reported the most. These differences may reflect both language and 'openness' of the different groups. Less than 50% of adults surveyed in Kuna communities spoke Spanish; in contrast, 98% and 100% of adults surveyed in Emberá and Black communities spoke Spanish, respectively. In the Darién-Chocó bioregion, historical exchange networks among Black and Emberá communities for labor and healing services are well documented (e.g., Losonczy 1997).

Exchanges among Kuna and either Emberá or Black communities are reported much less commonly in the literature. The relative openness of farmers' seed acquisition networks may explain the greater similarities we observed in the composition of the landrace assemblages of rice and *Musa spp*. in Black and Emberá communities.

While the utilitarian values of landraces may explain some of the variation in the number of landraces that we documented, in some cases farmers maintained landraces with no apparent use value or ecological benefit. For example, reasons for the incredibly high diversity of *Musa spp.* maintained by some Kuna households (up to 21 landraces), and of rice by some Emberá households (up to 10 landraces) could not always be explained. Other studies have emphasized that diversity itself holds aesthetic and magico-religious value to some individuals (Boster 1985; Salick et al. 1997; Ban and Coomes 2004; Benz et al. 2007). If such values are socially learned (McElreath 2004), then differences in the value systems of different cultural groups might be reflected in the management of crop diversity (Benz et al. 2007). This is a topic for future research.

Cultural identity influences management of crop diversity in response to markets. Farmer ethnicity explained 2.5 to 8.5 times more variation in the composition of maize, rice and *Musa spp*. assemblages than did village position relative to the highway, our proxy for market access. Only in the case of rice did highway position explain a significant proportion of the variation in composition among villages. For rice, homogenization of landraces occurred along the highway for villages of all cultural groups. Two landraces were particularly dominant: *rexoro blanco*, a flavorful variety that produced well, and *arroz MIDA*, which was a variety of rice engineered for large-scale, mechanized rice production, that was donated to many farmers on the highway by

the Panamanian Ministry of Agriculture (MIDA) in 2008 in an effort to encourage local food production in the face of soaring food prices. This provides an example of how a process not directly linked to markets may drive homogenization of crop diversity in areas that are more accessible.

Our data also revealed that relationships between crop diversity and market access varied with farmer ethnicity. For each of the four crops for which landrace richness was related to village position relative to the highway, there was also a significant interaction with ethnicity. In other words, relationships between landrace richness and market access were not consistent across ethnic groups; rather, farmers of each group managed crop diversity differently depending on their access to markets.

For rice, *Musa spp.* and cassava, farmers of the cultural group(s) maintaining the most diversity in remote villages maintained significantly fewer landraces of that same crop in highway villages. This result provides some support for the hypothesis that markets tend to erode crop diversity (Harlan 1975). Farmers explained these trends by decisions to specialize in landraces with high market value (see also Salick et al. 1997), or to reduce diversity because of time restrictions related to off-farm employment (see also Zimmerer 1991a). For example, many Kuna farmers in highway villages sold plantain and cassava to passing cars and occasionally to intermediaries. Because only a few varieties of *Musa spp.* and cassava have any market value, there were strong incentives for farmers to produce mainly these varieties. Emberá farmers on the highway still mainly grew rice for home consumption but explained that managing maturation times of different landraces was too time consuming given other opportunities to earn cash income.

On the other hand, diverse landrace assemblages of crops with indispensable culinary or ceremonial attributes were in some cases maintained in the face of market pressures (Brush 1995). For example, while many Black farmers on the highway planted a commercial variety of cassava with high market value (*yuca brasileña)*, they also maintained a particularly flavorful and fast-cooking variety of yellow cassava (*yuca antero*) for home consumption. Similarly, while highway Kuna farmers maintained fewer varieties of floury maize, and more varieties of hard-grained commercial maize than did Kuna farmers in remote villages (the number of floury landraces relative to hard-grained landraces was 1.2:0.7 in highway villages, compared to 2.5:0.2 in remote villages), the floury landraces were not completely eliminated from farmers' assemblages, ensuring that beverages relying on floury landraces could still be prepared in highway villages.

Support for the idea that markets augment crop diversity includes the finding that Black highway farmers maintained significantly more landraces of Musa spp. than Black farmers in remote communities. Also, the highest numbers of yam landraces per household were maintained in Black communities on the highway, marginally more than in remote Black villages. This likely reflects Black farmers' greater access to disease-resistant varieties through contact with yam intermediaries, as many Black farmers produce yams for markets.

Conclusions and implications

This research demonstrated the strong impact of cultural identity on crop diversity, with farmer ethnicity explaining 30% - 55% of the variation in the composition of landrace assemblages, and 2.5 to 8.5 times more variation in crop assemblages than village position relative to the highway, our proxy for market access. Importantly, differences in crop

assemblages among farmers of different ethnicities were complementary and served to bolster overall landscape-level crop diversity. Thus, efforts to conserve agrobiodiversity *in situ* should recognize that culturally diverse landscapes may be more resilient to the homogenizing effects of regional and global markets than culturally uniform landscapes. This is particularly important given global concerns surrounding declines in cultural diversity, as measured by losses of linguistic diversity (Maffi 2007; UNESCO 2003). Recognition of the territorial rights of minority groups has been proposed as one key action towards supporting connections between biological and cultural diversity (Maffi and Woodley 2010). We suggest that these be explored further in the context of agrobiodiversity.

Chapter 4: Complementary assemblages of agroforest species maintained by neighbouring ethnic groups

Introduction

Diversity in agricultural systems is important for both global and local food security. Diversity can help ensure stable food and income for farmers in the face of pest and disease outbreaks, climatic extremes, and volatile markets. Over the long-term, diverse species and varieties adapted to a broad range of conditions will be essential for global food security as humanity responds to persistent changes in climate (FAO 2010). Concern about losses of agrobiodiversity has motivated massive and expensive international efforts to collect and preserve crops and crop wild relatives in seed banks (Harlan 1975; Pretty et al. 1995, Thrupp 2000, FAO 2010). However, tropical trees and shrubs are very difficult to conserve ex situ (in seed banks) as the seeds of many species do not tolerate drying and freezing (Tweddle et al. 2003; Li and Pritchard 2009). Given the crucial role of tropical trees and shrubs in the production of fruits, nuts, fiber, fodder, biofuel and timber for both local and global consumption, in situ (on-farm) conservation of tropical tree and shrub species is paramount. Tropical agroforestry systems are hotspots for cultivated tree and shrub biodiversity (Okafor and Fernandes 1987; Juma 1989; Watson and Eyzaguirre 2002; Galluzzi et al. 2010), making such systems essential for in situ conservation.

---

[25] Co-authors: Kathryn R. Kirby, Sarah E. Gergel, and Domingo Diaz

In the tropics, agroforests are often part of dynamic swidden agricultural systems and are maintained by millions of small-scale farming families in an array of forms, including homegardens, outfield gardens, orchards, and managed fallows (Kumar and Nair 2004; Padoch and Pinedo-Vasquez 2010). The forested landscapes in which they are situated tend to be dynamic heterogeneous mosaics. First, they are mosaics of land managed by farmers of different ethnicities and backgrounds, whose farming practices reflect their histories, knowledge and belief systems, as well as their ongoing experiences in the landscape (Atran et al. 1999). Second, the landscapes are mosaics of villages with differing degrees of integration to market economies, largely due to their proximity to roads (Kramer et al. 2009). Thus, successful *in situ* conservation of tropical tree and shrub species will require understanding how agricultural practices of diverse peoples, with diverse needs, in a diverse landscape mosaic may change in the face of market integration.

Spatial economic theory predicts a decline of agrobiodiversity as farmers gain access to markets and specialize in species with commercial value. Interestingly, empirical evidence for this in agroforestry systems has been mixed. Some have documented a loss in species richness with market access (Vara 1980 in Rico-Gray et al. 1990; Soemarwoto 1987; Michon and Mary 1990; Rico-Gray et al. 1990), while others have reported increases (Wezel and Ohl 2005; Perrault-Archambault and Coomes 2008). An emphasis on diversity (or species richness) in many previous studies may have obscured shifts in the particular species maintained (REFS). For example, farmers in areas with greater market access may also acquire novel species, thus augmenting species richness in their agroforests, or replacing the number of species lost. In addition, farmers with greater market access may attempt to compensate for declines in species

traditionally harvested from the wild (e.g., valuable timber species such as mahogany) by cultivating such species.

Cultural identities of farmers also influence distributions of agrobiodiversity (e.g., Perales et al. 2005; Chapter 3). In part, this reflects the non-market values that farmers attribute to species, which are often strongly linked to shared traditions, knowledge systems and beliefs (Brush and Meng 1998). These values may influence the overall richness of farmers' agroforest assemblages (e.g., Perrault-Archambault and Coomes 2008). However, they also are likely to be linked to specific species and varieties with particular uses (e.g., Lamont et al. 1999; Zaldivar et al. 2002; Perrault-Archambault and Coomes 2008). For example, farmers may maintain species and varieties that are used in the preparation of traditional foods, or that have important ceremonial uses. Similarly, the different building styles associated with different cultural identities may lead farmers to maintain different assemblages of construction species – from cane, to bamboo, to preferred hardwood species.

Despite their importance, we currently have a poor understanding of the relative influence of cultural and economic factors on distributions of agrobiodiversity among smallholder agroforestry systems. Here, we examine the cultivated biodiversity within agroforests of Panama's Darien Region to ask: How do cultural identities, market access and primary use influence farmers' maintenance of agrobiodiversity? We contrast the agroforest species maintained by households in twelve villages that differ in terms of access to markets and ethnicity. Because little is known of the ways in which cultivated tree species are distributed amongst households and villages in tropical landscapes (e.g., are most species rare or widespread?), we also describe the frequency distributions, intraspecific diversity and abundance of the species we encountered in our surveys.

Our approach is novel in several ways. In comparisons of agrobiodiversity maintained by different cultural groups, very few previous studies have explicitly considered geographic differences among villages (e.g., proximity to markets) or controlled for local biophysical factors (e.g. elevation, rainfall), both of which may differ among the areas managed by different groups. While the influence of economic or cultural factors on agrobiodiversity has been studied in isolation (e.g. Cultural: Zaldivar et al. 2002, Perales et al. 2005; Economic: Rico Gray et al. 1990; Wezel and Ohl 2005), few have determined the relative importance of these factors or explored their potential interactions. Finally, the preponderance of studies focused on a single farming community has precluded an understanding of trends across broader landscapes and regions.

Methods

Study design. We selected study villages and controlled for confounding biophysical factors (e.g., rainfall, soils) as described in the Methods section of Chapter 3.

Agroforest inventories. Most households in the region maintained one or more agroforests in addition to annual rice, maize and tuber swiddens. These agroforests were located either immediately around the home (e.g., homegardens) or within walking distance from it (outfield gardens, managed fallows). In each village we randomly selected a sample of approximately ten households that maintained at least one agroforest (homegarden, outfield garden, or planted fallow). The actual number of households in each village ranged from 8-13 due to logistical

issues in different villages[26]. We considered a household to be a family unit that shared agricultural fields, seeds, and labor. Households with farmer(s) self-identifying as being part of the majority cultural group of the village were analyzed (123 of 125 households). Agroforest surveys were carried out between June 2007 and September 2008. We asked households to list all of the agroforests they maintained, and then spent up to half a day visiting and surveying as many of those agroforests as possible. Because some households maintained several small, dispersed agroforests while others maintained a single, large homegarden, we standardized the time spent surveying each household's agroforests, rather than the number of agroforests surveyed per household. To ensure there was no bias in our sampling effort, we used a factorial ANOVA to test whether the total area of agroforests surveyed per household (determined based on GPS mapping of the perimeter of each field) differed significantly among villages of different cultural groups and with different locations relative to the highway. The factorial ANOVA was not significant ($F_{5,6}$=1.683, p=0.27), indicating no systematic differences in the area of agroforests surveyed and confirming that our sampling effort was not biased towards households of a particular cultural group or location relative to the highway.

Our approach was designed to provide a complete count of the species and landraces of cultivated plants maintained in the agroforests surveyed for each household, as well as a count of individuals of each species. All surveys were carried out with one of the owners of the agroforest. We asked agroforest owners to identify each cultivated plant at the landrace level, where a "landrace" was defined as a farmer-differentiated variety. Landrace names were

[26]We sometimes were unable to work with ten households during the period we had reserved for work in each village (e.g., because of community-wide congresses and other events, or because of medical or transportation problems), and in some cases found ourselves with additional time and therefore worked with additional households.

standardized across all agroforests belonging to a single household, but not across households or villages. When we encountered a new species, a voucher specimen was collected and deposited at the herbariums of the Universidad Nacional de Panama and the Smithsonian Tropical Research Institute. Closely related species that were difficult to differentiate in the field were grouped for analyses (e.g., small peppers were grouped as *Capsicum spp.;* all banana and plantain varieties were grouped as *Musa spp.*).

We focused on cultivated species that were visible year-round and that were predominantly planted in agroforests in all villages. We considered a "cultivated plant" to be any tree, palm, shrub, liana, herb or grass that had been intentionally planted or that had sprouted independently but was actively maintained. We did not include species that were mainly ornamental, and at the request of participating communities we also excluded species that were primarily medicinal. In homegardens in particular, this meant excluding a large number of herbs planted in pots and raised beds (*zoteas;* Arroyo and Camacho 2000). To ensure that species presence/absence data among villages was comparable, we did not include species that were 'variably cryptic'. For example, many small herbs were easily overlooked in the dry season (e.g. ginger) but were evident in the wet season, and we sampled agroforests during both seasons. Similarly, some species were predominantly planted outside of agroforests in some villages but not others (e.g., pineapple and sugarcane). The list of species that were excluded, as well as some data on their distributions, are presented in Appendix 4.

Primary uses of species. Each tree and shrub species was assigned a primary use (food, fine-timber, construction, firewood, or other non-dietary household use) based on observation and interviews by KK over the three years she spent working with farmers on this study. In the case

of species with multiple uses, we classified them by their primary use. These primary uses were confirmed through a literature review (Duke 1968; Herlihy 1986; de Arauz 1970; Patiño 1993). Species classified as "food" species included those that were primarily valued for their edible fruits, nuts, seasonings, and/or oils; "timber" species included those planted primarily for the commercial value of their wood; "construction" species included those used primarily for local building, roofing or fencing; "firewood" species included species mainly maintained for shade in the short-term and firewood in the long-term, and species with "other (non-dietary) household uses" included those providing tools (e.g., calabash gourds, leaves for wrapping foods), dyes, resins, and fibers.

Statistical analyses

Describing patterns in the distribution, intra-specific diversity, and abundance of species. Before looking at the factors influencing species' distributions, we sought to describe these distributions in general terms. To explore how rare or widespread different species were, we summarized the number of villages in which each species was found and the proportion of households across all villages maintaining each species. We were also interested in across-village trends in the numbers of landraces and individuals maintained for each species per household, and so we summarized this information on a species-by-species basis.

Comparisons of species and landrace richness. To compare species and landrace richness, counts of species and landraces from the agroforest inventories were first totaled by household

and then averaged for a village. Average household richness was then compared using a factorial ANOVA where independent variables were cultural identity and highway access. Where significant differences were detected ($\alpha<0.05$), post-hoc pairwise comparisons of means were carried out using Tukey's test. We then calculated the average number of species of each primary use maintained per household, and again averaged these for each village. Average species richness of each primary use group was then analyzed using ANOVAs as for total species richness. Analyses were performed in R using the aov and TukeyHSD functions.

Comparisons of species composition. We used multivariate analyses to explore the similarity of the agroforest assemblages of farmers of different cultural identities and with contrasting access to the highway (this method was also used for composition analyses in Chapter 3). Compositional data for agroforest assemblages were first summarized in a village-by-species matrix, with the score for each species in each village given as the proportion of households in the village that maintained that species. This matrix was converted to a village-by-village dissimilarity matrix using the Bray-Curtis distance measure, as is recommended for species data (Legendre and Legendre 1998). We then used a permutational multivariate analysis of variance (PERMANOVA; Anderson 2001) with 9,999 permutations to test whether cultural group or highway access explained a significant proportion of the dissimilarity between villages. Analyses were performed in R using the adonis function of the vegan package (Oksanen et al. 2008). We repeated this analysis for each primary use group. That is, we created separate matrices for food species, timber species, construction species, and species with other household uses, and then analyzed each matrix following the steps described above for the original matrix. (Note: there

were not enough firewood species encountered in at least two villages to analyze these species separately).

Correlations of individual species to predictor variables. Because the multivariate analyses did not reveal which species varied with the independent variables (e.g., with cultural identity and highway access), we determined the Pearson correlation between the proportion of households per village maintaining each species and each of four village descriptors (e.g., Kuna, Emberá, Black, Highway – each coded using the dummy variables 0 or 1). The value of the correlation coefficients gives an indication of a species' tendency to be planted by a specific cultural group or in remote vs. highway villages; however, the statistical significance of the Pearson correlations should be viewed with caution because of a large number of comparisons.

Results

Overall, we encountered 178 species in agroforests in the region, not including ornamental and medicinal species. Of these, 72% were species of trees or woody shrubs, 5% were palm species, and 23% were herb or grass species (Fig. 4.1A). When considered by primary use, 61% were primarily food species (fruits, nuts, oils, aromatic herbs); 9% were commercially valuable timber species; 7% were firewood species; 9% were used primarily in local construction (building, roofing, fencing), and 14% had other household uses (dyes, fibers, tools; Fig. 4.1B). Of the 178 species, 30 species (26 herb species, 3 grass species, and 1 shrub species) were excluded from further analyses because they were deemed to be variably cryptic and therefore might have been missed in some villages (because of season or location of planting) but not others (Appendix 4).

(a) (b)

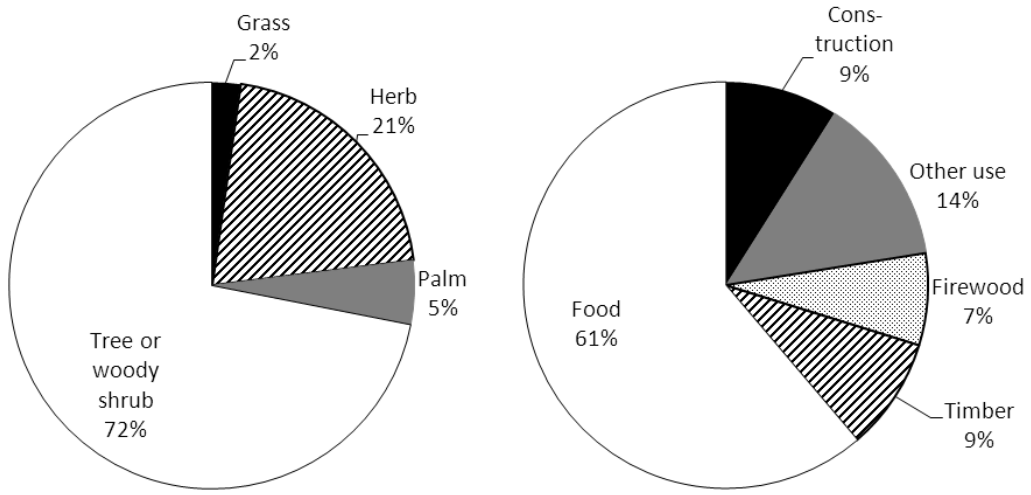


Figure 4.1. Percentage of the 178 species encountered by (a) life form and (b) primary use. Species with "other uses" included those used as dyes, tools, and fibers. Ornamental and medicinal species were not included in surveys due to logistics and at the request of communities, respectively.

Identifying rare vs. widespread species. Of the 148 species that were not cryptic, 35% were only encountered in one village (Fig. 4.2A), and 32% were only encountered in the agroforest(s) of a single household (Fig. 4.2B). These "singleton" species were encountered in 9 of the study villages, including both highway and remote villages and at least two villages of each cultural group. Uses of singleton species were primarily non-dietary (68% were used primarily for timber, construction, firewood, or to meet other household needs).

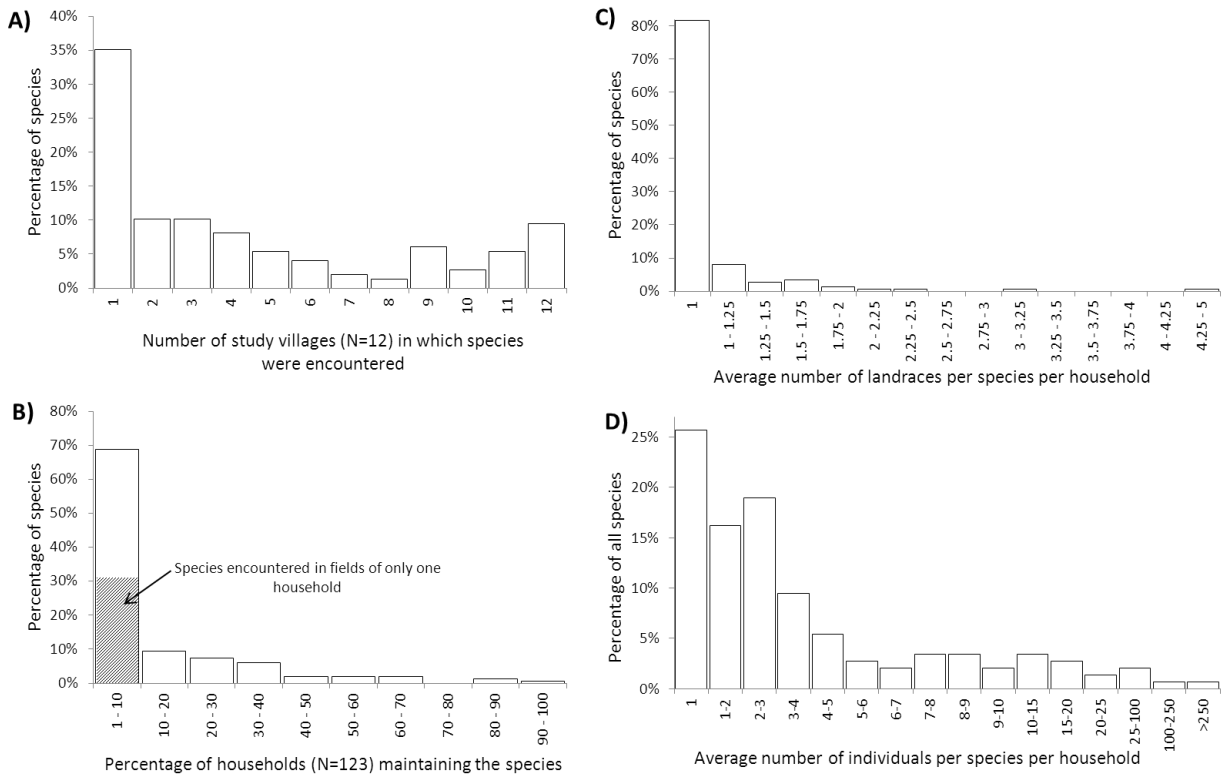


Figure 4.2 Of 148 species analyzed, many had limited distributions (encountered in one village or one household) and were represented by few landraces and individuals per household. (A) Distributions among villages: while 10% of species were encountered in all twelve villages, 35% of species were only encountered in one village. (B) Distributions among households: the majority of species (69%) were maintained by less than 1/10th of households and 32% were maintained by a single household (indicated by grey fill). (C) Intra-specific diversity: most species were represented by just one landrace per household (D) Abundance: a quarter of species were represented by one individual per household, and almost 2/3 of species were represented by three or fewer individuals.

In contrast, widespread species (encountered in all 12 study villages) included 13 species all of which were primarily used for food, except one. Widespread species included: peach palm (*Bactris gasipaes*), avocado (*Persea americana*), soursop (*Annona muricata*), *guaba* (*Inga spectabilis*), red mombin (*Spondias purpurea*), coconut (*Cocos nucifera*), mango (*Mangifera indica*), calabash (*Crescentia cujete*), 4 *Citrus* species, and the *Musa spp.* complex[27]. The most common species (found in at least 2 villages) are given in Table 4.1.

Number of landraces and individuals of each species per household. Most species were represented by one landrace in each household's agroforests (72% of species, Fig. 4.2C). However, species represented by more than one landrace per household tended also to be present in many more villages (9.7 villages, 95% confidence intervals (95% CI): 10.7, 8.6) than species represented by one landrace (3.3 villages, 95% CI: 2.6, 3.7). The landrace-to-species ratio was highest for food species, averaging 1.65 landraces for every food species (95% CI: 1.57, 1.74). For species with other household uses the ratio was 1.31 (95% CI: 1.15, 1.47), and for species in other primary use categories (timber, construction, firewood) ratios were not significantly different than 1. Species with the highest landrace-to-species ratio on a per-household basis were: *Musa spp.* (4.5 landraces per household), mango (3.2), coconut (2.4), avocado (2.1), cacao (1.8), peach palm (1.8), and chili peppers (1.7).

In terms of the number of *individuals* of each species maintained in each household, almost two-thirds of species were represented by three or fewer individuals per household (Fig.

[27]The language in which species names are given is indicated as follows. English names are in plain text, *Latin names* and local *Spanish names* are in *italic text*, and local ***Kuna names***^{K} **and** ***Emberá names***^{E} are in ***bold italic*** text, with the addition of the superscripts 'K' or 'E' to differentiate between the two.

4.2D). Among species where at least 10 individuals were maintained per household, 50% were food [coconut (*Cocos nucifera*), cacao (*Theobroma cacao*), coffee (*Coffea spp.*), *Musa spp.*, breadfruit (*Artocarpus spp.*), annatto (*Bixa orellana*), borojo (*Borojoa patinoi*)], 36% timber [*cedro amargo* (*Cedrela odorata*), *cedro espino* (*Pachira quinata*), teak (*Tectona grandis*), *tachuelo* (*Xanthoxylum sp.*)] and the remainder, local construction [*caña blanca* (*Gynerium sagittatum*)] or other household [*bijao* (*Calathea lutea*)].

Table 4.1 Species encountered in more than one village, organized by primary use: food, non-dietary household use, timber, or local construction. For each species, the number of study villages in which it was found, the proportion of households maintaining it, and average number of landraces and individuals maintained per household, are presented. Pearson's correlation coefficients relating the proportion of households in a village maintaining a species to highway position and cultural group are presented. Correlations greater than 0.5 are in bold.

Scientific name	English name	Local Spanish name	N villages	Prop. house-holds (all villages)	Avg. # land-races per house-hold	Avg. # indivi-duals per house-hold	Correl-ation to highway villages	Correl-ation to Black villages	Correl-ation to Emberá villages	Correl-ation to Kuna villages
Food species (fruits, nuts, oils, seasonings)										
Annona muricata	Soursop	Guanabana	12	0.50	1.03	3.26	0.33	0.29	-0.18	-0.11
Bactris gasipaes	Peach palm	Pifa	12	0.55	1.75	6.65	-0.23	-0.23	0.1	0.13
Theobroma cacao	Cacao	Cacao	12	0.51	1.79	15.33	-0.31	**-0.67**	-0.03	**0.7**
Citrus reticulata x C. paradisi		Mandarina japonesa	12	0.37	1.00	3.09	0.07	-0.5	**0.71**	-0.21
Citrus aurantifolia	Key lime	Limón pais	12	0.43	1.00	4.77	0.21	-0.14	-0.46	**0.6**
Citrus LimonChino		Limón chino	12	0.40	1.00	2.55	-0.48	0.49	-0.25	-0.24
Cocos nucifera	Coconut	Coco	12	0.82	2.36	12.09	-0.09	0.02	**0.59**	**-0.62**
Mangifera indica	Mango	Mango	12	0.81	3.23	9.40	0.22	0.23	-0.18	-0.06
Persea americana	Avocado	Aguacate	12	0.66	2.15	8.72	0.49	0.2	0.12	-0.32
Inga spectabilis		Guaba blanca/G. anaranjada	12	0.61	1.61	5.47	0.31	-0.3	0.28	0.03
Citrus sinensis	Orange	Naranja	12	0.64	1.00	7.77	0.1	0.49	0.02	**-0.51**
Musa spp	Plantain/banana	Guineo, Plátano, Cuadrado…	12	0.92	4.46	309.16	0.49	**-0.58**	0.25	0.33
Melicoccus bijugatus	Mamoncillo	Mamon	11	0.39	1.08	2.08	0.04	-0.04	**0.6**	**-0.56**
Citrus reticulata	Mandarin orange	Mandarina	11	0.21	1.00	3.04	0.11	-0.48	**0.59**	-0.11
Morinda citrifolia	Noni	Noni	11	0.31	1.00	3.71	0.04	**0.77**	-0.33	-0.44
Syzigium malaccense	Malay apple	Marañon curazao	11	0.28	1.00	2.59	-0.13	0.45	0.36	**-0.81**
Pouteria sapota	Mamey sapote	Mamey	11	0.35	1.51	3.95	-0.07	-0.17	0.12	0.06
Bixa orellana	Annatto	Achiote rojo	11	0.23	1.00	3.57	**-0.56**	-0.27	0.05	0.21
Matisia cordata	Matisia	Zapote	11	0.33	1.03	8.35	-0.26	-0.01	0.48	-0.46
Coffea spp	Coffee	Café	11	0.37	1.52	142.02	-0.15	**-0.55**	-0.2	**0.75**
Capsicum spp.	Chile pepper	Ají	10	0.42	1.69	4.21	**-0.61**	0.16	-0.11	-0.05
Psidium guajava	Guava	Guayaba	10	0.27	1.39	3.30	0.21	**0.81**	-0.15	**-0.66**
Carica papaya	Papaya	Papaya	9	0.23	1.11	2.07	-0.34	0.44	0.29	**-0.73**
Inga mucuna or I. goldmanii		Guaba peluda	9	0.25	1.00	2.29	0.1	**-0.58**	0.13	0.45
Artocarpus sp	Breadfruit	Fruta de pan	9	0.17	1.10	12.52	-0.04	0.24	0.46	**-0.7**
Bixa sp	Annatto	Achiote cascara amarilla	9	0.20	1.24	16.88	-0.35	-0.11	**0.74**	**-0.63**
Borojoa patinoi	Borojo	Borojo	9	0.25	1.00	22.42	-0.22	0.2	0.43	**-0.64**
Byrsonima spp.	Nance	Nance	8	0.37	1.28	4.52	0.05	0.25	**0.64**	**-0.89**
Cymbopogon citratus	Lemongrass	Hierba de limón	8	0.29	1.00	2.08	-0.3	0.5	0.19	**-0.69**
Cajanus cajan	Pigeon pea	Guandu	7	0.10	1.33	9.67	-0.03	0.36	0.38	**-0.74**
Tamarindus indica	Tamarind	Tamarindo	7	0.10	1.00	2.17	-0.03	0.18	0.34	**-0.53**
Anacardium occidentale	Cashew	Marañon de pepita	6	0.17	1.14	2.67	-0.34	0.36	0.11	-0.46

Table 4.1 (continued)

Scientific name	English name	Local Spanish name	N villages	Prop. house-holds (all villages)	Avg. # land-races per house-hold	Avg. # indivi-duals per house-hold	Correl-ation to highway villages	Correl-ation to Black villages	Correl-ation to Emberá villages	Correl-ation to Kuna villages
Food species (continued)										
Annona reticulata	Custard apple	Anon	6	0.07	1.00	1.33	0.08	0.18	0.01	-0.2
Chrysophyllum cainito	Star apple	Caimito morado grande	6	0.10	1.00	1.75	0.29	-0.43	**0.84**	-0.41
Elaeis oleifera	American oil palm	Corozo/Urraca	6	0.14	1.06	3.29	-0.37	0.3	0.24	**-0.54**
Citrus paradisi	Grapefruit	Toronja	6	0.09	1.09	1.82	0.06	0.32	0.02	-0.34
Passiflora sp	Passion fruit	Maracuya	5	0.05	1.00	1.50	0.01	0.25	0.28	**-0.54**
Pouteria caimito	Abiu	Caimito amarillo	5	0.14	1.06	2.53	-0.49	-0.19	**0.65**	-0.46
Theobroma bicolor	Tiger cacao	Bacao	5	0.13	1.00	3.19	**-0.51**	-0.28	**0.64**	-0.36
Annona montana	Mountain soursop	Chirimoya 1	5	0.05	1.00	2.17	-0.01	**0.56**	-0.3	-0.26
Solanum sp.	Lulo	Lulo	4	0.07	1.00	1.25	-0.35	-0.13	-0.28	0.41
Gustavia superba		Membrillo	4	0.03	1.00	1.50	-0.05	-0.49	-0.2	**0.7**
Inga edulis		Guaba Canales/Churima	4	0.07	1.00	2.00	-0.41	0.06	0.33	-0.39
Psidium friedrichsthalianum	Sour guava	Guayaba agria	4	0.04	1.00	1.00	-0.14	-0.18	**0.63**	-0.46
Spondias mombin	Hog plum	Jobo	4	0.07	1.00	5.44	-0.36	-0.3	0.11	0.19
Nephelium lappaceum	Rambutan	Mamón Chino	4	0.03	1.00	1.75	-0.37	0.25	-0.11	-0.14
Syzygium jambos	Malabar plum	Pomarrosa	4	0.03	1.00	2.25	-0.03	**0.99**	-0.5	-0.5
Capsicum sp2	Sweet pepper	Pimenton	4	0.07	1.00	4.00	-0.45	0.12	0.16	-0.28
Passiflora quadrangularis	Giant granadilla	Granadilla	3	0.06	1.00	1.57	-0.25	0.46	-0.07	-0.39
Annona purpurea		Toreto	3	0.02	1.00	1.33	-0.19	0	-0.09	0.1
Cassia grandis		Caña fistula	3	0.04	1.00	1.60	0.3	0.29	0.1	-0.39
Chrysophyllum sp		Caimito morado chiquito	3	0.04	1.00	1.60	0.1	-0.38	**0.77**	-0.38
Garcinia intermediana	Monkey fruit	Fruta de mono	3	0.04	1.00	1.40	0.17	-0.39	**0.77**	-0.39
Inga sapindoides		Cajetajo	3	0.04	1.00	1.80	-0.11	-0.16	**0.54**	-0.39
Oenocarpus mapora		Maquenque/Trupa	3	0.05	1.00	1.67	-0.01	0.19	0.17	-0.37
Renealmia sp		Pagua	3	0.10	1.00	2.33	0.03	-0.38	-0.38	**0.76**
Averrhoa carambola	Star fruit	Fruta china	3	0.02	1.00	1.33	-0.22	0.34	-0.41	0.06
Citrus aurantium	Bitter orange	Naranja agria	3	0.03	1.00	1.25	**0.56**	0.48	-0.08	-0.39
Citrus limetta	Sweet lemon	Limón dulce	3	0.02	1.00	1.00	0.08	-0.08	-0.4	0.48
Duguetia sp		Yaya	2	0.02	1.00	1.50	0.45	-0.32	0.18	0.14
Herrania purpurea	Monkey cacao	Chocolatillo de monte	2	0.02	1.00	2.33	-0.14	-0.3	**0.59**	-0.3
Inga pezizifera or vera or venusta		Churima	2	0.02	1.00	2.00	0.4	-0.05	0.33	-0.28
Rollinia sp		Anon (Rollinia sp.)	2	0.02	1.00	1.67	-0.2	-0.08	-0.27	0.35
No id		Zapatero	2	0.02	1.00	1.00	0.45	0.12	0.2	-0.31
Abelmoschus esculentus	Okra	Ñaju	2	0.02	1.00	7.50	-0.44	0.1	-0.31	0.21
Citrus limonia	Rangpur lime	Limón cascara anaranjada	2	0.02	1.00	2.50	0.45	0.18	-0.32	0.14
Spondias dulcis	Ambarella	Mangotin	2	0.02	1.00	1.00	-0.45	0.63	-0.32	-0.32

Table 4.1 (continued)

Scientific name	English name	Local Spanish name[1]	N villages[2]	Prop. house-holds (all villages)[3]	Avg. # land-races per house-hold[4]	Avg. # indivi-duals per house-hold[5]	Correl-ation to highway villages	Correl-ation to Black villages	Correl-ation to Emberá villages	Correl-ation to Kuna villages
Species with non-dietary household uses										
Calathea lutea		Bijao	6	0.09	1.00	12.64	0.4	-0.28	0.3	-0.02
Ceiba pentandra		Bongo	2	0.02	1.00	2.00	-0.44	-0.31	0.1	0.21
Crescentia cujete	Calabash tree	Totumo	12	0.54	1.58	2.82	0.16	**-0.64**	0.33	0.32
Genipa americana	Genipap	Jagua	7	0.10	1.00	1.17	-0.02	**-0.71**	0.37	0.33
Gossipium sp	Cotton	Algodón	5	0.07	1.00	1.67	-0.39	0.21	0.31	**-0.52**
Ochroma pyramidale	Balsa	Balso	4	0.03	1.00	3.00	-0.04	-0.15	0.2	-0.06
No id		Hoja para bollos	3	0.08	1.00	2.10	-0.23	0.02	0.3	-0.32
Terminalia catappa	Sea almond	Almendro	5	0.07	1.00	3.25	**0.58**	0.25	0.28	**-0.54**
Timber species (commercially valuable)										
Anacardium excelsum		Espavé	9	0.17	1.00	6.90	**0.57**	**-0.58**	0.33	0.25
Cedrela odorata	Tropical cedar	Cedro amargo	10	0.32	1.13	23.56	0.24	-0.01	0.22	-0.21
Cordia alliodora		Laurel	2	0.02	1.00	8.00	-0.45	**0.63**	-0.32	-0.32
Dalbergia retusa	Cocobolo	Cocobolo	4	0.06	1.00	6.14	0.39	-0.39	**0.57**	-0.18
Pachira quinata		Cedro espino	10	0.22	1.00	18.22	0.05	-0.21	0.48	-0.28
Pino amarillo		Pino amarillo	5	0.06	1.00	4.14	0.29	-0.07	**0.54**	-0.47
Sterculia apetala		Árbol Panamá	3	0.03	1.00	1.50	0.26	0.2	-0.09	-0.11
Swietenia macrophylla	Mahogany	Caoba nativa	9	0.13	1.00	9.25	**-0.61**	0.26	0.17	-0.43
Tabebuia guayacan		Guayacán	3	0.02	1.00	1.67	0.18	-0.41	**0.82**	-0.41
Tabebuia rosea		Roble	9	0.15	1.00	5.72	**0.59**	0.41	0.29	**-0.7**
Zanthoxylum sp		Tachuelo	4	0.04	1.00	12.00	0.37	0.05	0.4	-0.45
Khaya senegalensis	African mahogany	Caoba africana	5	0.10	1.00	8.08	0.12	-0.25	**0.77**	**-0.52**
Tectona grandis	Teak	Teca	9	0.15	1.00	94.53	0.19	**0.51**	0.04	**-0.54**
Construction species (used for local building, fencing, roofing)										
Gliricidia sepium		Mataraton	2	0.03	1.00	1.00	-0.41	-0.29	0.32	-0.03
Spondias purpurea		Ciruela	12	0.24	1.14	8.55	0.17	0.38	**-0.8**	0.42
Cryosophila warscewiczii		Guagara	4	0.03	1.00	7.25	0.27	-0.49	0.2	0.29
Gynerium sagittatum		Caña Blanca	2	0.03	1.25	36.00	-0.07	-0.31	-0.31	**0.62**
Bambusa sp		Bambú	3	0.04	1.00	1.80	**-0.56**	-0.4	0.48	-0.09
No id		Macano	2	0.02	1.00	10.33	-0.16	-0.29	0.31	-0.02
No id		Sigua	2	0.02	1.00	3.00	-0.14	0	0.3	-0.3

Variation in species and landrace richness with highway access and ethnicity. On average, 17.3 (±1.3 S.E.) species and 26.8 (±2.2) landraces were encountered in the inventoried agroforests of each household. Neither species nor landrace richness varied with village cultural identity or village position relative to the highway (Species: $F_{5,6}$=1.42, P=0.34; Landraces: $F_{5,6}$=0.39, P=0.84; Table 4.2). Households maintained a large number of food species (14.1 ±1.1 S.E.) compared to species with timber, firewood, construction and non-dietary household uses (3.2 ± 0.3). There was no difference in the number of species maintained in each primary use group with village cultural identity or location relative to the highway, except in the case of timber. A greater number of timber species were found in highway (vs. remote villages) and in agroforests of Emberá (vs. Kuna) households. The number of timber species maintained by Black households did not differ from either Emberá or Kuna households.

Table 4.2 Comparison of species and landrace richness among villages demonstrates no difference in the total number of species (or landraces) per household with ethnicity or highway access. When considered by primary use, timber species differed with farmer ethnicity and highway access. Post-hoc pairwise comparisons (not shown) revealed that assemblages of timber species were more diverse in Emberá vs. Kuna villages (Black villages did not differ from either other group) and in highway vs. remote villages. Note that these comparisons exclude ornamental, medicinal, and variably cryptic species.

	Mean number per household (± 1 S.E.)	Comparisons among villages: effect of cultural identity and market access		
		F-stat	DF	P
Species (all uses)	17.3 (± 1.3)	1.179	5,6	0.417
Landraces (all uses)	26.8 (± 2.2)	0.385	5,6	0.843
Food species	14.1 (± 1.1)	1.190	5,6	0.416
Timber species	1.4 (± 0.2)	4.822	5,6	**0.041***
Species with other household uses	1.1 (± 0.1)	1.322	5,6	0.367
Construction species	0.5 (± 0.1)	0.498	5,6	0.770
Firewood species	0.1 (± 0.1)	1.238	5,6	0.395

Comparative analyses of composition. In terms of the *composition* of farmers' agroforest assemblages, PERMANOVA analyses revealed significant differences with cultural identity (p=0.001). Cultural identity explained 42% of the variation among villages, with distinct assemblages maintained by households in villages of each cultural group (all post-hoc p<0.05). In contrast, assemblages did not differ among remote and highway villages (p=0.13; Table 4.3). When species were analyzed in groups according to their primary uses, cultural identity continued to explain a significant portion of the variation for all primary use groups (range: 28-42% of variation explained; p<0.01 in all cases; Table 4.3). However, assemblages were not distinct among all cultural groups for each use. For example, in the case of timber species, the assemblages maintained by households in Black and Emberá villages did not differ (p=0.34), yet both differed from the timber species maintained by households in Kuna villages (p=0.02 for both). In contrast, for species that were mainly used in local construction, the assemblages

maintained by households in Black and Emberá villages differed from each other (p=0.02), but neither differed from those maintained by households in Kuna villages (Table 4.3).

Table 4.3 Distinctness of species assemblages. The composition of agroforest assemblages differed with village cultural identity for all primary uses (see Table 4.1). Ethnicity explained 28%-42% of variation in the composition of species assemblages. Highway access explained 15% of the variation in timber species assemblages (p=0.024) and 12% of the variation in construction species assemblages (p=0.095). Where highway access was significant, it explained only half the variation explained by ethnicity. Species assemblages were compared using PERMANOVAs. P-values are based on 9,999 permutations. Differences in assemblage composition between villages of specific cultural groups and remote vs. highway villages are based on post-hoc comparisons of means (p<0.1), and are indicated in the table with '≠', where K=Kuna villages, B=Black villages, E=Emberá villages, H=highway villages and R=remote villages.

	Cultural identity			Access to markets		
	Variance explained (R^2)	P	Differences (based on post-hoc pairwise comparisons)	Variance explained (R^2)	P	Differences (based on post-hoc pairwise comparisons)
Agroforest species (all)	0.42	**0.000**	K ≠ B ≠ E	0.09	0.121	NS
Food species	0.42	**0.000**	K ≠ B ≠ E[2]	0.08	0.187	NS
Species with other household uses	0.34	**0.021**	K,E ≠ B	0.05	0.678	NS
Fine timber species	0.28	**0.017**	K ≠ B,E	0.15	**0.024**	H ≠ R
Construction species[1]	0.34	**0.011**	B ≠ K,E	0.12	**0.095**	H ≠ R
[1]Interaction significant: Construction materials: Identity x Access: R^2=0.24, p=0.053						
[2]B vs. E only marginally significant (p=0.09)						

Correlations of individual species to cultural identity and highway access. The results of the correlation analyses relating each species to village descriptors are presented in Table 4.1. The three species most strongly correlated with Black villages were: guava (*Psidium guajava*), noni (*Morinda citrifolia*) and Malabar plum (*Syzygium jambos*); with Emberá: star apple (*Chrysophyllum cainito*), *caimito chico* (*Chrysophyllum sp.*), and monkey fruit (*Garcinia intermediana*); and with Kuna: cacao, coffee, and ***pagua***^{K} (*Renealmia sp.*). Timber and

construction species most strongly correlated to remote villages were native mahogany (*Swietenia macrophylla*) and to highway villages, *roble* (*Tabebuia rosea*).

Discussion

A richer understanding of species composition and rarity, not merely species richness, is essential to inform regional-level agrobiodiversity conservation. Cultural identity explained 42% of the variation in species composition among villages, but almost none of the variation in species richness. We did not detect differences in species composition or richness with village position relative to the highway, our proxy for market access. Together, our findings suggest that agrobiodiversity in the broader region benefits from each ethnic group's practices, as they create complementary species assemblages that result in a greater number of species being maintained overall. However, we also found that a large proportion of species were quite rare, found in a single village or only a few households. This suggests that specific villages and households may need to be targeted for successful in situ conservation of individual species. At the same time, because rare species were not all concentrated in one village (or even in the village of one cultural group or in remote/highway villages), efforts to conserve regional agrobiodiversity will need to include multiple villages in order to capture as many rare species as possible. In the following sections I discuss our findings in more detail and examine some of the factors that may underlie the patterns we observed.

Ethnic identities underpin the species composition of agroforests. Our finding that 42% of the difference in species composition among villages was due to cultural identity provides strong

support for the biocultural diversity hypothesis (Chapter 1). While previous work on agroforest species has suggested a causal linkage between cultural factors and agroforest biodiversity, such suggestions have often been confounded by the different environments occupied by different cultural groups. For example, tobacco, coffee and medicinal species were intensively cultivated in homegardens in Muslim districts of southern Ethiopia, but were absent from homegardens in Christian northern Ethiopia (Simoons 1965 in Soemarwoto 1987). It is unclear to what extent these findings reflected cultural vs. environmental differences among the two areas. Similarly, in two indigenous reserves in Costa Rica homegardens of farmers from the same ethnic group were found to be more similar in species composition (Zaldivar et al. 2002). However the fact that the different ethnic groups occupied different reserves suggests that these findings could also reflect differences in the environments of the two reserves.

An array of processes could underlie our finding that farmers of different ethnicities maintained distinct agroforest assemblages, including differences in species valuation based on distinct culinary and ritual practices, varying uses of species for building materials, and culturally-bounded knowledge- and seed-exchange networks. For example, we found that Kuna households were most likely to maintain cacao. There is an extensive literature describing the importance of cacao as a food, as well as an important ceremonial and medicinal plant to the Kuna (see Barnes (2008) for review). Similarly, genipap (*Genipa americana*) was absent from the agroforests of Black households, but maintained by 15-20% of Kuna and Emberá households. Genipap is used as a body dye by both the Emberá and Kuna, but to our knowledge is not used by Blacks. In terms of construction materials, *caña blanca* (*Gynerium sagittatum*) is

used as siding on Kuna longhouses and was only encountered in Kuna agroforests. This species is much less common in home construction of Emberá and Blacks, who generally harvest it wild.

While we do not explore the influence of social networks on seed acquisitions here, our analysis of maize and rice acquisitions by the same farmers suggested that seed exchange networks were strongly constrained by ethnicity (Chapter 3). As with rice and maize assemblages, we would expect ethnically-bounded exchange networks for agroforest species to reinforce differences among groups. Exchanges of information on agrobiodiversity may be as important as exchanges of germplasm in reinforcing similarities among members of a social network, encouraging farmers to seek out a particular variety or species. For example, noni (*Morinda citrifolia*) was most strongly associated with Black villages. Many Black households recounted seeking noni seed because they had heard that noni would soon be a lucrative cash crop, with a huge export market in Japan (at the time the research was carried out, this market had failed to develop).

Species richness did not differ with farmer ethnicity or highway access. In contrast to the strong relationships for species composition, species and landrace richness were unrelated to cultural identity, except in the case of timber species. For timber, we found a higher diversity of species in Emberá household homegardens relative to Kuna, and intermediate diversity levels in the homegardens of Black households. Because on average, households maintained <2 timber species, timber species differences had little impact on the overall numbers of species maintained. This finding stands in contrast to previous studies reporting strong differences in

agroforest richness with cultural identity (e.g., Abdoellah 1980 in Soemarwoto 1987; Perrault-Archambault and Coomes 2008).

Highway access was not linked to changes in composition for most species. The integration of farmers to regional markets has not yet lead to homogenization of agroforest assemblages among villages. An exception was for timber species and species used in local construction which accounted for less than 7% of the species maintained by a typical household. Soil characteristics differed between remote and highway villages (Chap. 1); however, we feel they are unlikely to have influenced timber assemblages. Rather, we suspect that differences in timber species reflect the better access of highway households to seedlings sold or donated by the Ministry of Environment, as well as from commercial plantations along the highway. Households in remote villages have more access to the 'wild' timber species nearly eradicated by selective logging in forests along highways. For example, native mahogany was more common in remote villages, and most farmers cultivating it reported encountering the seeds from wild individuals in the forest. In contrast, the higher occurrence of teak (*Tectona grandis*) in highway villagers' agroforests likely reflected their greater access to the teak plantations lining the Panama highway, where many are employed.

A caveat to our findings with regard to the effects of highway access on agroforest composition is that we did not control for tree age. It is plausible that there were shifts in composition occurring that were disguised by the long-lived nature of many trees. This topic should be

addressed in future research to ensure that the trends reported here do not mask more subtle, long-term shifts in species composition.

Many species have limited distributions. Many of the species we encountered had very restricted distributions, with about one third of species maintained by a single household. Further, rare species were not all concentrated in one village, or even in the village of one cultural group, or primarily in remote or highway villages. Work in other parts of the humid tropics has similarly highlighted the limited distribution of many agroforest species (e.g., Ban and Coomes 2004). While some of our rare species were volunteer species (i.e., from the surrounding forest that owners decided to maintain), others were expressly planted, and listed as species of concern at national and international levels (ANAM 1998, IUCN 2010). For example, mountain soursop (*Annona spraguei*), encountered at one household, is listed as "vulnerable" to extinction by the International Union for the Conservation of Nature (IUCN 2010).

Maintaining the landrace diversity of species is a priority of agrobiodiversity conservation (FAO 2010). Our research revealed that many species were only represented by one landrace in a household agroforest. Particularly diverse species, such as mango, avocado and cacao were each represented by at least ten landraces across the villages we surveyed, and probably more. Future work will aim to standardize landrace identities across villages (as we did for rice, maize and Musa spp. in Chapter 3), allowing us to assess whether species that currently appear to be widespread are in fact represented by different landraces in each locale, as was recently shown for trees in homegardens in Italy (Pavia et al. 2007).

Significance for conservation of agrobiodiversity and biocultural diversity studies

Previous work recommends that on-farm conservation include multiple agro-ecological zones to maximize the diversity maintained (Brown and Marshall 1995). Our results suggest this approach would be insufficient in some respects. We found strong relationships between the ethnicity of farmers in a village and the composition of their agroforests. This suggests that (for any given number of villages) higher levels of agrobiodiversity might be fostered across regions which support culturally diverse populations. Together with our finding that many species were rare, these findings underscore the need for culturally inclusive on-farm conservation initiatives, targeted at the level of landscapes (many villages). Thus, we extend earlier recommendations to encourage conservation initiatives that explicitly include and support the diverse, socio-cultural systems underlying the diversity within any agro-ecological zone (e.g., Maffi and Woodley 2010).

Our findings also have implications for the field of biocultural diversity research. A growing body of work in historical ecology indicates that the species composition of old-growth or 'primary' tropical forests - once considered 'pristine' - bear the signature not only of current, but past swidden agriculturalists (e.g. Balee 1993; Ross 2011). In Darién, this relationship was pointed out to me and further linked to the distinct agricultural practices of farmers of different ethnicities by an Emberá elder who had grown up on the Mogue River, an area which today is only inhabited by Emberá. In describing the area where she had grown up she said "There are cacao trees in the forests at the headwaters of the river. The trees were planted by the Kuna who lived there in the time of our grandparents."

In this study we demonstrated that the species composition of contemporary agroforests in a swidden landscape reflected the ethnic identities of its farmers. As these agroforests are abandoned, the cultivated tree species they contain are likely to influence the successional trajectories of the forests that replace them. As such, it is extremely likely that tomorrow's forested landscape would bear the signature of today's cultural diversity. This type of relationship provides a causal mechanism for observations of a correlation between cultural diversity and biological diversity (e.g., Moore et al. 2002), and is an exciting extension of our research.

Chapter 5: Understanding spatial and temporal dynamics of shifting cultivation: the roles of ethnicity and markets

> *It is useless to think of transforming the primitive agriculture of the Indians and Negroes [of Darién] without at the same time modernizing the entire cultural milieu.* (Pagnini 1970:231)

Introduction

Shifting cultivation supports millions of small-scale farmers world-wide. Also known as swidden or slash-and-burn agriculture, shifting cultivation is a form of agriculture in which the location of fields is shifted over time to allow soil recovery between periods of cultivation (Conklin 1957; Spencer 1966; McGrath 1987; Brookfield et al. 2002; Fig. 5.1). In tropical areas, the complex spatial and temporal dynamics of shifting cultivation systems have often overwhelmed attempts to characterize them (Padoch and Pinedo-Vasquez 2010). Fields under active cultivation can contain one or a variety of crop types and are managed using a combination of burning, mulching, intercropping and/or crop rotation. Fields left fallow are rapidly colonized by secondary forest vegetation. The broad array of field types, management regimes, and forest stages create heterogeneous patchwork landscapes renowned for their diversity (Padoch and De Jong 1992; Rerkasem et al. 2009; Padoch and Pinedo-Vasquez 2010).

---

[28] This chapter is co-authored with Sarah E. Gergel and Domingo Diaz.

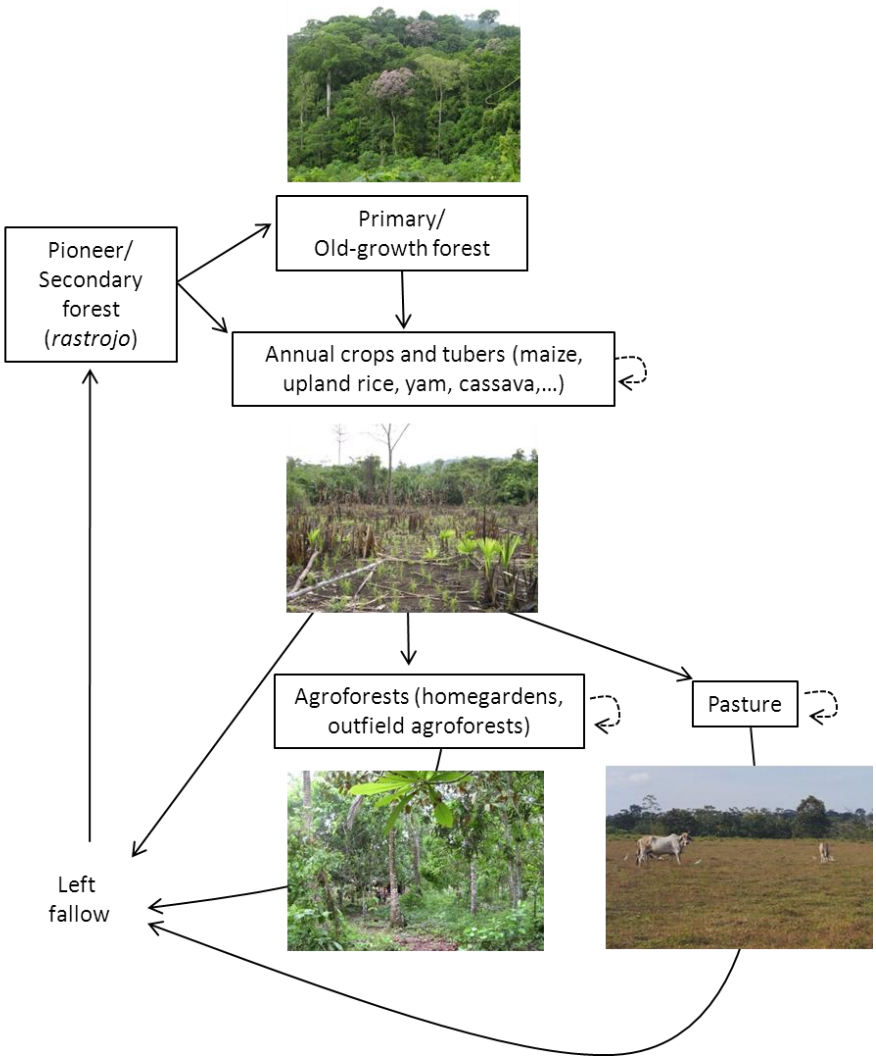


Figure 5.1 Example of a shifting cultivation cycle from Panama's Darien Region. Newly cleared fields are planted with annual crops or tubers. After 1-4 years, these fields are left fallow, planted with perennial agroforest species, or seeded with pasture grasses. Agroforests (particularly homegardens) and pastures may be maintained indefinitely with regular management. Other fields are eventually left fallow, and colonized by secondary forest species until being cleared again. This cycle differs from traditional systems of shifting cultivation in the region in that it includes pastures.

The causes of variation in the spatial and temporal structures of swidden landscapes merit attention for at least two reasons. First, swidden landscapes typically include significant areas of

forest and thus offer great potential for biodiversity conservation. However, the conservation value of these forests depends on their spatial structure (Ranganathan 2007; Norris 2008; Chazdon et al. 2009; Dent and Wright 2010; DeClerck et al. 2010; Fahrig et al. 2011; Fig. 5.2). For example, the movement of forest-dependent species may be restricted by large agricultural clearings (or clusters of smaller clearings of the same type), whereas the same species may move easily through landscapes in which small clearings are interspersed with agroforests and forest patches (Laurance and Gomez 2005). The average size and spatial arrangement of patches in a landscape also has important impacts on the delivery of ecosystem services of local and global benefit. For example, pollination (Ricketts 2004), natural pest predation (Settle et al. 1998), water quality (Gergel et al. 2002), and carbon storage (Laurance et al. 1998) can all be affected not only by the total area of land under different uses, but also by the arrangement of different land-use types within a given area. Similarly, the temporal dynamics of swidden agriculture determine the age range of regenerating patches, which may influence their suitability for some forest-dwelling species (DeWalt et al. 2003). Understanding the causes of variation in the spatial arrangement and temporal cycling of fields is therefore needed to inform conservation initiatives in swidden landscapes.

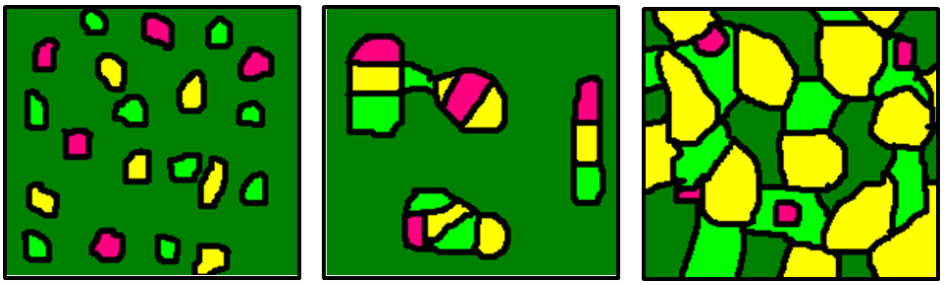


Figure 5.2 Bird's-eye views of three landscapes differing in the abundance, size, and spatial arrangement of various field types (yellow, pink and light green patches). The patterning of field types influences the fragmentation and connectivity of surrounding forest (dark green), which in turn can impact the conservation value of the landscape and the delivery of ecosystem services such as pollination, seed dispersal, and natural pest control.

The second motive for studying the spatial and temporal dynamics of swidden systems is to better inform policy. In many regions of the world, misconceptions and misinformation surrounding shifting cultivation continue to support policies that negatively impact shifting cultivators (e.g., Dove 1983; Rerkasem et al. 2009). For example, assumptions surrounding the inefficiencies of shifting cultivation have been used to justify the redistribution of forest lands maintained by swidden communities (Chapter 2; Kane 1986:201). At the same time, arguments citing the ecological destructiveness of shifting cultivation have been used to justify the relocation of swidden communities from parks and protected areas (Agrawal and Redford 2009; Lasgorceix and Kothari 2009). Furthermore, in many regions where it is practiced, shifting cultivation continues to be perceived and portrayed as a "primitive" form of agriculture (Velásquez Runk 2005:344; Condominas 2009). However, studies of shifting cultivation generally reveal it to be an economically rational agricultural system that has long sustained communities and is highly resilient to environmental shocks (Rice 2003; Mertz et al. 2009). The

same studies reveal it to be a highly variable system, and additional, site-specific studies are therefore needed for the development of socially just and scientifically sound policy.

Many landscapes dominated by shifting cultivation are culturally diverse and are increasingly connected to regional and global markets. Previous studies exploring factors that influence patterns of shifting cultivation have emphasized household-level factors such as access to land, capital and labour (e.g., Chayanov 1986; Stier 1982; Coomes et al. 2000; Tschakert et al. 2007). Less attention has focused on the influences of famer ethnicity and access to markets, both of which have been shown to be useful proxies for factors that impact agricultural practices (previous chapters). Unlike factors that vary among households, farmer ethnicity and market access often vary widely across landscapes, reflecting the tendency for ethnic groups to partition landscapes (Moore et al. 2002; Manne 2003), and for market access to vary with distance to roads and other transport corridors (Kramer et al. 2009; Salonen et al. 2011). This broad-scale variation suggests the possibility of a landscape mosaic in which the areas managed by different ethnic groups, or with differing access to markets, may have distinct patterns of fragmentation and connectivity (i.e., distinct patchwork structures). While the striking pattern of deforestation near roads throughout the tropics is well known (e.g., Chomitz and Gray 1996; Kirby et al. 2006), and some studies have compared rates of deforestation at broad scales among indigenous vs. non-indigenous territories (with the former generally dominated by swidden agriculture and the latter by cattle ranching; Chapin 1992), comparisons of the spatial and temporal dynamics of shifting cultivation among neighbouring groups of shifting cultivators with contrasting access to markets are rare.

A variety of mechanisms are likely to underlie relationships between ethnicity, market access, and the structure of swidden landscapes. For example, settlement patterns (e.g., dispersed vs. dense settlements), crop preferences, and taboos and ideologies surrounding land use and management are often shared by members of an ethnic group and may impact land-use practices (e.g., Herlihy 1986; Godoy 1998; Atran et al. 1999; Tengö et al. 2007). Ethnicity may also be correlated with land rights and political power, which in turn may influence land use by determining, among other things, the extent to which members of an ethnic group must compete with other groups for land (Bourgois 1988:329 in Wali 1989:5).

Market access can impact the types and characteristics (e.g., size) of fields maintained by shifting cultivators if markets create demand for particular crops or facilitate access to agricultural technologies (e.g., machinery, engineered seed, synthetic inputs) that encourage particular field types (reviewed in Kramer et al. 2009). Market access may also impact landscape structure indirectly by increasing competition for land. Land scarcity, in turn, has been shown to encourage shorter fallow periods and/or longer cultivation periods, and may result in less forest cover in a landscape (e.g., Boserup 1965). Finally, market access may alter patterns of land-use by providing alternatives to farming as an income source, or by providing access to imported substitutes for food crops, thereby reducing the portion of the population relying on agriculture for their livelihoods (reviewed in Kramer et al. 2009).

Here, we explore the influence of farmer ethnicity and market access on patterns of shifting cultivation in Panama's Darien Region. The Darien Region is a global biodiversity hotspot housing the largest remaining area of semi-deciduous tropical forest on the Pacific Slope of Central America (Conservation International 2005). It is home to farmers of several ethnicities

who manage different parts of the landscape and have differing access to regional agricultural markets. Using field-based measurements and household interviews, we describe the spatial and temporal dynamics of shifting cultivation practices in the region. In particular, we explore several commonly-measured indices from landscape ecology, including number, size, and spatial arrangement of fields, and we also look at field development histories and management regimes (e.g., use of petrochemicals). Our second objective is to explore if and how these measures are influenced by farmer ethnicity and market access. While a number of studies have addressed agricultural practices in the region (e.g., Torres de Arauz 1970; Pagnini 1970; Herlihy 1986; Wali 1989; Velásquez Runk 2005; Tschakert et al. 2007; Sloan 2007), to our knowledge this is the first study to characterize fields from across the region and from villages representing a cross-section of both ethnic groups and access to markets.

Methods

Study region and population. Most villages in Panama's Darien Region are segregated along ethno-linguistic lines. We worked with Black, Emberá and Kuna farmers. These three cultural groups have shared the landscape of the Chocó bioregion, which has its northern limits in Panama's Darién, for over five centuries. Today, the three groups manage approximately 61% of the landscape of the Darien Region (Chapter 2). Farmers of all groups rely on shifting cultivation for subsistence and/or income. Typically, farmers clear forest for new fields during the annual dry season (December-March). Clearings are burned just before the onset of the rainy season (April), and planted with annual crops or tubers shortly thereafter. After one to four years of cultivation (with 1 to 2 crop cycles per year), fields may be left fallow, converted to agroforests,

or converted to pasture (Fig. 5.1). Agroforests and pasture can be maintained indefinitely with management in some sites. Fallowed fields (of any type) are quickly recolonized by secondary forest species, with small- to medium-sized trees forming a secondary forest canopy within three-to-five years of abandonment (Herlihy 1986:43). Throughout the region, usufruct rights to land (including fallow fields) were traditionally granted to the farmers or families who originally cleared them, with a few exceptions (Herlihy 1986:193; Howe 2002:10; Torres de Arauz 1970:56; Perafán and Nessim 2002:25).

We worked with four villages of each cultural group[29], two that were located on or close to the Pan-American Highway (hereafter referred to as "highway villages") and two that were more remote, with difficult access to the highway and therefore to Panama City markets ("remote villages"; Fig. 5.3). All Kuna and Emberá villages were located on reserve lands with collective titling systems, whereas all Black villages were located on lands eligible for private titling. The selection of study villages and their characteristics are described in detail in previous chapters.

[29] Except for Kuna villages, where we worked in five because competing activities during our second visit to one village meant we were unable to find enough participants to continue the study there. Village K1a was replaced with village K1b for analyses related to fields other than agroforests and homegardens.

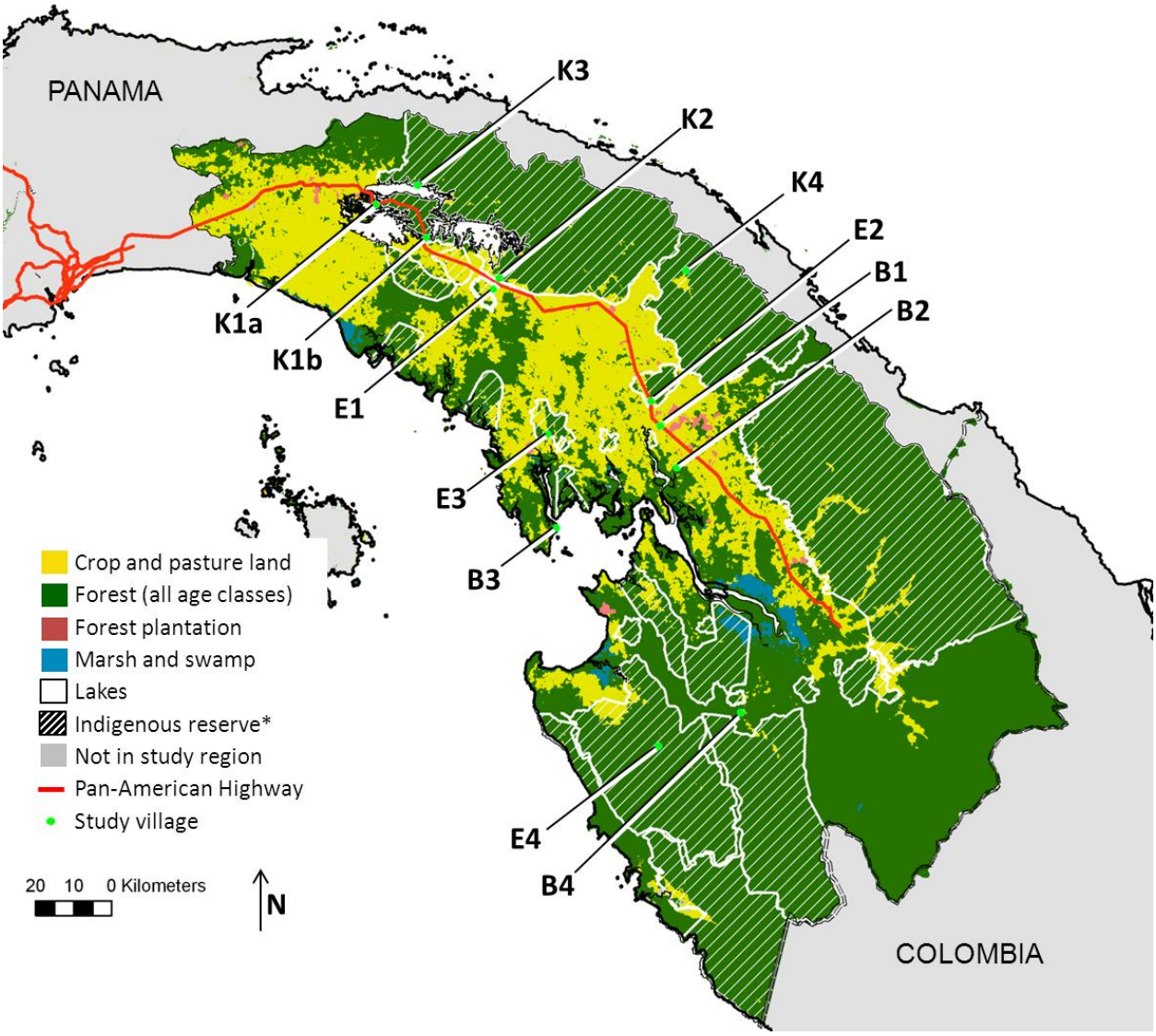


Figure 5.3 Location of study villages with respect to indigenous reserves and forest cover in the year 2008 in Panama's Darién Region. Study villages are indicated by a two-character code where the prefix indicates the cultural group of the village (B=Black, K=Kuna, E=Emberá) and the suffix indicates whether the village was considered a highway village (1-2) or remote village (3-4). All indigenous villages were located in indigenous reserves where land is owned collectively. Villages K1-K3 were in the Comarca Kuna de Madungandí; village K4 was in the Comarca Kuna de Wargandí. Emberá villages E1-E3 were each in a *tierra colectiva*, while village E4 was in the Comarca Emberá-Drua. All Black villages were on lands outside indigenous reserves. Data on land cover are from ANAM (2009). Data on boundaries of indigenous reserves are described in Appendix 2.3.

Identification of basic field "types". The research began with informal interviews and participant observation during stays of approximately one month in one village of each cultural group in early 2007. During these visits KK participated in agricultural activities whenever possible and worked to identify broadly relevant field "types" that were both meaningful to farmers and would allow for comparative analyses among villages (cf. the "land-use stages" of Brookfield et al. 2002). The second phase of the research (2007-2008) documented these field types in the thirteen study villages though a combination of household surveys on field holdings, ground-based mapping of fields, and the collection of detailed land-use histories for a subset of fields.

Household field holdings. In each village we worked with a random sample of approximately 10 households to describe the number of fields of each "type" under current cultivation. Here we define a household as a group of people sharing a home. We first asked household farmer(s) to list and describe their fields under current cultivation. Following this free-listing, farmers were read a list of crops common in the region and were asked if they cultivated any of them, and, if so, in which of their listed field(s). This exercise helped to clarify how farmers viewed field "units" and in some cases led to fields being added or removed from the household's field list. If fields were shared with other households, we noted the number of sharing households. To control for the impact of household size on field holdings (e.g., Stier 1982), we recorded the number of active adults per household, which we defined as the number of able-bodied persons who spent most of their time working (as opposed to studying, playing or resting). Finally, in 2009, in a

follow-up visit to each community, we asked farmers if they had cleared any new fields in 2008 after our visit(s) (cf. Herlihy 1986:209). Any new fields were added to the household's field list.

Mapping spatial characteristics of fields. In order to determine the size and spatial dispersion of fields we spent approximately one day (in total) with each household mapping as many of their fields as possible[30]. All fields planted in annual crops and tubers were mapped during the 2008 growing season (April-December), while agroforests and homegardens were mapped during a visit in either 2007 or 2008. Each field was mapped with a GPS (N=645 fields) and field area was later determined using GIS mapping software (ArcGIS v. 9.2, ESRI). Due to the large size of pastures (and thus the time that would have been required to measure them), we relied on owners' estimates of size. These estimates are considered reliable as they are required for many pasture-related purchases (e.g., barbed wire, grass seed, and herbicides). We also used GIS to explore field arrangement. In particular, we measured the Euclidean distance between the centre of each field and the centre of the owner's home village and we identified the "nearest neighbour" for each field using the Euclidian distances between the centres of all measured fields. We noted whether the nearest neighbour was a field of the same "type," and whether it belonged to the same farmer.

Land-use histories. Finally, we collected detailed land-use histories for a subset of annual-tuber fields (only those annual-tuber fields that were dominated by rice or maize, N=202 fields)

[30] Detailed inventories of cultivated plants were also carried out during this time, limiting the number of fields that could be mapped – see crop diversity research presented in Chapters 3 and 4.

belonging to each participating household. We limit our land-use history analysis to this field type because these field types were maintained by most households and tended to represent the first phase in the field rotation cycle (Fig. 5.2).We asked owners (1) when the primary[31] forest at the site had been cleared; (2) if the field had ever been fallow; (3) if so, for how many years it had been fallow during the most recent fallow period; (4) when the field had last been burned; (5) if herbicides, pesticides, or fertilizer had been used in the field during the 2008 season; and (6) to describe the yearly use of the field over the last 8 years.

Statistical Analyses

Testing the influence of ethnicity and market access on field holdings and field characteristics. We contrasted field holdings, field characteristics and management practices associated with each field type among farmers of different ethnicity and farmers located in villages with differing access to the highway, which we used as a proxy for market access. We only compare within field types (e.g., among pastures, among homegardens, etc.), because large differences among field types (e.g., in average field size and distance from villages)make general comparisons less meaningful. Also, the different species and primary uses associated with each field type may result in distinct responses to market forces. To account for differences in sampling effort among villages, analyses used either village-level averages or proportions. Where multiple fields of one type had been sampled for one household, we calculated

[31] By primary forest I refer to what Spanish speakers in the region call *monte virgen* (virgin forest) or *montaña* (which is used locally to refer to mature forest not known to have been cleared), and what the Kuna call ***ney serret***^{K} (forest not cleared in living memory; Stier 1982:525). The long history of human management in the region suggests that few of these forests are actually primary forests (Herlihy 1986:42; Chapter 2).

household-level averages prior to calculating village-level averages (e.g., the areas of all the annual fields that a household maintained were averaged before calculating the village-level average for annual fields). When calculating the number of fields of each type maintained per household, we counted fields that were shared with other household(s) as fractions (e.g., if a household had 5 annual fields, but one was shared with another household, they were considered to have 4.5 annual fields). To account for the possible influence of household size on a household's field holdings, we tested for differences not only in the number of fields per household, but also in the number of fields per active adult. In the case of homegardens, which were limited to one per household, we tested for differences in the proportion of households maintaining a homegarden.

Continuous variables were tested using a factorial ANOVA in which the independent variables were ethnicity and highway access (Table 5.1). Variables were transformed prior to analysis, as appropriate, as determined through examination of residuals. In two cases where transformations could not meet assumptions of homogeneity of variances, we compared rank scores using ANOVA (field distance to village, years since old-growth forest cleared). Proportion data were tested using a logistic generalized linear model with a binomial or quasi-binomial error distribution, as was most appropriate given the dispersion parameter (Table 5.1). Analyses that grouped fields of all types treated data from villages K1a (in which we only measured agroforests and homegardens) and K1b (in which we only measured annual-tuber and minor crop fields) as follows. For total numbers of fields, we used data from only one village (in which we had asked households to list all their fields of each type, even though we didn't measure annual-tuber and minor-crop fields). For distances of fields to villages, we used the

average of data from both villages. For nearest neighbour analyses, we did not include data from either village (as in one case all fields would have had agroforests as nearest neighbours, and in the other annual fields). To allow us to carry out the nearest neighbour analyses we therefore applied the average value from all study villages to village K1. We felt this would create the least bias in our analyses of differences among villages of different ethnic groups/highway access, as any differences detected for Kuna highway villages would reflect the strong effect of village K2.

Table 5.1 Dependent variables examined for their relationship with farmer ethnicity and highway access. Proportion data were tested using logistic generalized linear models (Logistic GLM), while continuous data were tested using Analysis of Variance (ANOVA).

Variable	Analysis
Household field holdings (currently under cultivation)	
Proportion of households maintaining a homegarden	Logistic GLM
Number of fields of each type per household	ANOVA
Number of fields of each type per active adult	ANOVA
Spatial arrangement of fields	
Field size (ha)	ANOVA
Distance from village (km)	ANOVA
Distance to closest measured field ("nearest neighbour")	*Not tested*
Nearest neighbour is same field type? (yes/no)	Logistic GLM
Nearest neighbour belongs to same household? (yes/no)	Logistic GLM
Temporal cycling of fields (land-use histories of annual fields)	
Time since old-growth forest cleared (years)	ANOVA
Time since field burned (years)	ANOVA
Duration of current cultivation period (years)	ANOVA
Proportion of fields ever fallow	Logistic GLM
Duration of last fallow period (years)	ANOVA
Proportion of fields with herbicide application in 2008	Logistic GLM
Proportion of fields with pesticide application in 2008	Logistic GLM
Proportion of fields with fertilizer application in2008	Logistic GLM

Results

Field types. Five general field types could be consistently identified across all villages: (1) homegardens, defined as an agroforest adjacent to a house that typically contained a mixture of fruit trees, Musa spp., and herbs, (2) outfield agroforests, which included all fields planted in *Musa spp.* and/or fruit trees and other perennial species (but not homegardens), (3) annual-tuber fields dominated by maize, rice, old world yams, cassava or sweet peppers, (4) pastures, and (5) minor crop "patches" – small monocultures of crops such as taro, new world yams, pineapple, sugar cane, and ginger (Table 5.2).

In total, we mapped and measured 645 fields. An example of the field mapping data for participating households in one village is given in Figure 5.4. In the following sections, we describe basic field types and associated characteristics and land-use practices at the regional-level (i.e., averages from across the thirteen study villages). We then report results of analyses of relationships between farmer ethnicity, highway access and field characteristics and land-use practices.

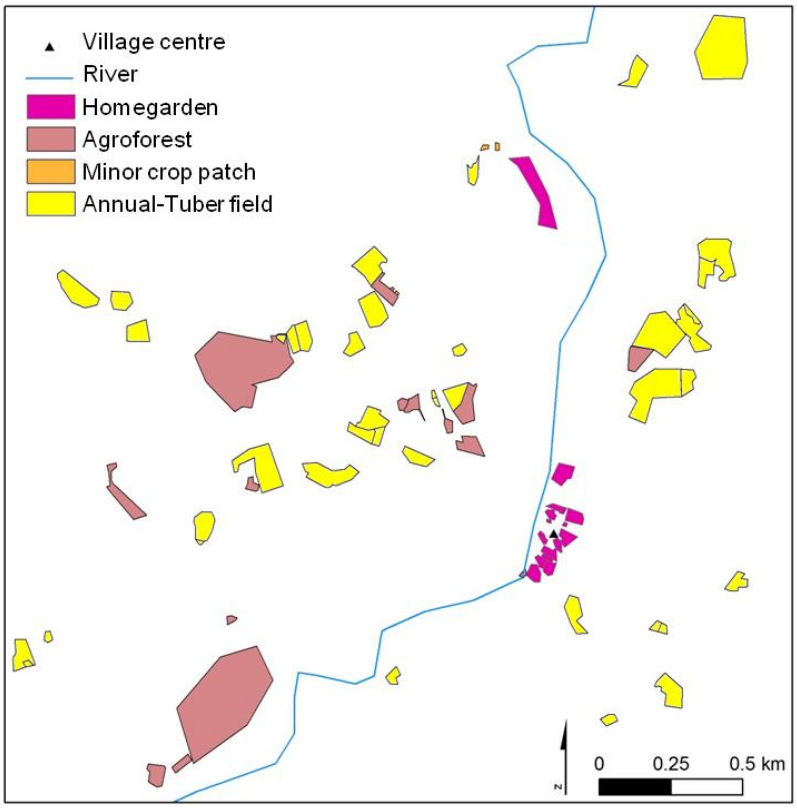


Figure 5.4 Mapped fields for participating households in one Emberá village. Homegardens (and homes) were concentrated in the village with one exception. Other field types were located at distances of up to 2 km from the village centre. Note that there are only two small 'minor crop patches' (the third and fourth patches from the top of the figure).

Regional averages

Household field holdings. Across all villages, 90% of households maintained a homegarden. Pastures were maintained by 23% of households, with all but two of these households maintaining a single pasture. In addition, households on average maintained 4.5 (±1.0 SE) outfield agroforests, 3.4 (±0.4) annual-tuber fields, and 0.9 (±0.2) minor crop "patch" fields (Table 5.2).

Size and spatial arrangement of fields. Ranked from largest to smallest, mean field sizes in hectares were: pastures (25.43 ± 7.45 SE), annual-tuber fields (0.52 ± 0.05), agroforests (0.38 ± 0.05), homegardens (0.15 ± 0.03), minor crop fields (0.05 ± 0.02). Ninety-two percent of homegardens were located within 1 km of a village centre; those that were farther away belonged to the few participating households that were based outside of a village proper (Fig. 5.4). In contrast, fields of other types were on average 2.7 km from a village (excluding pastures, for which we did not have distance data) (Table 5.2). The frequency distributions of distances to village centres for these field types are shown in Figure 5.5.The most distant fields were at just over 13 km from a village centre.

Table 5.2 Description and characteristics of main field types. Values shown are means and standard errors across villages, and are based on village-level means for participating farmers in each study village.

	Homegardens (N=115)	**Agroforests** (N=187)	**Annual-Tuber** (N=303)	**Minor crop "patches"** (N=40)	**Pasture** (N=33)
Most commonly encountered crops (in descending order)	Mixed fruit trees, Musa spp., mixed tubers (cassava, yam, taro), herbs for cooking, medicinal plants	Mixed fruit trees, Musa spp., species for timber, construction, fiber, fencing	Rice, maize, cassava, yam, pepper, beans	Sugar cane, taro, pineapple, ginger, ñampi, pigeon pea, cucumber, squash, sweet potato	Grass types (local names): *Ratana, Brizantha, Tanner, Indiana, Faragua, Estrella, Alicia*
Proportion of households with this field type in 2008	**0.90 (± 0.04)**	**0.89 (± 0.03)**	**0.92 (± 0.04)**	**0.52 (± 0.07)**	**0.23 (± 0.06)**
Number of fields per household	**0.90 (± 0.04)**	**4.5 (± 1.0)**	**3.4 (± 0.4)**	**0.9 (± 0.2)**	**0.2 (± 0.1)**
Number of fields per adult	**0.33 (± 0.03)**	**1.3 (± 0.2)**	**1.2 (± 0.2)**	**0.3 (± 0.1)**	**0.09 (± 0.03)**
Mean field size (ha)	**0.15 (± 0.03)**	**0.38 (± 0.05)**	**0.52 (± 0.05)**	**0.05 (± 0.02)**	**25.43 (± 7.45)**
Mean distance from village center (km)	**0.28 (± 0.73)**	**2.74 (± 0.48)**	**2.70 (± 0.50)**	**2.92 (± 1.00)**	**NA**
Mean minimum distance to another measured field (to "nearest neighbour") (km)	**0.08 (± 0.01)**	**0.20 (± 0.04)**	**0.21 (± 0.09)**	**0.05 (± 0.02)**	**NA**
Proportion for which nearest neighbour field was same field type	**0.86 (± 0.04)**	**0.54 (± 0.07)**	**0.72 (± 0.05)**	**0.25 (± 0.12)**	**NA**
Proportion for which nearest neighbour field belonged to same household	**0.08 (± 0.03)**	**0.61 (± 0.07)**	**0.77 (± 0.07)**	**0.98 (± 0.02)**	**NA**

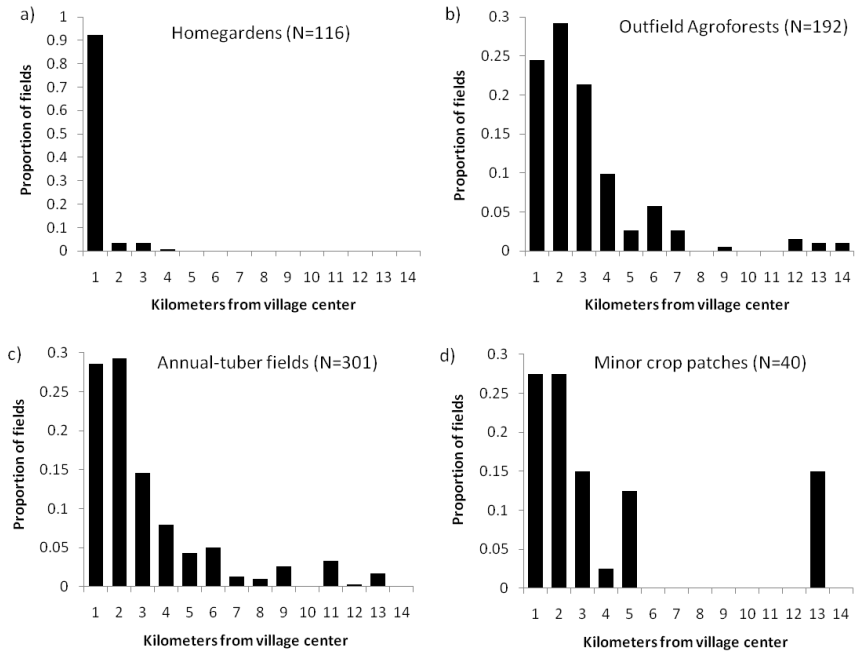


Figure 5.5 Proportion of fields at 1 km intervals from village centres. Each panel represents the dispersion of one field type around the study villages: (a) homegardens, (b) outfield agroforests, (c) annual-tuber fields and (d) minor crop patches. Note that the scale of the Y axis differs for panel (a). The median distance of fields to their owners' villages was 1.1 km. The most distant field was at 13.2 km. All distances are Euclidean.

Nearest-neighbour analyses revealed that the minimum distance to the centre of another measured field was 80 m (± 14 m) for homegardens, 210 m (± 87 m) for annual-tuber fields, 199 m (± 45 m) for outfield agroforests, and 54 m (± 21 m) for minor crop fields. The vast majority of homegardens (86%) had another homegarden as a nearest-neighbouring field, reflecting the fact that homegardens were concentrated in villages. However, annual-tuber fields also tended to be clustered in space, with 72% having another annual-tuber field as a nearest neighbour. In contrast, only 54% of agroforests and 25% of minor crop patches had another field of the same type as a nearest neighbour. We also looked at whether nearest neighbour fields were owned by the same household or a different household: 98% of minor-crop fields had a nearest-neighbour

field belonging to the same household, compared to 77% of annual-tuber fields, 61% of outfield agroforests, and just 8% of homegardens (Table 5.2).

Land-use histories of annual fields. We obtained land-use histories for 202 annual fields that were dominated by rice or maize during our survey. The average time since primary forest had been cleared at the sites of these fields was 17.9 (±2.5) years. Seventy-five percent of annual fields had been fallow at some point in their history, and the average length of the most recent fallow period was 6.7 (±1.4) years. The average time the measured fields had been under continuous cultivation was 0.8 (±0.3) years. In terms of field management, 97% of fields had been burned at the beginning of the 2008 season. Applications of herbicides were made to 42% of fields (both to clear vegetation prior to planting and for in-crop targeting of weeds), of pesticides to 15% of fields, and of fertilizer to 2% of fields (Table 5.3). The historical land-use trajectories of 198 fields for which farmers were able to provide at least 1 year of data are summarized in Fig. 5.6. The previous year's use of the 2008 annual fields was: fallow (55%), annual-tuber field (21%), primary forest (19%), agroforest (3%), and minor crop field (2%). Only 8% of the 2008 fields had been annual-tuber fields continuously for more than two years (i.e., in 2008, 2007, and 2006), and only 2% had been annual-tuber fields continuously since the year 2000.

Table 5.3 Land-use histories of annual fields planted in rice or maize in 2008. Averages for all study villages with standard errors.

	Annual fields dominated by rice and maize in 2008 (N=202)
Years since old-growth forest cleared	17.9 (± 2.5)
Proportion ever fallow	0.73 (± 0.07)
Length of previous fallow period (years)	6.7 (± 1.4)
Years since burned	0.04 (± 0.02)
Length of most recent cultivation period (years)	0.79 (± 0.26)
Proportion with use of herbicides in 2008	0.42 (± 0.09)
Proportion with use of pesticides in 2008	0.15 (± 0.04)
Proportion with use of fertilizer in 2008	0.02 (± 0.02)

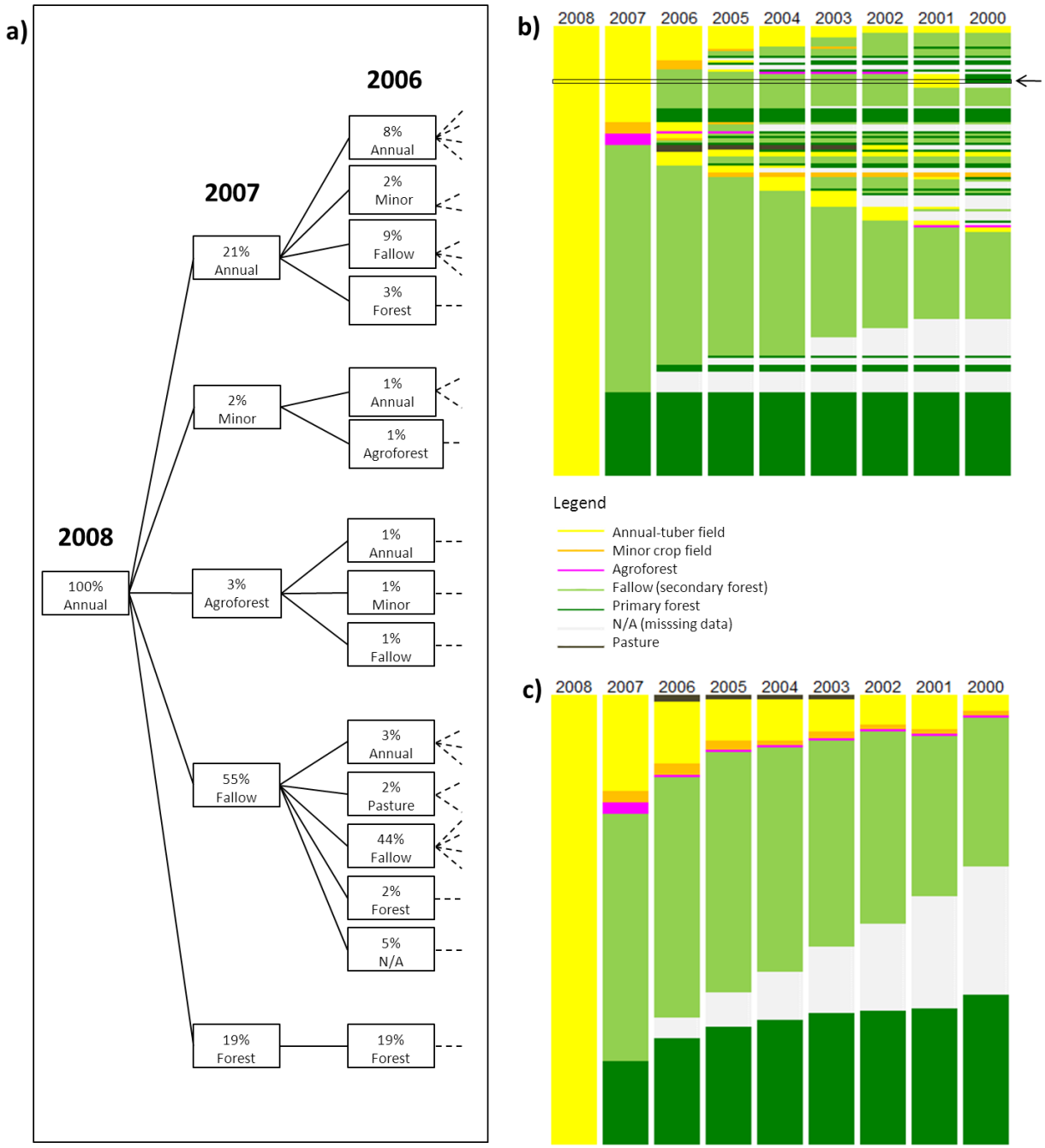


Figure 5.6 Land-use histories of 198 annual-tuber fields planted with maize or rice in 2008. Panel (a) shows uses of these fields in 2007 and 2006. Panel (b) shows the same data in graphical form, but extends back eight years. Scanning horizontally across panel (b) from left to right reveals the land-use history of a field between 2000 and 2008 (for example, the field indicated with " ← " was under primary forest in 2000, cleared and planted with annual crops in 2001, was fallow from 2002-2006, and then was planted with annual crops again in 2007 and 2008). Panel (c) shows the total percentage of the 2008 annual fields under each land-use type during each of the preceding 8 years. Note that grey cells indicate missing data. Between a third to a half of fields were under primary/old-growth forest at the beginning of the period. Only 2% of fields were used

continuously as annual fields from 2000-2008 (yellow in all time periods in panel (b)). The remainder of fields cycled between annual-tuber and fallow phases, or, rarely, between annual-tuber fields and minor crop fields, agroforests dominated by Musa spp., or pasture.

Influence of ethnicity and highway access

Number and spatial arrangement of fields - all types. The total number of fields per household differed with farmer ethnicity, with Kuna households maintaining significantly more fields per household (14.5 (± 3.69) fields) than Black or Emberá households (7.5 (± 1.96) fields and 7.6 (± 1.55) fields per household, respectively; $F_{2,6}$ group =11.78, p=0.008; contrasts K-E and K-B p<0.01[32]; Table 5.4). However, this difference among groups in number of fields disappeared when considered on per-adult basis because of the greater number of active adults in Kuna households[33]. There was no difference in the total number of fields per household or per active adult between remote and highway villages.

Nearest neighbour analyses revealed that Black and Emberá farmers were more likely to group their fields in one area, whereas Kuna farmers were more likely to intersperse their fields with the fields of other farmers. In addition, fields in remote villages, and particularly in remote Kuna villages, were more likely to be interspersed by owner than were fields in highway villages

[32] Statistical results are presented using "group", "access", and "group x access" to indicate whether an F statistic and associated P value refers to the effects of the independent variable ethnic group, market access, or to the interaction between the two. To denote groupings I use K (Kuna), E (Emberá), B (Black), H (Highway), R (Remote).

[33] The number of active adults per household was highest in Kuna villages (4.32 ± 0.36 SE) where post-marital residence was matrilocal, and it was common for adult daughters and their young family to share their parents' home (table 4). The number of active adults per household was significantly lower in Emberá (3.06 ±0.35) and Black (2.84 ± 0.53 SE) villages ($F_{2,6}$ group=7.25, p=0.02; contrasts K-E: p=0.03, K-B: p=0.05, B-E: p=0.86), where adult children with young families were less likely to remain living with their parents or in-laws. The number of active adults per household did not differ with market access (p=0.90).

($F_{2,6}$ group =30.16, p<0.001; $F_{2,6}$ access =23.50, p=0.003; $F_{2,6}$ group x access =12.8, p=0.007). Fields were more likely to be clustered by "type" in Black villages on the highway and in Emberá and Kuna villages that were more remote ($F_{2,6}$ group x access =3.94, p=0.08).

Homegardens. The proportion of households with a homegarden differed significantly with farmer ethnicity but not with highway access (Table 5.5). All surveyed Emberá households maintained a homegarden, a significantly higher proportion ($F_{2,6}$ group=6.43, p=0.04) than in either Black (0.88 ± 0.06 SE) or Kuna (0.82 ± 0.08) villages (contrasts: E-K: p<0.0001, B-K: p=0.39, B-E: p<0.0001). However, the size of homegardens did not differ with farmer ethnicity or highway access (table 5).

Outfield agroforests. The number of outfield agroforests per household was related to both ethnic group and highway access ($F_{2,6}$ group x access=12.58, p<0.01), with Kuna households in remote villages maintaining almost twice as many agroforests as Kuna households in highway villages (KR=11.44 (±1.31) vs. KH=6.28 (±0.48) agroforests per household; contrasts KR-KH: p= 0.008), and over five times the number of agroforests of Black or Emberá households, (E=2.52 (±0.34), and B=2.05 (±0.47) agroforests per household; contrasts KR-KH: p= 0.008; KR, KH vs. all others: p<0.005; table 5.6). Even when corrected for the number of active adults per household, over twice as many agroforests were maintained in remote Kuna villages than in Black or Emberá villages. There was a marginal difference in the size of outfield agroforests, with larger agroforests maintained by Emberá households in remote villages ($F_{2,6}$ group x access=3.44, p=0.1; Table 6).

Annual-tuber fields. There was no difference in the number, size, or distance from villages of annual-tuber fields with ethnicity or highway access (Table 5.7). Primary forests had been cleared more recently at the sites of the annual fields of Kuna farmers than of Black and Emberá farmers, irrespective of position relative to the highway (time since old-growth forest felled at site: K=9.85 years (±2.70 SE), E=20.96 years (±4.78), and B=23.01 years (±2.08); $F_{2,6}$ group=8.43, p=0.02; contrasts: K-E=0.08, B-E=0.45, B-K=0.02, Table 5.7). Accordingly, a greater proportion of the annual fields of Black and Emberá farmers had been fallow at some point in their histories (proportion ever fallow: B=0.87 (±0.04 SE), E=0.84 (±0.10), K=0.47 (±0.13); $F_{2,6}$ group=13.39, p= 0.001; contrasts: K-E=0.07, B-E=0.62, B-K=0.02), though the length of the last fallow period did not differ with farmer ethnicity or position relative to the highway. There also was no difference with ethnicity or highway access in the number of years a field had been under continuous cultivation, or the time since fields had been burned (almost all fields were burned annually, regardless of whether they had been cultivated the previous year; Table 5.7).

The use of herbicides and pesticides differed with both farmer ethnicity and highway access (Herbicides: $F_{2,6}$ group= 46.70, p <.0001, contrasts: K-E<0.0001, B-E=0.60, B-K<0.0001; R-H=0.1; Pesticides: $F_{2,6}$ group x access=11.67, p=0.003, contrasts: BH, BR, KH > ER,EH (p<0.07); BH, BR, KH >KR (p<0.001); EH, ER>KR (p<0.0001)). Black and Emberá farmers in highway villages were most likely to use herbicides (70% using herbicides), and Kuna farmers were least likely to use herbicides (5% using herbicides; Table 5.7). The number of farmers using pesticides was generally lower than the number of farmers using herbicides, with the

exception of Kuna farmers in highway villages, where an average of 26% of farmers reported using pesticides in 2008; Table 5.7). Only two farmers in any of the study villages reported using fertilizers; both were from a Black village on the highway.

Minor-crop fields. There was no difference in the number, size, or distance from villages of minor-crop fields with ethnicity or highway access (results not shown).

Pastures. The number of pastures per active adult was marginally higher in highway villages than in remote villages ($F_{2,6}$ access=3.94, p=0.08; contrast Highway-Remote p=0.1), and in Black villages compared to Kuna villages ($F_{2,6}$ group=3.60, p=0.1; contrasts B-K p=0.09, E-K p=0.15, B-E p=0.88; Table 5.8). The absence of pastures in all but one Kuna village meant that we were unable to formally test for differences in pasture size by ethnicity or highway access. However, the pastures of Black farmers were on average three times larger than those of Emberá farmers (average sizes: Black: 37.3 ha (±12.2 ha), Emberá: 11.97 ha (±5.00 ha)).

Table 5.4 Comparison of the number and spatial arrangement of fields of all types* maintained by households of different ethnicities and with differing access to the highway. (*Homegardens were excluded from nearest neighbour and distance analyses because we were interested in the arrangement of fields located outside of villages (i.e., in the field-forest matrix). Values in brackets are standard errors.

All field types	Remote			Highway			Statistical differences G=Ethnic group, A=Market access
	Black	Emberá	Kuna	Black	Emberá	Kuna	
Number of fields per household	6.28 (± 1.03)	6.42 (± 0.35)	16.5 (± 2.75)	8.8 (± 1.25)	8.7 (± 0.97)	12.63 (± 2.34)	G** (K > B,E)
Number of fields per active adult	2.72 (± 0.89)	2.36 (± 0.41)	4.12 (± 0.1)	3.78 (± 0.55)	3.03 (± 0.01)	3.65 (± 1.52)	NS
Average distance from village centre (km)	3.54 (± 0.63)	1.27 (± 0.32)	3.47 (± 3.18)	4.05 (± 2.88)	2.42 (± 0.93)	1.57 (± 0.30)	NS
Minimum distance to another measured field (to "nearest neighbour") (m)	87.72 (± 0.57)	100.59 (± 13.78)	532.9 (± 475.12)¶	98.93 (± 4.7)	149.8 (± 48.14)	138.92 (± NA)†	NS
Nearest neighbour field same field type	0.4 (± 0.12)	0.7 (± 0.16)	0.76 (± 0.03)	0.66 (± 0.23)	0.54 (± 0.03)	0.56 (± NA)†	GxA. (BH > BR; KH,EH <KR,ER)
Nearest neighbour field same owner	0.9 (± 0.04)	0.7 (± 0.05)	0.25 (± 0.05)	0.85 (± 0.15)	0.89 (± 0.06)	0.74 (± NA)†	G**, A**, GxA* (K < E,B; R < H; KR < KH)

Significance codes: '***' 0.001; '**' 0.01; '*' 0.05; '.' 0.1; 'ns' > 0.1; Not tested: '--'. Post-hoc comparisons: B=Black, E=Emberá, K=Kuna, H=Highway, R=Remote

¶ High value (and variance) reflects the fact that in one remote Kuna village some very distant fields were located on islands in the Bayano Reservoir

†Here we only show values from village K2. Values from villages K1a and K1b were replaced by a regional average for the analysis because we measured only agroforests/homegardens in K1a and only annual-tuber/minor crop fields in K1b; see Methods.

Table 5.5 Comparison of homegarden holdings among households of different ethnicities and with differing access to the highway. Homegardens were located beside a household's primary dwelling, which were located in villages with a few exceptions. The values in brackets are standard errors.

Homegardens	Remote			Highway			Statistical differences G=Ethnic group, A=Market access
	Black	Emberá	Kuna	Black	Emberá	Kuna	
Proportion of households with homegarden	0.80 (± 0.1)	1 (± 0)	0.88 (± 0.13)	0.96 (± 0.04)	1 (± 0)	0.76 (± 0.14)	G* (E > B,K)
Average homegarden size (ha)	0.05 (± 0.01)	0.17 (± 0.03)	0.11 (± 0.05)	0.27 (± 0.11)	0.20 (± 0.05)	0.10 (± 0.06)	NS

Significance codes: '***' 0.001; '**' 0.01; '*' 0.05; '.' 0.1; 'ns' > 0.1; Not tested: '--'. Post-hoc comparisons: B=Black, E=Emberá, K=Kuna, H=Highway, R=Remote

Table 5.6 Comparison of outfield agroforest holdings among households of different ethnicities and with differing access to the highway. Values in brackets are standard errors.

Outfield agroforests	Remote			Highway			Statistical differences G=Ethnic group, A=Market access
	Black	Emberá	Kuna	Black	Emberá	Kuna	
Number of fields per household	2.14 (± 0.44)	2.25 (± 0.17)	11.44 (± 1.31)	1.97 (± 0.37)	2.8 (± 0.02)	6.28 (± 0.48)	GxA** (KR > KH > others)
Number of fields per active adult	0.89 (± 0.4)	0.86 (± 0.11)	2.85 (± 0.13)	0.79 (± 0.23)	0.99 (± 0.1)	1.62 (± 0.44)	GxA. (KR > others, except
Average field size (ha)	0.33 (± 0.02)	0.68 (± 0.06)	0.27 (± 0.09)	0.34 (± 0.17)	0.30 (± 0.09)	0.37 (± 0.10)	GxA. (ER > others)
Average distance from village centre (km)	3.52 (± 0.36)	1.19 (± 0.19)	3.41 (± 2.12)	4.03 (± 1.98)	2.43 (± 0.59)	1.83 (± 0.14)	NS

Significance codes: '***' 0.001; '**' 0.01; '*' 0.05; '.' 0.1; 'ns' > 0.1; Not tested: '--'. Post-hoc comparisons: B=Black, E=Emberá, K=Kuna, H=Highway, R=Remote

Table 5.7 Comparison of annual-tuber field holdings and characteristics among households of different ethnicities and with differing access to the highway. Values in brackets are standard errors.

Annual-Tuber fields	Remote			Highway			Statistical differences G=Ethnic group, A=Market access
	Black	Emberá	Kuna	Black	Emberá	Kuna	
Number of fields per household	2.42 (± 0.62)	2.47 (± 0.35)	3.19 (± 1.06)	4.42 (± 1.63)	3.62 (± 1.16)	4.01 (± 1.09)	NS
Number of fields per active adult	1.09 (± 0.41)	0.87 (± 0.15)	0.81 (± 0.17)	1.87 (± 0.68)	1.16 (± 0.23)	1.29 (± 0.65)	NS
Average field size (ha)	0.47 (± 0.02)	0.41 (± 0.01)	0.64 (± 0.14)	0.65 (± 0.27)	0.56 (± 0.08)	0.40 (± 0.18)	NS
Average distance from village centre (km)	3.74 (± 0.78)	1.31 (± 0.28)	3.51 (± 2.36)	3.68 (± 1.74)	2.65 (± 0.58)	1.31 (± 0.56)	NS
Field histories							
Years since old-growth forest cleared	20.78 (± 3.53)	28.28 (± 5.28)	11.97 (± 1.31)	25.25 (± 1.88)	13.65 (± 1.42)	7.74 (± 5.74)	G* (B, E > K)
Proportion ever fallow	0.83 (± 0.08)	0.99 (± 0.01)	0.50 (± 0.05)	0.91 (± 0.04)	0.68 (± 0.1)	0.45 (± 0.33)	G** (B, E > K)
Length of previous fallow period (years)	5.08 (± 0.58)	6.09 (± 1.55)	14.77 (± 6.6)	5.56 (± 0.14)	4.36 (± 0.36)	4.58 (± 2.58)	NS
Years since burned	0 (± 0)	0.08 (± 0.05)	0 (± 0)	0.08 (± 0.08)	0.04 (± 0.04)	0.01 (± 0.01)	NS
Length of most recent cultivation period (years)	0.62 (± 0.47)	0.52 (± 0.52)	0.45 (± 0.34)	1.1 (± 0.6)	1.77 (± 1.38)	0.31 (± 0.29)	NS
Proportion with use of herbicides	0.53 (± 0.02)	0.52 (± 0.18)	0.03 (± 0.03)	0.72 (± 0.09)	0.68 (± 0.04)	0.07 (± 0.03)	G**, A. (B, E > K)
Proportion with use of pesticides	0.18 (± 0.07)	0.05 (± 0.05)	0 (± 0)	0.31 (± 0.01)	0.07 (± 0)	0.27 (± 0.03)	GxA** (KH, BH, BR > ER, EH > KR)
Proportion with use of fertilizer	0 (± 0)	0 (± 0)	0 (± 0)	0.13 (± 0.13)	0 (± 0)	0 (± 0)	--

Significance codes: '***' 0.001; '**' 0.01; '*' 0.05; '.' 0.1; 'ns' > 0.1; Not tested: '--'. Post-hoc comparisons: B=Black, E=Emberá, K=Kuna, H=Highway, R=Remote

Table 5.8 Relationship of pasture holdings to farmer ethnicity and highway access. All but two households maintained a single pasture, but pastures were sometimes shared with other households. Pastures were not mapped, and data on size are therefore based on owners' estimates. Small sample sizes meant that we did not test for differences in field characteristics or management. 'NA' indicates missing data (in some cases, because field type not present in a village). Values in brackets are standard errors.

Pasture	Remote			Highway			Statistical differences G=Ethnic group, A=Market access
	Black	Emberá	Kuna	Black	Emberá	Kuna	
Number of pastures per household	0.23 (± 0.07)	0.21 (± 0.21)	0 (± 0)	0.45 (± 0.05)	0.48 (± 0.26)	0.09 (± 0.11)	NS
Number of pastures per active adult	0.15 (± 0.03)	0.16 (± 0.16)	0 (± 0)	0.32 (± 0.03)	0.37 (± 0.21)	0.04 (± 0.05)	G. (B, E> K), A. (H > R)
Average pasture size (ha)	51.75 (± 19.25)	16.1 (± NA)	NA	22.85 (± 10.55)	9.9 (± 7.9)	18.3 (± NA)	--

Significance codes: '***' 0.001; '**' 0.01; '*' 0.05; '.' 0.1; 'ns' > 0.1; Not tested: '--'. Post-hoc comparisons: B=Black, E=Emberá, K=Kuna, H=Highway, R=Remote

Discussion

Our study shows that the spatial and temporal dynamics of swidden cultivation differ in areas managed by different ethnic groups and between areas with varying access to the highway, which we used as a proxy for access to markets. In particular, we found that farmers of different ethnicities maintained different numbers and/or sizes of homegardens, outfield agroforests, and pastures; arranged their fields differently; and managed annual-tuber fields using different rotation periods and inputs. Field holdings and field characteristics also differed with farmers' access to the highway, however in almost all cases differences in land-use practices with highway access presented themselves as an interaction with farmer ethnicity. In other words, the land-use strategies adopted by farmers in highway vs. remote villages (or, alternatively, the rate of adoption of a strategy) differed with farmer ethnicity. These results suggest that field and forest fragmentation patterns will be heterogeneous across the region, potentially providing different ecosystem services in territories managed by different ethnic groups. In the following sections we argue that observed relationships between land use, farmer ethnicity and highway access may reflect a combination of historic settlement patterns, collective land rights (or lack thereof), culturally important crops, shared beliefs surrounding land-use practices, and the availability of alternative livelihoods to farming.

Historic settlement patterns

Some of the differences we encountered in the types and arrangement of fields among ethnic groups mirror traditional settlement patterns of each group. For example, we found that a greater proportion of Emberá households maintained a homegarden compared to Kuna and Black households. Until the 1960s, most Emberá lived in dispersed family groups, with dwelling sites

typically separated by one or more ‘bends’ in a river. A large homegarden surrounded each dwelling, serving as the symbolic nucleus of a family’s space (Covich and Nickerson 1966; Herlihy 1986; Fig 5.7). In contrast, for at least three centuries, Black and Kuna families have lived in dense village settlements. As such, homegardens in these communities have long been fit in and around village house sites, possibly explaining their lower importance. The average size of homegardens that we surveyed in Emberá communities (2,075 m^2 ± 335 SE) was under half that of homegardens surveyed around dispersed Emberá dwellings in the 1960s (4,886 m^2 ± 1406 SE; Covich and Nickerson 1966), which may partly explain why Emberá families also maintained outfield agroforests, a practice that was relatively rare among Emberá 50 years ago (see also Herlihy 1986:213).

While Black and Kuna families have long lived in village settlements, the farming practices of these two groups are also described differently in the literature, and may explain the tendency we observed for fields of different ethnic groups to be clustered vs. interspersed by owner. The few available historical accounts of Black agriculture suggest that Black families maintained farms that were far enough from their home village that they would typically spend from a few nights to a few weeks working at their farms before returning to their villages (e.g., Pagnini 1970). This pattern was confirmed by elders in Black villages. For example, one man (in his seventies) from the community of Tucutí (B4) described how he and his wife had farmed in the past:

> *Once I married [in the late-1940s], my wife and I would go to the monte [land] for 2-3 months at a time. We always came back when we needed to buy things. After some time in our monte, we would come back [to Tucutí] for a few months.*

> *We had three farms. Each farm had a rancho [small house]. We would go from one farm to another clearing and preparing the land.*

A woman in her 60s from Tucutí described a similar pattern:

> *When [my husband and I] were younger we would go to our monte for the summers. The whole family would go. During the school year, I stayed in Tucutí and my husband would come and go. We had one farm with one rancho.*

This practice of village-living and more-distant-farming likely would have resulted in a pattern of agricultural land use similar to that of the Emberá (Fig. 5.7), with families working 'family areas' so that fields tended to be clustered by owner. Where Black farmers have privately titled land, this tendency to concentrate land holdings in one or a few areas has been made more permanent, as it has in Emberá territories on the highway that have divided their collective lands into 'family parcels,' to which families maintain usufruct rights.

In contrast, most historical accounts suggest Kuna farms were generally established within a days' round trip from villages (e.g., Torres de Arauz 1970). In part, this practice may reflect the importance of participating in evening Congress meetings, which remain a significant part of daily Kuna life (Howe 2002). As such, most Kuna farms were concentrated along the river on either side of a community, or along the array of paths that radiated out from each village (Torres de Arauz 1970). Indeed, Kuna villages from throughout the region were, and continue to be, linked by a network of footpaths, providing long stretches along which land was cleared and cultivated (a pattern not reported for Emberá or Black villages, who are almost always described as working as close to the river's edge as possible; Bennett 1962; Fig. 5.8). The necessity of locating land within a half-day's travel from a village may have led Kuna families to

‘leap frog’ over one another from year-to-year when establishing fields, making it common for the fields of different households to be interspersed. Together, these patterns help to explain our findings that the fields of Emberá and Black farmers were more likely to be clustered by owner, while those of Kuna farmers were more likely to be interspersed by owner.

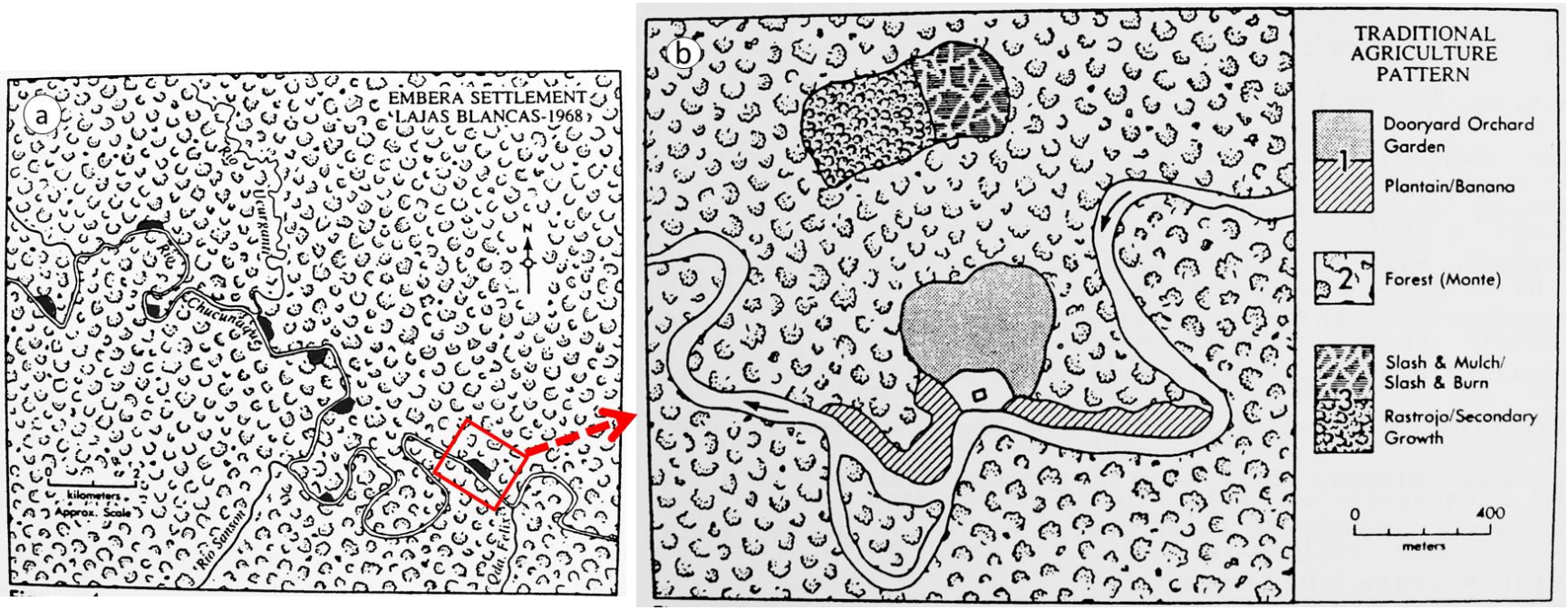


Figure 5.7 a and b. Land-use pattern of Emberá families in the early- to mid-20th century (prior to settlement in villages) (Herlihy 1986). The Emberá lived in dispersed family groups, with dwellings usually separated by one or more 'bends' in a river (a). Families farmed the land immediately around their home (b).

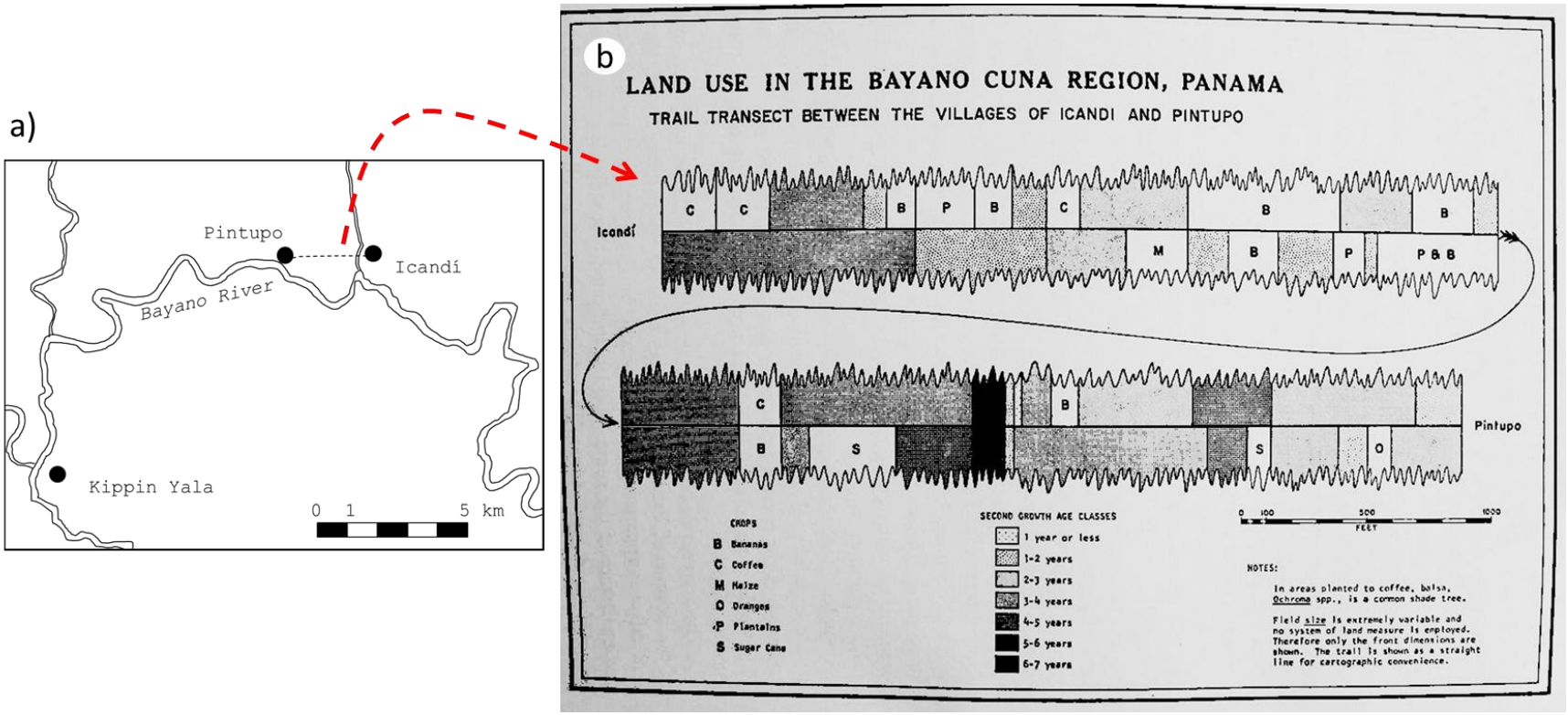


Figure 5.8 Land-use pattern along trail between two Kuna villages in the mid-20th century. Unlike Emberá families (Fig. 5.7), Kuna families have long lived in dense villages and have farmed areas within a day's round trip from these villages. Panel (b) is a sketch by Bennett (1962) showing the distribution of fields and forest regrowth along the trail. (Note that the dominant species in a field is indicated with a letter on white background (e.g., C=coffee, B=bananas) and the age of forest regrowth is indicated with different shades of grey (range is from < 1 year (lightest) to 6-7 years (darkest)). Panel (a) provides landscape context for (b), and includes the location of the villages at either end of the trail (Wali 1989:300).

Shared crop preferences and land-use ideologies

The tendency for Kuna households to maintain many outfield agroforests relative to Black and Emberá households may reflect the importance of coffee and cacao to the Kuna, which dates back at least three centuries (Stier 1979:81; Barnes 2011; Chapter 4). Of 274 outfield agroforest fields for which we had inventory data, 32 were dominated by coffee or cacao species (in terms of number of stems). Of these, 27 (84%) belonged to Kuna households. Kuna farmers also maintained agroforests of mixed fruit trees and other useful perennial species, similar to those maintained by Emberá and Black farmers, such that cacao- and coffee-dominated agroforests were generally additional to those.

However, we also found a higher number of outfield agroforests per household in remote Kuna villages relative to Kuna villages on the highway, which suggests that greater access to markets is influencing agroforest management by Kuna households. This trend is consistent with a number of predictions of how land-use might change with market access in response to increased availability of other types of employment, increased availability of foods available for purchase, and the decreased availability of land (Kramer et al. 2009).

Fewer agroforests in Kuna highway villages may also reflect changes in the prestige and/or beliefs associated with agroforests. Traditionally, agroforests have played important material and spiritual roles in the Kuna inheritance system. Before their death, parents divided their fields among their children, with both sons and daughters able to inherit land. Trees planted in agroforests became living symbols of the deceased parents, providing for children long after their parents' death (D. Diaz, Pers. Obs.). Kuna cosmology also promises a better life to those

who dedicate their time on earth to establishing fields and caring for many plant and animal species. These customs and beliefs lent prestige to the practice of maintaining many fields (ibid). With market integration and the emergence of new livelihood opportunities, the prestige associated with maintaining agroforests may be declining. One Kuna elder in a highway village derided the lack of effort made by members of his community to establish agroforests for future generations, carefully distinguishing between the wealth represented by land and the wealth represented by established fields:

> *Our future generation will not have an easy time. Not only is their land being taken from them [by non-Kuna colonists], but parents today don't want to do the work to prepare fields for their children. As a result, [their children] will be poor and without land.*

Links between land rights and land use

The management histories of annual fields differed in two important ways among farmers of different ethnic groups. First, the time since old-growth forests had been felled was much more recent for fields managed by Kuna households (Table 5.7). This may reflect the greater availability of primary forest to Kuna villagers. Although all indigenous villages were located in indigenous reserves, all Kuna villages were in a *comarca*, compared to only one of four Emberá villages and none of the Black villages (Fig. 5.3). The other three Emberá villages were in a *tierra colectiva*, smaller reserves that contained less forest area and were surrounded on all sides

by the pastures of colonist cattle ranchers[34] . Black villages did not have any collective land holdings, and were most likely to be in areas with little remaining unprotected forest (Fig. 5.3). As such, Black and Emberá farmers may simply have had less primary forest at their disposal. However, this does not seem to entirely explain the differences observed, given the long average time since forest had been felled at field sites in the Emberá village in a *comarca* (E4 in Fig. 5.3). As such, primary forest clearing may be better explained by a complex trade-off between primary forest availability, fallow land availability, and current vs. historical numbers of people engaged in agriculture. This hypothesis could be explored by combining our data with spatial data on primary and secondary forest cover and farming population densities.

The second difference in the management of annual fields, more use of herbicides and pesticides, was also related to farmer ethnicity. Herbicide use was more common among Black and Emberá farmers relative to Kuna farmers. This may reflect the greater need for herbicides in the fields of Black and Emberá farmers, which were less likely to have been cleared from primary forest. According to farmers of all ethnicities, many fewer weeds were typically encountered in fields cleared from primary forest (see also Pagnini 1970; Herlihy 1986). In the case of pesticides, Emberá farmers used less than Black farmers, and Kuna farmers fell at either end of the spectrum, with none of the Kuna farmers in remote villages using pesticides, and almost 30% of Kuna farmers in highway villages using pesticides (Table 5.7). Interviews revealed that many farmers in Kuna villages on the highway had received donations of pesticides

[34] Kuna comarcas are also being encroached upon, but because the *comarcas* are much larger and abut the Comarca Kuna Yala to the North, the impact of colonist land clearing likely has less impact on land use by the average household.

in 2008 as part of a Ministry of Agriculture effort to promote food security amidst soaring food prices. In the absence of this donation, we suspect the use of pesticides by Kuna farmers on the highway would have been much lower. The costs of acquiring pesticides were often reported as prohibitive, and Emberá and Kuna farmers tended to be poorer than Black farmers (Chapter 3). Differences in ideology may also partially explain differences in pesticide use among groups (Godoy et al. 1998), and is something that might be explored in future work.

Despite these differences in management strategies among ethnic groups, several management variables were consistent across groups, including length of last fallow period, length of current cultivation period, and time since field burned. This suggests that across the region there may be certain ecological imperatives surrounding the time needed for fields to recover their fertility, particularly given the (almost) non-existent use of organic or synthetic fertilizers.

Farmers in highway villages were more likely to maintain pasture than were farmers in remote villages, a pattern common to areas throughout the Neotropics (Chomitz and Gray 1996). There were also differences in pasture holdings with farmer ethnicity. Kuna congresses had imposed a general ban on pastures in the Kuna *comarcas*, and aside from a handful of farmers who apparently were exempt from the ban[35], few Kuna farmers maintained pasture. There was

[35] Wali (1993:120) reports that while the ban on cattle ranching was imposed by the congress of the Comarca Madungandí in the 1970s shortly after Kuna communities were relocated because of the flooding of the Bayano Dam reservoir, some communities maintained pastures left by colonists (who had been relocated out of the area). Initially these pastures were owned collectively, though in 2008 the farmers we interviewed reported sharing their pastures with an average of only 2 other farmers.

no difference in the number of pastures maintained by Emberá vs. Black households[36]. However, the characteristics of the pastures of each group differed substantially. Black households tended to maintain larger pastures, and these pastures tended to be for personal use. In contrast, Emberá households maintained smaller pastures, often grazed by just one or a few head of cattle (or horses). In addition, a number of Emberá pasture owners (particularly on the highway) were renting their pastures to ranchers from neighbouring *interiorano* [colonist] communities. Of the cattle grazing in the pastures of Black vs. Emberá farmers in 2008, 5% vs. 37% were owned by outside 'renters', respectively. Renting land to outsiders is one of the few ways for indigenous farmers to earn income from their land; because land is owned collectively, it cannot be sold or used as collateral to obtain a loan or credit. As such, pasture rental provides an incentive for pasture creation even for farmers who cannot afford their own livestock. Farmers of all ethnic groups reported gradually increasing pasture size over time, generally by seeding previous years' annual fields with grass seed.

The regional average area of pasture owned per household was five times smaller than for neighbouring colonist farmers for whom small-scale cattle ranching is a multi-generational tradition (6.10 ha vs. 32.3 ha; Table 5.9; Sloan 2007:54). However, this difference is only two times smaller when only considering households from both studies that maintained at least one pasture (25.4 ha vs. 51.9 ha; Sloan 2007:54). Although pastures were maintained by less than a quarter of the households we worked with, the 'footprints' of these households on the forest landscape were generally much greater than those of households without pasture. Given the

[36] Note that pastures were also banned in one of the remote Emberá communities (E4; Fig. 5.3). However, a number of households in the other remote Emberá village (E3) maintained pasture, so that the overall average was high.

economic attractiveness of this land-use type, pasture holdings are likely to further increase in the future (see also Coomes et al. 2008).

We were surprised by the lack of a significant trend in either the size or number of annual-tuber fields maintained per household in remote vs. highway communities (Table 5.7). Previous research on the influence of markets on patterns of land-use has reported an increase in the number and size of fields of cash crops (Vadez et al. 2004). While our data reveal a trend towards more annual-tuber fields per household and towards longer cultivation periods (e.g., fields maintained for more successive seasons) along the highway, these trends were not significant (Table 5.7). In part we believe this reflects the high variability in livelihood strategies available to farmers on the highway. For example, some farmers may choose to expand the area of fields under cash crops in response to market opportunities, while others choose to pursue an alternative source of income (e.g., wage labour, salaried position, etc.). Farmers choosing the second option may reduce the area of land under active cultivation, eliminating any surplus that was previously sold and maintaining just enough to provide for household food needs. We hope to tackle these questions in the future by incorporating household-level information into our analysis.

It is worth noting that, although we find important differences with ethnicity and highway access, our estimates of area under active cultivation for the average household in any of our study villages (3.45 ha under crops and 6.10 ha under pasture) are consistent with those of previous studies of shifting cultivation in the region (Table 5.9; Herlihy et al. 1986; Tschakert et al. 2007). The similarity between our study and these others indicates that a coarse measure, such as total area under cultivation, can mask a diversity of farming approaches within an area. It is

also important to note that these estimates provide an indication of the total area under active cultivation per household but fail to represent the total area of land required per household. In particular, they ignore land holdings under forest regrowth or primary forest, which provide sites for new fields once active fields are left fallow (see Table 5.9 for estimates of fallow landholdings from other studies in the region). They also do not consider land used for hunting and gathering, a critical source of protein, medicines, and construction and craft materials for all the communities with which we worked (Chapin and Threkeld 2001 in Velasquez Runk 2007). Nevertheless, they provide insight into typical practices in the region. Finally, they do not consider land cultivated by collectives of farmers. While such collectives were rare in our study villages (but see Kane 1986:199; Howe 2002), collective fields were sometimes established just inside the boundaries of Emberá or Kuna collective lands to dissuade encroachers from moving into these areas.

Table 5.9 Comparison of our findings with those of other studies of land-use by small-scale farmers in the region. All area estimates are in hectares. We estimated the area per household under crops/pasture by multiplying the number per household of each field type by their average size. Previous studies have reported similar estimates of cropped area per household (once differences in household size are taken into account). For pastures, our estimate is similar to that reported for Emberá families in one highway village (Tschakert et al. 2007), but five times lower than for neighbouring colonist farmers for whom small-scale cattle ranching is a multi-generational tradition (Sloan 2007).

Study	Study population(s)	Year of data collection	Total area under crops per household (homegarden, outfield agroforest, annual and tuber fields)(± SE)	Total area under pasture per household (± SE)	Total area under regrowth per household (landholdings under fallow) (± SE)	Average household size (± SE)	Number of active adults per household (± SE)	Source of area estimates
This study	Shifting cultivators in 12 villages (123 households), including Black, Emberá, and Kuna villages	2008	3.45 (±0.41)	6.10 (±2.09)	NA	6.66 (±0.62)	3.41 (±0.24)	Interviews, GPS measurement of sample of fields
Herlihy 1986 (Table 11)	Shifting cultivators in 1 Emberá village near highway (36 households)	1984	4.77 (±0.42)[a]	0 (±0)	8.83 (±1.30)[b]	7.75 (±0.63)	NA	Interviews, ocular inspection of fields where possible
Tschakert et al. 2007 (Table 4)	Shifting cultivators In 1 Emberá village on highway (36 households)	2003	3.03 (±1.75)[c]	8.60 (±4.00)[c]	10.93 (±4.07)[c]	6.77 (±0.84)[c]	3.27 (±0.81)[c]	Interviews
Sloan 2007 (Table 1; p.54)	Colonists[d] from central and western Panama along highway (55 households)	2006	2.3 (± NA)[e]	32.3 (±7.70)	4.2 (±0.98)	4.0 (±0.2)	2.4 (±0.13)	Interviews

[a]Homegarden area not estimated/included. [b]Fallow areas include those containing yam ("yam banks"). [c]Paper presents results by wealth tercile, we report the mean (and standarde error) of the these three values. We exclude the "other" land-use category. [d]Mainly engaged in small-scale cattle ranching [e]Estimated by subtracting area under pasture, forest, and regrowth from total landholding.

Summary and conclusion

Overall, more of the variation in land-use was explained by farmer ethnicity than by highway access. In particular, the proportion of households with a homegarden, the number and size of outfield agroforests and pastures, the frequency of primary forest felling and the use of herbicides and pesticides differed with farmer ethnicity. Additional variability in land-use practices was introduced by highway access, our proxy for market access, with distinct responses to market opportunities and constraints adopted by different ethnic groups. Differences among ethnic groups likely reflect a mix of, on the one hand, shared customs and ideologies (e.g., traditional settlement patterns, crop preferences, beliefs surrounding the value of land) and, on the other hand, modern-day political and economic relationships with the state (e.g., collective land rights, the availability of agricultural credit, and the intervention of state agencies in agricultural activities such as donations of seeds and chemical inputs). Our findings provide a strong argument for going beyond household-level analyses and considering the shared beliefs, customs, and experiences of groups of people (e.g., ethnic and other cultural groups), when trying to understand the agricultural practices of small scale farmers.

Given the growing pressure on tropical landscapes from the global demand for food and biofuels, a better understanding of land-use by small-scale farmers will be critical to ensuring that policy interventions that aim to protect the sustainability and resilience of tropical landscapes are scientifically sound and socially just. Our study provides an important step towards this understanding, and suggests that future work incorporating both landscape-level and household-level information may help to unravel the complexity of shifting cultivation.

Chapter 6: Conclusion

The benefits of diverse agricultural systems are increasingly being recognized by policy makers (e.g., Brookfield and Stocking 1999; IAASTD 2008; de Schutter 2010; Table 6.1), and concern is growing over the impacts of market integration on agricultural biodiversity (e.g., Harlan 1975, IAASTD 2008, FAO 2010). While few expect that globalization will lead to total uniformity in the agricultural systems of the future, it remains unknown at what scales, and under what conditions, diversity in agricultural systems will persist. In this dissertation I have explored the relative influences of market access and cultural identities on the management of agrobiodiversity by shifting cultivators in eastern Panama. Here, I summarize my findings, and then discuss some of the conclusions to emerge from these findings and their implications for the conservation of agrobiodiversity. Finally, I briefly review limitations of this research and priorities for future research.

Table 6.1 Potential benefits of agrodiversity (Table 1 in Brookfield and Stocking 1999)

Improving food security through a greater range of plant and animal varieties which reduce the risk of loss due to pests, and increase tolerance to climatic stress
Assisting nutrition and health by providing a wider source of nutrients, medicines and vitamins
Increasing total production through greater biomass output
Enabling support of greater population densities through provision of wider range of outputs and employment opportunities
Providing crop protection against epidemic pathogens
Employing indigenous technologies of plant production, tillage, soil management, and crop protection that are acceptable to local people and proved technically in specific environments
Reducing environmental risk through supporting ecosystem processes which are accessible to poor people
Underwriting livelihoods by ensuring a greater diversity of sources of income and subsistence
Enhancing the empowerment of local communities through technologies available within their own resources and own control

Adapted from Koziell (1998) and Thrupp (1998).

A conceptual spatial model for considering agrobiodiversity, markets and culture was introduced in Chapter 1 (Fig. 6.1). The model incorporates distance from a central market as well as non-overlapping territories of multiple cultural groups. It was proposed that within a given cultural territory, shared histories, beliefs, customs and social networks might predispose members towards particular production strategies. One possible outcome of the interaction between market- and culture-related factors was depicted, wherein the distinct agricultural strategies of different groups were overwhelmed by market forces in areas closest to markets (Fig. 6.1). One of the goals of this dissertation was to explore the validity of this outcome in the culturally diverse agricultural frontier of Panama's Darien Region.

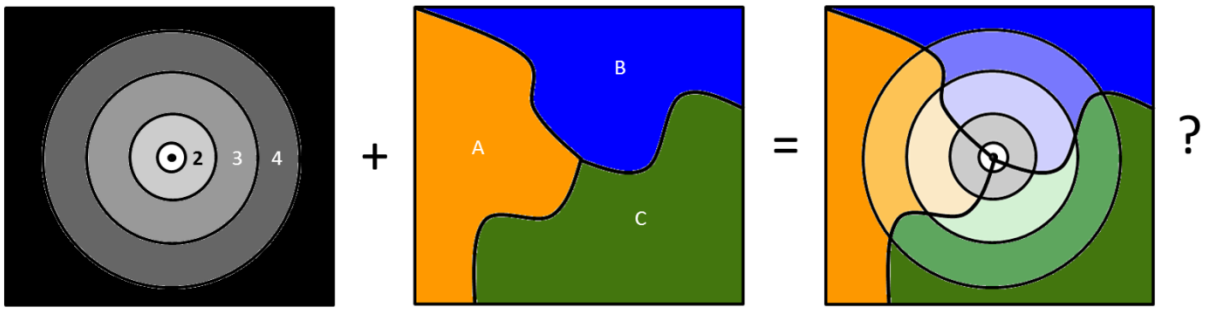


Figure 6.1 Integration of spatial theories of the effects of markets and culture on agrobiodiversity. "Von Thünen rings" surrounding a central market city (see Fig. 1.2) are combined with non-overlapping cultural territories (see Fig. 1.3). In each case, different colours/tones represent different agricultural production strategies and crop assemblages. In the final panel, one possible outcome of interactions between markets and cultural identities on agrobiodiversity is considered, in which market forces in the areas closest to the market overwhelm the distinct production strategies of farmers of different cultural territories.

To this end, I worked with farmers identifying as belonging to three different ethnic groups. The three ethnic groups represented in the study are the primary users of approximately 2/3 of the landscape of the study region (Fig. 6.2). However, unlike the simple cultural mosaic

introduced in Fig. 6.1, the cultural mosaic of eastern Panama is complex, with communities and territories of each ethnic group interspersed with those of other groups, and with contrasting access to the region's only highway, and thus to the main agricultural markets in Panama City. This provided an exceptional landscape in which to explore the relative influence of cultural identities and access on agrobiodiversity.

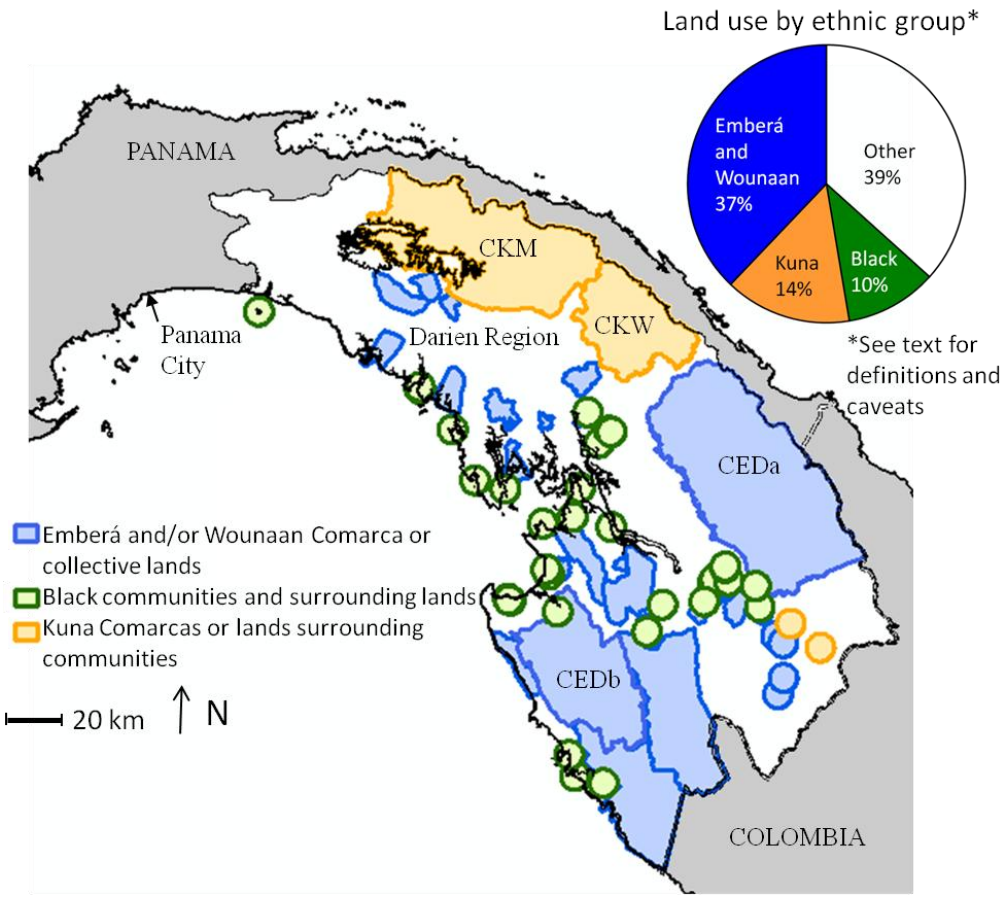


Figure 6.2 Areas titled, claimed or surrounding Emberá-Wounaan, Kuna and Black communities in the Darien Region. Please see Fig. 2.10 and Appendix 2.3 for a detailed description of the methods used to produce this map and the caveats associated with it.

Relationships between farmer ethnicity and agrobiodiversity

Annual food crop diversity differed with farmer ethnicity for five of the six crops studied (Chapter 3). Importantly, the ethnic group maintaining the highest-diversity landrace assemblages differed by crop. For example, the most diverse assemblages of maize were maintained by Kuna farmers, of rice by Emberá farmers, and of yams by Black farmers. The composition of these assemblages also differed with ethnicity. For instance, in the case of maize, I found that floury varieties of maize were typically maintained by Kuna farmers, a thin-cobbed, hard-grained variety was typically maintained by Emberá farmers, and a wider-cobbed, fast-maturing variety was typically maintained by Black farmers.

I also explored the diversity and distributions of species grown in agroforests (homegardens or outfield agroforests) (Chapter 4). Analyses of the distributions of 148 species of (mainly) trees and shrubs again revealed strong patterning by farmer cultural identity. Indeed, farmer ethnicity explained 42% of the variation in the composition of agroforest assemblages, while highway access did not explain a statistically significant portion of the variation. Together, the results of Chapters 3 and 4 suggest that complementarity among the landrace and species assemblages of farmers of different ethnicities bolsters agrobiodiversity in the broader region. In other words, the cumulative agrobiodiversity in the region is higher because of the presence of all three ethnic groups. These results offer what may be the strongest support to date for a causal relationship between cultural diversity and agrobiodiversity. Complementarity in the crop assemblages of neighbouring ethnic groups has been previously shown for a single crop in a centre of diversity (maize in Mexico, Perales et al. 2005), but to my knowledge this is the first time it has been demonstrated at a regional level and when considering the full array of crops maintained by small-scale farming communities.

The mechanisms underlying associations between particular crops and particular ethnic groups were in themselves diverse. First, farmers tended to maintain more landraces of the crops most important in the local diet (Chapter 3). Differences in ceremonial and medicinal needs of different groups were also reflected in the species assemblages; for example, cacao, which has important medicinal, ceremonial and spiritual values for the Kuna, was most often encountered in Kuna agroforests. In some cases, associations between particular crops and particular ethnic groups appeared to be the 'chance' product of ethnically-bounded social networks, which are known to influence the exchange of both seeds and knowledge (e.g., Perrault-Archambault 2005). On average, farmers conducted 74% of seed exchanges with individuals of their own ethnic group, reinforcing differences in crop assemblages among ethnic groups. Knowledge-exchange networks may be equally important in influencing farmers' decisions surrounding agrobiodiversity. For example, noni (*Morinda citrifolia*) was most common in Black agroforests, and Black farmers from throughout the region reported planting this fruit tree because they had 'heard' that a boom in noni exports was imminent.

In the case of land use, I also saw important differences in the spatial and temporal dynamics of field management among farmers of different ethnicities (Chapter 5). The proportion of households with a homegarden, the number and size of outfield agroforests and pastures, the frequency of primary-forest felling and the use of herbicides and pesticides all differed with farmer ethnicity. I argue that these differences among ethnic groups reflect a mix of, on the one hand, shared customs and ideologies (e.g., traditional settlement patterns, preferences for particular crops, beliefs surrounding the value of land) and, on the other hand, modern-day political and economic relationships with the State. The differences I observed in the numbers, arrangement and temporal dynamics of fields suggest that farmers of each ethnicity

tend to produce landscapes with distinct patchwork structures. Combined with differences in assemblages of landraces and species, the data suggest that distinct agricultural practices associated with each cultural group combine to create a heterogeneous landscape mosaic in eastern Panama, with heterogeneity expressed at a variety of levels of biotic organization: from landrace, to species, to patch, to landscape (Fig. 6.3).

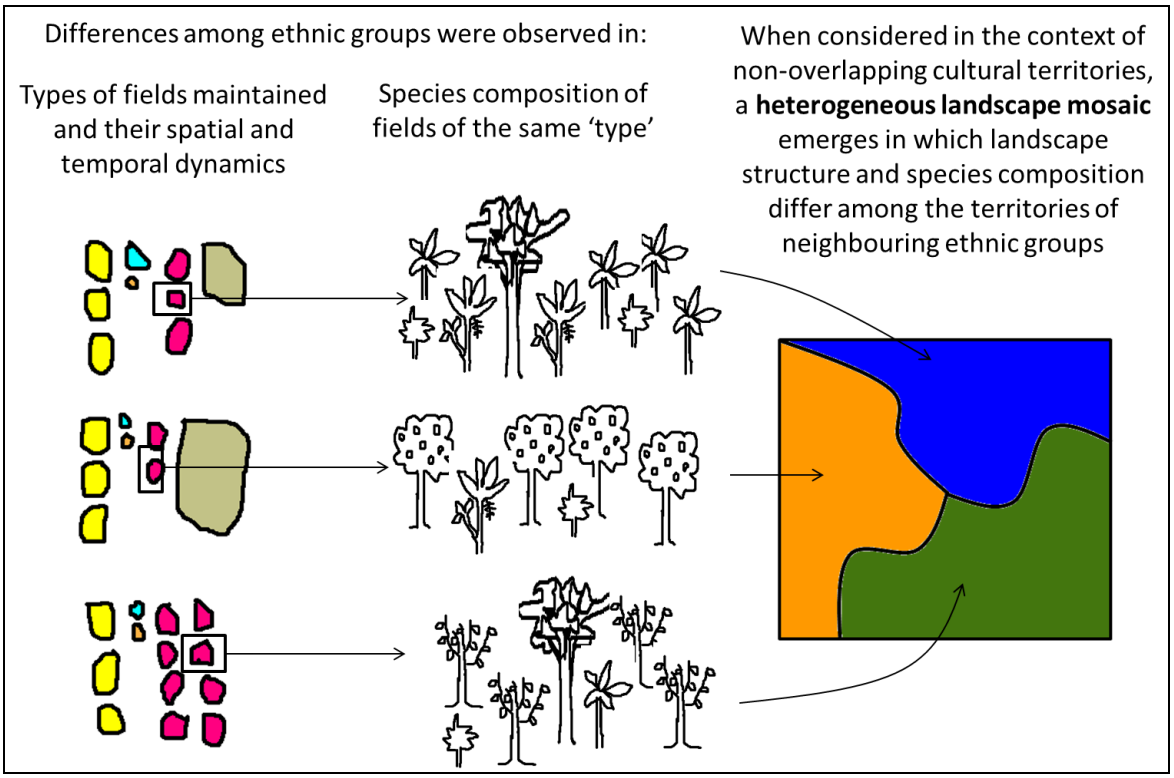


Figure 6.3 Summary of research findings with regard to relationships between farmer ethnicity and agrobiodiversity. I believe a diverse set of factors explains the differences I observed, including differences in beliefs, customs and ideologies, political and economic relationships with the state, and social networks.

Relationships between agrobiodiversity and market access

Only a handful of measures of agrobiodiversity varied with market access – as proxied by village position relative to the highway - independently of farmer ethnicity (composition of rice,

timber and construction tree assemblages, as well as number of pastures, use of herbicides). In most cases, relationships between agrobiodiversity and access were highly influenced by their cultural context. For example, for four of the six crops examined in Chapter 3, the number of landraces maintained per household differed with access (rice, yams, cassava and *Musa spp.*). However, in each case the direction of the trends differed depending on farmer ethnicity. I found similar results when looking at patterns of land use. For example, the number of agroforests maintained per household was higher in remote than highway villages in the case of the Kuna, but not the other two groups. This strong dependence on cultural context suggests that market-adaptation strategies are to some extent shared within ethnic groups, with farmers of each group maintaining some landraces, species, or land use practices that historically have provided a source of ethnic identity/differentiation. At an individual level, Velásquez Runk (2007) similarly reported that the income portfolio and livelihood decisions of Wounaan in eastern Panama were strongly influenced by their cultural beliefs.

In some cases where our field surveys suggested that agrobiodiversity was influenced by market access independent of ethnicity, interviews revealed differing motivations for adopting particular practices among ethnic groups. For example, while there were no differences in the number of pastures maintained by Black or Emberá households in highway villages, Black farmers were more likely to maintain pasture for personal use, while Emberá farmers were more likely to rent pasture space to colonist ranchers.

What explains the weak relationship between market access and agrobiodiversity?

Given that agrobiodiversity is being lost world-wide, I was surprised that there were not greater differences in the numbers and types of landraces, species and field types between remote and highway villages. I propose two possible explanations for this finding. First, the relatively secure, collective land rights held by two of the three ethnic groups in our study meant that farmers in those communities were not at risk of losing their land[37], in the classic Von Thünic sense, if they did not adopt the most commercially profitable production strategy. Secure, collective land rights may give small-holders more choice in determining how they will participate in markets, and thus may serve to foster diversity in livelihood and production strategies (Maffi and Woodley 2010). If this is the case, ethnically-diverse landscapes where communities lack land rights may respond to markets in a more homogeneous fashion, with a result more similar to the scenario presented in the final panel of figure 6.1 (i.e., with market forces overwhelming cultural differences near markets).

A second reason may be the lack of long-term data, given that my study captures a 'snapshot' in time. It is possible that significant losses of agrobiodiversity (from both highway and remote villages) have already occurred. Some evidence supports this possibility. Black and Emberá farmers in both remote and highway villages recounted that their parents' generation had frequently used floury maize of the type I encountered almost exclusively in Kuna villages. In addition, the use of floury maize in the mid-20th century was documented for Emberá farmers in

[37] Though as collectives, Kuna and Emberá communities were all engaged in a constant struggle to protect their lands from encroachers. The cost of these struggles was high (including lawyers' fees, frequent travel to government offices, document preparation, etc.), and communities were often funding their struggles by selling logging and grazing contracts to outsiders. The costs in terms of community members' time were also significant.

Panama and the Colombian Chocó, and Black farmers in the Colombian Chocó; Nickerson and Covich 1966; Patiño 1956; and West 1957. However, the fact that a 'traditional' variety had been lost from both remote and highway villages in itself is not evidence of systemic change in response to markets, as farmers made it clear that crop assemblages have always been dynamic, with new, high-performing landraces replacing the old (see also Dennis 1987).

Alternatively, major changes in highway villages may have yet to occur. Predictions by farmers of future losses of agrobiodiversity were widespread. The Pan-American Highway through the region was being paved for the first time while I carried out my research (paving began in 2001 and was completed in 2009). This has greatly reduced travel times to Panama City markets, and further increased the value of land along the highway. However, a primary reason put forward by study participants for future agrobiodiversity loss was a lack of interest in agriculture among younger generations, as well as changing values of farmers of all ages. In Chapter 5, I proposed that changing perceptions of wealth may explain the lower number of agroforests maintained in Kuna highway villages relative to Kuna remote villages. In the case of crop diversity, some farmers said that they were not upholding previous generations' traditions of planting particular varieties because of a lack of time, given the urgent need to earn cash income for the household. For example, one Emberá man in his 40s described how, in his youth, his grandmother had admonished him to plant some black rice and red rice every year. This advice accompanied a story in which these two varieties ensured Emberá survival when the world ended and other varieties stopped producing[38]. He said that, while he would never forget

[38] I found this story particularly interesting given the (relatively) short history of rice cultivation among the Emberá.

his grandmother's words, he had not tried to obtain replacement seed for these varieties after the seed a few years earlier, because he was too busy trying to make ends meet.

Many elders, particularly Kuna elders, accused the federal educational system of fostering a 'need' for money. A Kuna elder from the Bayano area summarized:

> *We have more natural resources than any other social group [in the area]. But the government has derailed us, and [now] we are running after money […] We are losing our knowledge of the land, and our children are locked away between four walls, becoming intellectuals […] But the education system fortifies the* **wagas**[K,39]*, it does not fortify our knowledge or language. […]*

Another emphasized the lack of prestige that young people associated with agriculture: "Our children spend all day learning that they should aspire to be teachers, doctors and lawyers. Never do they learn that it is also respectable to become a farmer or a healer."

Few families can afford to send their children to high school. As a result, the careers to which teachers, textbooks and many parents suggest that children should aspire are often out of reach. Ironically, for those able to attend high school, one of the very few programs available provides graduates with a technical diploma in agriculture. The focus of the program is very much on mechanized, high-input agricultural systems and may therefore accelerate the erosion of knowledge surrounding local varieties, species and land-use practices.

In sum, there is evidence to suggest that some changes in response to markets have already taken place, while others have yet to occur. A follow up study in the future would

---

[39] In this case, '*wagas'* refers to Panamanians belonging to the political/economic elite.

provide a fascinating way to explore changes to the ‘snapshot’ I have presented in this dissertation (e.g., Hamlin and Salick 2003).

Implications of findings for agrobiodiversity conservation

Brush (2000:4) distinguished two types of *in situ* agrobiodiversity conservation. The first results from the routine farming practices of local people, while the second is prompted by external conservation interventions. The first form of agrobiodiversity conservation is desirable in that it is driven by endogenous processes. In eastern Panama, even in the absence of external interventions, the distinct crop assemblages of farmers of different ethnicities combined to bolster agrobiodiversity in the broader region. This pattern was all the more remarkable considering the region’s dynamic history, which has seen farmers of all ethnic groups integrating novel crops and varieties into their production systems for at least five centuries. Together, these observations suggest that policies supportive of the continued freedom of each of these groups to define and redefine their relationships to agrobiodiversity may go a long way to conserving regional agrobiodiversity. As I have already discussed, secure land rights may provide this type of autonomy. Maintenance of agrobiodiversity by social groups with high levels of cultural and economic autonomy has been demonstrated elsewhere in Latin America (Brush et al. 1992; Zimmerer 1996).

In cases where conservation interventions are necessary, my research highlighted the importance of a landscape-scale perspective. In particular, a rich understanding of agrobiodiversity in eastern Panama benefited from consideration of a diversity of field types, multiple villages of each social group, and multiple social groups. Had I considered only homegardens, I likely would have missed many perennial species planted in outfield agroforests.

Similarly, many species, including 35% of agroforest species, were only encountered in one village, and the consideration of additional villages would almost certainly have resulted in more species being added to the regional list. Importantly, my approach revealed that disparate territories in the landscape were linked by 'cultural corridors,' which served to increase the similarity of their species and landrace assemblages. Therefore, to be effective, conservation efforts will need to consider agrobiodiversity distributions at the level of the landscape, and possibly work with indigenous regional congresses to support agrobiodiversity exchange networks that span large areas.

Another theme to emerge from this work is the importance of prestige associated with traditional foods, ceremonies, and even field types in supporting agrobiodiversity. While Panamanians take pride in their country's pluricultural image, my experience is that there is an overwhelming pressure for conformity in day-to-day life, such that in practice cultural differences are rarely celebrated (or even supported) to the extent that the country's reputation would suggest. In addition, the faith of many agricultural extension workers in green-revolution-type approaches to agriculture means that local systems and landraces are often overlooked as sources of solutions to emerging challenges, such as new pest and disease outbreaks (Altieri 1990:551; Fig. 6.5). As minority communities become increasingly integrated to dominant economic, education, and health systems, campaigns promoting an appreciation of the benefits of diversity in crops and agricultural practices may help to reinforce a sense of prestige surrounding their maintenance. Conservation initiatives that do focus on the cultural links between people and agrobiodiversity will need to be designed to support people's rights to define and re-define their cultural systems and relationships to biodiversity, while avoiding essentializing these relationships in ways that are limiting (Shepherd 2010; Barnes et al. 2010).

Figure 6.4 Sign on the side of the Pan-American Highway in eastern Panama, urging farmers to "Use Certified Seed" (in other words, to buy rather than to save seed, as indicated by the money sign on the bag of seed in the farmer's hand). The campaign was part of an effort to control a rice pest, but without considering possible resistance among existing seeds of minority farmers.

Limitations of study

Choice of explanatory variables. In analyzing my data, I focused on contrasting agrobiodiversity in villages with differing access to the highway and different dominant ethnicities. In limiting the number of explanatory variables to those to which the study had been explicitly designed to test, the power of the statistical tests was maximized. The approach revealed that a significant portion of the variation in crop holdings among farmers was explained by access and farmer cultural identity. However, some of the unexplained variation may have been explained by additional village-level variables, or by household- and field-level variables. For example, I could have explored the effects of village size or village establishment date on agrobiodiversity, or the effects of household size, wealth, and landholdings on households'

species and landrace assemblages, or the effects of field slope, waterlogging, or flooding frequency on the agrobiodiversity encountered in a given field. Much of this data was collected as part of my field surveys, and I plan to explore additional scales and explanatory variables through future work.

Cross-section approach. My study contrasts agrobiodiversity in villages with differing access to markets. An implicit assumption of this design is that space can be substituted for time. In other words, it assumes that remote villages would become more like highway villages if they gained better access to markets. It has been recognized that this approach is less powerful than approaches that directly manipulate peoples' access to markets, or that monitor changes in farmer behavior in response to changes in market access over time (Godoy 2001). However, the approach used here (which included multiple villages in both 'remote' and 'highway' areas) provides a powerful alternative for short-term studies, and a strong foundation for future, follow-up work.

Binary definition of market access (highway vs. remote). I chose to group villages into one of two categories based on their relative access to markets (remote vs. highway). However, an alternative approach would have been to use a continuous measure of market access (e.g., time to market; Salonen et al. 2011) and to use a regression approach to relate this continuous measure to selected indicators of agrobiodiversity. Future work will explore the impacts of alternative measures of market access on the study's findings.

Scale of agrobiodiversity measures. I chose to contrast the diversity maintained by an average household in villages with differing access to markets and different dominant ethnicities. While considering agrobiodiversity management at the level of a household is arguably the most relevant scale of analysis from a conservation perspective (as decisions to maintain diversity are

ultimately made by households), I could also have chosen to contrast the cumulative number of species or varieties maintained in each surveyed field, each village, or in all highway villages vs. remote villages, or in all villages of one cultural group. Selecting a different scale of analysis would allow different questions to be explored surrounding the turnover in species and landraces with space.

Relevance of findings to other regions of the world

Although this research focused on eastern Panama, the questions, approach, and findings are relevant to landscapes throughout the tropics where smallholder agriculture (and shifting cultivation in particular) remain important (Table 6.2). Like eastern Panama, many of these landscapes are cultural territorial mosaics experiencing rapid change as a result of the expansion of regional and global trade networks. Ongoing highway expansion projects in Bolivia and Tanzania, which received considerable international press over the last year because of their potential negative environmental and cultural impacts, are just two examples (Anonymous 2011a; Hance 2011).

Few studies from other regions have contrasted the effects of market access vs. local cultural systems on agrobiodiversity while also controlling for environmental covariates (but see Atran et al. 1999; Perales et al. 2005). However, studies exploring these themes in general terms have generally supported this study's findings of an important influence of farmer cultural identity on agrobiodiversity, even where market access is high (e.g., Asia: Dobby 1955; Voon Phin Keong 1967, both in Morgan 1977; Africa: Horvath 1964; Nasser-Baco et al. 2007; Oceania: Chandra et al. 1974 in Morgan 1977; South America: Burrough 1973 in Morgan 1977; Lamont et al. 1999; Perreault-Archambault and Coomes 2008; Stromberg et al. 2010), with some

exceptions (e.g., Willemen et al. 2007). Many of these studies were reviewed in Chapters 3 and 4 and thus will not be revisited here. However, it is fascinating to consider how relationships among farmer cultural identity, markets, and agrobiodiversity would play out in places like Papua New Guinea, where ethnolinguistic diversity is over an order of magnitude higher than it is in Panama (Papua New Guinea is home to over 800 distinct language groups). It would also be interesting to extend the findings of this study to landscapes in which cultural identity is based not on ethnic heritage or language, but rather on other pools of shared information.

Table 6.2. Selected demographic, linguistic, environmental and economic characteristics for Panama and other tropical countries, grouped by region. Tropical countries were defined as having at least half their territory between the Tropics of Cancer and Capricorn (IUCN 1986). Only countries with a population of at least 100,000 were included in regional averages. Note that regional averages are based on data aggregated at the country-level, so should be interpreted as the average value for a country in a particular region, rather than the average for the region (given differences in territory and population size among countries). While Panama's economic indicators suggest that it is one of a minority of tropical countries with a relatively high Gross Domestic Product (GDP) and rate of GDP growth, the country's wealth is distributed highly unequally, as indicated by the Gini coefficient for income, which is in the top 10% for tropical countries (UNDP 2010; final column in Table 6.2). Panama's high GDP largely reflects the strong service sector surrounding the Panama Canal, and much of Panama's wealth is concentrated among a minority in Panama City. The result is that the economic situation in rural regions of Panama is similar to that in areas of the humid tropics that have much lower rates of GDP growth.

Tropical region or country	Average population density per country in 2008 (persons per square kilometer)[a]	Average number of living languages per country (2009)[b]	Average index of language diversity (2009)[c]	Average % of territory per country that is forested (2010)[d]	Average annual % change in remaining forest cover per country 2005-2010[e]	Average GDP per country (per capita PPP) (2010)[f]	Average annual % growth rate in GDP per country (2010)[g]	Gini coefficient for income (2000-2010)[h]
AFRICA	93	62	0.67	31	-0.96	$ 3,559.59	4.9	45
ASIA	659	134	0.58	35	-0.20	$ 11,614.27	4.7	39
OCEANIA	149	66	0.44	46	-0.07	$ 4,731.50	1.3	51
LATIN AMERICA AND THE CARIBBEAN	158	28	0.22	47	-0.30	$ 11,808.44	4.3	52
Caribbean	242	4	0.16	42	0.01	$ 14,934.85	4.1	48
Central America	91	53	0.26	39	-0.95	$ 7,902.88	3.9	53
South America	20	60	0.32	65	-0.43	$ 7,898.00	5.4	52
Panama	45	18	0.32	44	-0.36	$ 12,498.00	9.2	55

[a] Source: UN 2011.

[b] Source: Lewis 2009.

[c] Greenberg's diversity index. This is the probability that any two people of the country selected at random would have different mother tongues. A value of 1 indicates total diversity (no two people have the same mother tongue) while a value of 0 indicates no diversity (everyone has the same mother tongue). Source: Lewis 2009.

[d] Source: FAO 2010.

[e] Rate of gain or loss in percent of the remaining forest area each year within the given period. Source: FAO 2010.

[f] Per capita gross domestic product (GDP) is expressed at purchasing power parity (PPP). Source: FAO 2010.

[g] Source: FAO 2010.

[h] Measure of the deviation of the distribution of income (or consumption) among individuals or households within a country from a perfectly equal distribution. A value of 0 represents absolute equality, a value of 100 absolute inequality. Source: UNDP 2010.

Recurring themes: displacement of smallholders, loss of prestige

A number of the political, social and economic factors identified as important threats to biodiversity in eastern Panama recur in the agrobiodiversity literature. For example, I have discussed how a lack of land rights (or enforcement of land rights) in eastern Panama threatens the future of shifting cultivation in the region. Similarly, studies from all continents report that land encroachment and the appropriation of land for industrial agriculture and biofuel plantations has displaced small farmers, or drastically reduced the land base available for shifting cultivation, thereby negatively impacting agrodiversity (Cotula et al. 2008; Cotula et al. 2009). This is the case in areas of southeast Asia where palm oil plantations have become especially profitable (Belcher et al. 2004; Rist et al. 2010), areas of Africa where governments are leasing agricultural land to foreign speculators aiming to capitalize on rising food prices ('land grabs for agriculture'; MacFarquar 2010), and areas of South America where the concentration of land in the hands of large cattle ranchers and soy farmers continues to displace shifting cultivators and other smallholders (Fearnside 2001; Nepstad et al. 2006; Anonymous 2011b). In some regions, violent conflict and climate change are also important causes of smallholder displacement (Kundermann 2000; CBDC Africa Network 2009; Gaviria 2004; M. Isaac, pers. comm.). Displaced farmers may lose seeds they cannot bring with them, or may lack land for cultivation in areas of resettlement. The result can be a long-term loss of agrobiodiversity (ibid).

Similarly, just as I discussed how losses of prestige surrounding local farming practices could lead to future losses of agrobiodiversity in eastern Panama, studies from various regions of the world have emphasized the negative impacts on agrobiodiversity of the clash between traditional farming systems and neoliberal development policies. For example, in Laos, as in many regions, an emphasis of development initiatives on monocropping, synthetic inputs, and

the elimination of borders and trees from annual fields have resulted in losses of agrobiodiversity (Nieman and Kamp 2009). Other examples point to a loss of prestige associated with local foods. For example, in many southern African countries, modernization policies aiming to speed the adoption of conventional agricultural practices resulted in local leafy vegetables being seen as shameful 'poverty foods,' in contrast to 'modern' cabbage. The result was an abandonment of local vegetable species by a large sector of the population, and a corresponding decrease in vitamin and micronutrient intake in the region (Bioversity International 2010). Similarly, in Pohnpei, Micronesia, changing social norms led to the abandonment of many traditional foods, with consequences not just for agrobiodiversity but also for local population health (Galluzzi et al. 2010). In both southern Africa and Micronesia, campaigns have been initiated to reintroduce local vegetables and other traditional, nutrient-rich foods to people's diets, with some success (ibid). In Nepal, efforts to conserve agrobiodiversity are similarly focusing on reversing the negative 'message' farmers received over the last decades surrounding the value of local landraces and foods (Johns and Stahpit 2004).

Future work

My research points to a number of additional topics that should be explored in future work to further explore how socio-economic, cultural and ecological forces interact to influence distributions of agrobiodiversity. In previous chapters I outlined a number of questions that were particularly relevant to eastern Panama, many of which build on the findings presented herein. In particular, I suggest that future work on agrobiodiversity in eastern Panama address the following questions:

- To what extent do differences in the socio-economic characteristics of individual households explain distributions of agrobiodiversity? For example, how is agrobiodiversity related to factors such as household wealth, size, time-since-establishment, off-farm employment, and livelihood diversity more generally? Addressing this question would provide an understanding of how the characteristics of individual households work in conjunction with the larger-scale influences (cultural identity, market access) that I measured to influence distributions of agrobiodiversity. More generally, this question touches on an important theme in social-ecological studies, namely identifying how processes at different scales (in this case, individual household and village) combine to influence regional-level outcomes.
- If the age of trees planted in agroforests is taken into account, do shifts in the species planted in areas with greater access to markets become evident? For example, is the age distribution of some species skewed towards old trees, suggesting that these species are not being replaced? Addressing this question is important for all agricultural systems that use long-lived species, such as tropical agroforests and temperate orchards.
- How do the historical experiences of different cultural groups (e.g., their origins in the Colombian Choco vs. Africa, their participation in early-20th century export markets for bananas in Darien) map onto the varieties and species associated with each group? This question should be addressed in Panama, but also more generally in order to understand the effects of historical experiences on modern-day practices. By understanding these effects, scientists may better predict how and why cultural practices change, and may explain when we would expect to see lags between new conditions and changes in agricultural systems.

- An extension of the previous question would be to explore agrobiodiversity in *Latino* and Wounaan communities in eastern Panama. This would provide a clearer understanding of how agrobiodiversity is distributed in eastern Panama, and would also allow for a more complete understanding of overlaps and differences among neighbouring cultural groups.

Future work should also explore whether generalizations can be made across social-ecological systems surrounding relationships among indicators of agrobiodiversity at different scales. For example, researchers might ask:

- How is the total (cumulative) number of crop landraces and agroforest species in a given village related to the number of crop landraces and agroforest species maintained by households in that village? In other words, to what extent are the agricultural assemblages of neighbouring households redundant?
- What are the relationships between diversity at the level of fields, species, and landraces? For example, do farmers with more species also maintain more landraces per species?

If these relationships are found to vary highly between social-ecological systems, it would then be interesting to explore socio-economic, ecological and cultural predictors of the relationships.

Finally, I would suggest that there are questions that might be explored in a number of agricultural regions simultaneously, using similar methodologies such that the generality of findings could be considered.

- To what extent are seed and knowledge acquisition networks constrained by farmer cultural identity vs. geographic distance? And, what historical/political economic/biophysical

factors explain these constraints? Addressing these questions would provide insight into the generality of the insularity of exchange networks, and would provide an important step in understanding whether the link between exchange networks and agrobiodiversity observed in my study is a general phenomenon.

- How and when do culturally transmitted views of the intrinsic values of biodiversity affect farmers' decisions to maintain diverse assemblages? It is well understood that different cultural practices and belief systems create different social norms. However, we do not know how commonly belief systems support the maintenance of agrobiodiversity, nor if acting on these belief systems is contingent on other factors. My work suggests that understanding how and when these systems are acted upon may be important to the agrobiodiversity that farmers maintain.

In summary

Agricultural biodiversity is critical to human well-being, yet is being rapidly eroded world-wide. My research revealed strong relationships between agrobiodiversity and farmer ethnicity, even in areas where access was high. For staple food crops (e.g., maize, rice, yam, cassava, bananas, and taro), ethnicity explained 2.5 to 8.5 times more variation in assemblages than did access. Distinct assemblages of staple crop landraces (varieties) and agroforest trees and shrubs were associated with different ethnic groups, even in highway villages, reflecting culturally patterned dietary preferences, ceremonial or customary uses, and culturally-bounded seed-exchange networks. Mean number, size, and types of fields maintained (homegardens, outfield agroforests, annual fields, pastures), as well as their management (e.g., primary-forest felling, herbicide use), also varied among ethnic groups. These differences reflected culturally-

based crop preferences, ideologies surrounding the values of land, traditional settlement patterns, and modern-day relationships to other actors, including the Panamanian government. Together, the distinct agricultural practices of individual ethnic groups combined to create diversity across many levels of biotic organization: from landrace, to species, to patch, to landscape. These findings strongly suggest that new approaches to conservation that support and respect heterogeneous socio-cultural systems will be critical to the maintenance of the world's agrobiodiversity.

Bibliography

Agrawal A, and Redford, K. (2009). Place, Conservation, and Displacement. *Conservation and Society 7*:56-8

Altieri, M. (1990). Why study traditional agriculture? In Carroll, R., Vandermeer, J., and Rosset, P. (Eds.), *Agroecology* (pp. 551-564). New York, NY: McGraw-Hill.

Altieri, M., and Merrick, L. C. (1987). In situ conservation of crop genetic resources through maintenance of traditional farming systems. *Economic Botany 41*(1):86–96.

ANAM (Autoridad Nacional del Ambiente). (1998). *Primer informe de la riqueza y estado de la biodiversidad de Panamá.* Panama City, Panama.

ANAM (Autoridad Nacional del Ambiente). (2009). *Cobertura boscosa y uso del suelo de la República de Panamá: 1992, 2000, 2008.* GIS shapefiles obtained from ANAM in February 2010.

Anderson, C. L. G. (1941). *Life and letters of Vasco Núñez de Balboa*. New York, NY: Fleming H. Revell Company.

Anderson, M. J. (2001). A new method for non-parametric multivariate analysis of variance. *Australian Ecology 26*: 32-46.

Anonymous. (2011a). UN culture body warns Tanzania on Serengeti highway. AFP News, 15 November, 2011. Available online at: http://www.google.com/hostednews/afp/article/ALeqM5j4rI9Nh3jV9EGRPRN6Bv2Vd7oOfw?docId=CNG.6bd1dce2080c827db63977c69f88bac1.191.

Anonymous. (2011b). Brazil indigenous Guarani leader Nisio Gomes killed. BBC News, 18 November, 2011. Available online at: http://www.bbc.co.uk/news/world-latin-america-15799712.

Arroyo, J. E., and Camacho, J. (Ed.) (2000). *Zoteas: Diversidad y relaciones culturales en el Chocó Biogeográfico Colombiano.* IIAP-Fundación Natura-Swissaid. Medellin: Intempo.

Atran, S., Medin, D., Ross, N., Lynch, E., Coley, J., Ek' E. U., and Vapnarsky, V. (1999). Folkecology and commons management in the Maya Lowlands. *Proceedings of the National Academy of Sciences of the United States of America, 96*(13), 7598-603.

Balée, W. (1993). Indigenous transformation of Amazonian forests: an example from Maranhão, Brazil. *L'Homme, Paris: Ecóle des Hautes Études en Sciences Sociales*, 33(126/128): 231-254.

Ban, N., and Coomes, O.T. (2004). Home gardens in Amazonian Peru: diversity and exchange of planting material. *The Geographical Review 94*(3) July: 348–367.

Barnes, J. I. (2008). *Cacao: a cultural keystone species among the Kuna of three communities in San Blas, Panama*. M.A. thesis, Ottawa, ON: Department of Geography and Environmental Studies.

Barnes, J. I., Diaz, D., and Ballamingie, P. (2011). Missed understandings: Cultural and communication disconnects in indigenous livelihood revitalization and conservation. *Society and Natural Resources*, 0:1-12. DOI: 10.1080/089412920.2011.559616.

Belcher, B., Rujehan, Imang, N., and Achdiwan, R. (2004). Rattan, rubber, or oil palm: cultural and financial considerations for farmers in Kalimantan. *Economic Botany*, 58(Supplement 1): S77-S87.

Bellon, M. (1991). The ethnoecology of maize variety management: A case study from Mexico. *Human Ecology, 19*(3), 389–418.

Bellon, M. R., Pham, J. L., Sebastian, L. S., Francisco, S.R., Loresto, G. C., Erasga, D., Sanchez, P., Calibo, M., Abrigo, G., and Quilloy, S. (1998). Farmers' perceptions of varietal

diversity: implications for on-farm conservation of rice. In: Smale, M. (Ed.), *Farmers, gene banks and crop breeding*, (pp. 95–108). Boston: Kluwer Academic Publishing.

Bellon, M.R. (1996). The dynamics of crop intraspecific diversity: a conceptual framework at the farmer level. *Economic Botany 50*: 26-39.

Bellon, M.R. and Taylor, J.E. (1993). 'Folk' soil taxonomy and the partial adoption of new seed varieties. *Economic Development and Cultural Change 41*: 763-786.

Bennett, C. F. (1962). The Bayano Cuna Indians, Panama: An Ecological Study of Livelihood and Diet. *Annals of the American Association of Geographers, 52*(1), 32 -50.

Benz, B., Brush, S. B., and Perales, H. (2007). Tzeltal and Tzotzil Farmer Knowledge and Maize Diversity in Chiapas, Mexico. *Current Anthropology 48*: 289–300.

Bioversity International. (2010). Annual Report 2009. *Sustainable agriculture for food and nutrition security.* Bioversity International, Rome, Italy.

Bliss, N., Olsen, L., and S. Jenson. (2006). 30 ARC-SECOND DEM for South America. Dataset Creator: USGS/EROS DATA CENTER. DIF Creation Date: 1996-11-18; Last Revision Date: 2006-06-01. Accessed: March 2011. URL: http://gcmd.nasa.gov/records/ GCMD_GNVd0192_104.html

Boserup, E. (1965) *The conditions of agricultural growth*. Chicago: Aldine.

Brush, S. B. (1991). A farmer-based approach to conserving crop germplasm. *Economic Botany, 45*: 153–165.

Boster, J. S. (1985). Selection for perceptual distinctiveness: Evidence from Aguaruna cultivars of Manihot esculenta. *Economic Botany 239*(3):310-325.

Boster, J. S. (1986). Exchange of varieties and information between Aguaruna manioc cultivators. *American Anthropologist 88*(2):429-436.

Brookfield, H. and Stocking, M. (1999). Agrodiversity: definition, description and design. *Global Environmental Change, 9*: 77-80.

Brookfield, H., Stocking, M., Brookfield., M. (2002). Guidelines on agrodiversity assessment. In Brookfield, H., C. Padoch, H. Parsons, and M. Stocking, (Eds), *Cultivating biodiversity: understanding, analysing and using agricultural diversity* (pp.41-56). London: United Nations University.

Brown, A.H.D., and D.R. Marshall. (1995). A basic sampling strategy: theory and practice. In Guarino, L., V. Ramanatha Rao and R. Reid (Eds.) *Collecting plant genetic diversity - technical guidelines* (pp. 75-91). Wallingford, UK: CAB International.

Brush, S. B. (1992). Ethnoecology, Biodiversity, and Modernization in Andean Potato Agriculture. *Journal of Ethnobiology 12*:161–185.

Brush, S. B. (1995). In situ conservation of landraces in centers of crop diversity. *Crop Science 35*:346-354.

Brush, S. B. (2000). The issues of in situ conservation of crop genetic resources. In Brush, S. B. (Ed.), *Genes in the field: on-farm conservation of crop diversity* (pp. 3-26). Rome, Italy: International Plant Genetic Resources Institute.

Brush, S. B., and Meng, E. (1998). Farmers' valuation and conservation of crop genetic resources. *Genetic Resources and Crop Evolution 45*: 139-150.

Brush, S. B. (2004). *Farmers' bounty: Locating crop diversity in the contemporary world*. New Haven: Yale University Press.

Brush, S. B., Taylor, J. E., and Bellon, M. R. (1992). Biological diversity and technology adoption in Andean potato agriculture. *Journal of Development Economics 39*:365-387.

Brush, S., and Perales, H. (2007). A maize landscape: Ethnicity and agro-biodiversity in Chiapas Mexico. *Agriculture, Ecosystems and Environment, 121*(3), 211-221. DOI: 10.1016/j.agee.2006.12.018.

Bush, M. B. and Colinvaux, O. A. (1994). Tropical forest disturbance: paleoecological records from Darién, Panama. *Ecology 75*(6): 1761-1768.

Carney, J. (2002). African rice in the Columbian exchange. *The Journal of African History*, 42(3), 377–396.

Carney, J. and Rosomoff R. N. (2010). *In the shadow of slavery: Africa's botanical legacy in the Atlantic World*. Berkeley and Los Angeles, CA: University of California Press.

Castella, J. M., Pham, H. M., Suan, P. K., Villano, L., and Tronche, N. R. (2005). Analysis of village accessibility and its impact on land use dynamics in a mountainous province of northern Vietnam. *Applied Geography*, 25(4), 308-326.

CBDC (Community Biodiversity Development and Conservation Programme). (2009). *Agro-biodiversity feeds the world: Status report on agrobiodiversity in Africa*. March 2009. Community Biodiversity Development and Conservation Programme: Temuco, Chile.

Ceccarelli, S. (1994). Specific adaptation and breeding for marginal conditions. *Euphytica 77*:205–219.

Chapin, M. (1992). *Indigenous peoples and natural ecosystems in Central America and Southern Mexico*. Map. National Geographic and Center for the Support of Native Lands.

Chapin, M. and B. Threkeld. (2001). *Indigenous landscapes: a study in ethnocartography*. Washington DC: Center for the Support of Native Lands.

Clawson, D. L. (1985). Harvest security and intraspecific diversity in traditional tropical agriculture. *Economic Botany 39*:56–67.

Chapin, M. (1992). Indigenous peoples and the environment in Central America. *National Geographic Research and Exploration 8*(2): 232-234.

Chayanov, A. V. (1986). *On the theory of peasant economy*. Thorner, D., B. Kerblay, R.E.F. Smith (Eds.). Foreword by T. Shanin. Manchester, UK: Manchester University Press.

Chazdon, R.L., Peres, C.a., Dent, D., Sheil, D., Lugo, A.E., Lamb, D., Stork, N.E. and Miller, S.E. (2009) The potential for species conservation in tropical secondary forests. *Conservation Biology, 23*: 1406-1417.

Chomitz, K. and D. Gray. (1996). Roads, land use, and deforestation: A spatial model applied to Belize. *World Bank Economic Review 10*(3): 487-512. DOI: 10.1093/wber/10.3.487

Coates, Anthony G. (1997). The forging of Central America. In Coates, A. G. (Ed.), *Central America: A natural and cultural history* (pp. 1-37). New Haven, Connecticut: Yale University Press.

Colin, F. L. (2010). *"Nosotros no solamente podemos vivir de cultura": Identity, Nature and Power in the Comarca Emberá of Eastern Panamá*. Ottawa, ON: Department of Geography and Environmental Studies, Carleton University.

Colman, D. and Young, T. (1989). *Principles of agricultural economics*. Cambridge University Press.

Condominas, G. (2009) Anthropological Reflections on Swidden Change in Southeast Asia. *Human Ecology, 37*: 265-267.

Conservation International. (2005). *Biodiversity Hotspots*. Map. Accessed: March 2011. URL: http://www.conservation.org/Documents/cihotspotmap.pdf.

Contraloría de Panamá. (1951). *I Censo Nacional Agropecuario.* Dirección de Estadística y Censo, República de Panamá.

Contraloría de Panamá. (1961). *II Censo Nacional Agropecuario*. Dirección de Estadística y Censo, República de Panamá.

Contraloría de Panamá. (1971). *III Censo Nacional Agropecuario*. Dirección de Estadística y Censo, República de Panamá.

Contraloría de Panamá. (1981). *IV Censo Nacional Agropecuario*. Dirección de Estadística y Censo, República de Panamá.

Contraloría de Panamá. (1991). *V Censo Nacional Agropecuario*. Dirección de Estadística y Censo, República de Panamá.

Contraloría de Panamá. (2001). *VI Censo Nacional Agropecuario*. Dirección de Estadística y Censo, República de Panamá.

Contraloría de Panamá. (2000). *Censos de Población y Vivienda de Panamá: Año 2000.* Accessed: January, 2011. URL: http://www.contraloria.gob.pa/dec/redatam/index_censospma.htm.

Contraloría de Panamá. (2010a). *Censos nacionales 2010 XI de Población y VII de Vivienda: Resultados Finales Básicos*. Cuadro 20 (Población indígena en la República, por sexo, según Provincia, Comarca indígena, grupo indígena al que pertenece y grupos de edad: Censo 2010). Accessed: January, 2011. URL: http://www.censos2010.gob.pa/Resultados/.

Contraloría de Panamá. (2010b). *Censos nacionales 2010 XI de Población y VII de Vivienda: Resultados Finales Básicos*. Cuadro 32 (Población total y afrodescendiente en la Republica, por grupo al que pertenece, según Provincia, Comarca indígena, Distrito y Corregimiento: Censo 2010). Accessed: January, 2011. URL: http://www.censos2010.gob.pa/Resultados/.

Contraloría de Panamá. (2010c). *Definiciones y Explicaciones.* Censos nacionales 2010 XI de Población y VII de Vivienda: Resultados Finales Básicos. Accessed: January 2011. URL: http://estadisticas.contraloria.gob.pa/Resultados2010/Tabulados.aspx.

Cooke, R. (1998). *Subsistencia y economía casera de los indígenas precolombinos de Panamá*. Separata del Tomo I de la obra "Antropología Panameña Pueblos y Culturas." Colección de libros de la Facultad de Humanidades. Editorial Universitaria Panamá.

Cooke, R. and L. A. Sanchez Herrera. (2004). *Panamá indígena: 1501-1550*. Historia General de Panamá Volumen I, Tomo I: Las Sociedades Originarias, El Orden Colonial. A. Castillero Calvo. Panama City, Panama, Ministerio de la Presidencia de la República de Panamá: 47-78.

Conklin, H. C. (1957). *Hanunoo agriculture: A report on an integral system of shifting cultivation in the Philippines*. FAO, Rome.

Coomes, O. T. (2010). Of stakes, stems, and cuttings: The importance of local seed systems in traditional Amazonian societies. *The Professional Geographer, 62*(3): 323-334. DOI: 10.1080/00330124.2010.483628.

Coomes, O. T., Grimard, F., and Burt, G. J. (2000). Tropical forests and shifting cultivation: secondary forest fallow dynamics among traditional farmers of the Peruvian Amazon. *Ecological Economics 32*(1):109-124.

Coomes, O.T., Grimard, F., Potvin, C., and Sima, P. (2008). The fate of the tropical forest: carbon or cattle? *Ecological Economics 65*(2):207-212.

Cotula, L., Dyer, N., and Vermeulen, S. (2008). *Fuelling exclusion? The biofuels boom and poor people's access to land*. London: IIED.

Cotula, L., Vermeulen, S., Leonard, R., Keeley, J. (2009). *Land grab or development opportunity? Agricultural investment and international land deals in Africa*. London/Rome: IIED/FAO/IFAD.

Covich, A. P. and N. H. Nickerson. (1966). Studies of cultivated plants in Choco dwelling clearings, Darien, Panama. *Economic Botany*, *20*(3): 285-301, DOI: 10.1007/BF02904280

Crosby, A. W. (1972). *The Colombian Exchange: Biological and cultural consequences of 1492*. Greenwood Press, Westport, Connecticut.

Dames and Moore Group Company. (1998). *Estrategia de ordenamiento territorial y protección de la calidad ambiental: Resumen ejecutivo*. Panama City, Panama, Programa de Desarrollo Sostenible de Darién: 48pp + maps.

Dames and Moore Group Company. (2001). *Programa de Desarrollo Sostenible de Darién: Estrategia de ordenamiento territorial y protección de la calidad ambiental* (Volumen 2). Panama City, Panama, Dames and Moore Group Company.

DeClerck, F. A. J., Chazdon, R., Holl, K. D., Milder, J. C., Finegan, B., Martinez-Salinas, A., Imbach, P., Canet, L., Ramos, Z. 2010. Biodiversity conservation in human-modified landscapes of Mesoamerica: Past, present and future. *Biological Conservation 143*(10): 2301-2313. DOI:10.1016/j.biocon.2010.03.026

De Janvry, A., Fafchamps, M., Sadoulet, E. (1991). Peasant household behaviour with missing markets – some paradoxes explained. *Economic Journal 101*:1400-1417.

De la Peña, G. (2005). Social and cultural policies toward indigenous peoples: perspectives from Latin America. *Annual Review of Anthropology 34*: 717-39.

DeWalt, S. (2003) Changes in vegetation structure and composition along a tropical forest chronosequence: implications for wildlife. *Forest Ecology and Management, 182:* 139-151.

Dennis, E., Ilyasov, J., van Dusen, M. E., Lee, S., Treshkin, S., and Smale, M. (2005). Social institutions and seed systems: the diversity of fruits and nuts in Uzbekistan. In Smale (Ed.), *Valuing crop biodiversity: On-farm genetic resources and economic change*, (pp. 192–210). Wallingford: CABI.

Dent, D.H. and Wright, S.J. (2009) The future of tropical species in secondary forests: A quantitative review. *Biological Conservation, 142*: 2833-2843.

De Schutter , O. (2010). *Food commodities speculation and food price crises: Regulation to reduce the risks of price volatility.* Briefing Note 02 by the United Nations Special Rapporteur on the Right to Food.

Dixon, J. E. (2001) Human colonization of the Americas: timing, technology and process. *Quaternary Science Reviews, 20*: 277-299.

Dove, M. R. (1983). Theories of Swidden Agriculture and the Political Economy of Ignorance. *Agroforestry Systems 1*: 85–99.

Duke, J. A. (1970). Ethnobotanical observations on the Choco Indians. *Economic Botany 24*:344–366.

Duke, J.A. (1968). *Darien ethnobotanical dictionary*. Bioenvironmental and Radiological Feasibility Studies: Atlantic-Pacific Interoceanic Canal. Columbus, Ohio: Battelle Memorial Institute, U.S. AEC report. BMI-171- 4.

Duke, J. A. (1975). Ethnobotanical observations on the Cuna Indians. *Economic Botany, 29*: 278-293.

Ellis, F. (1993). *Peasant economics: Farm households and agrarian development*, 2nd Edition, Cambridge: Cambridge University Press.

Esquinas-Alcázar, J. (2005). Protecting crop genetic diversity for food security: political, ethical and technical challenges. *Nature Reviews: Genetics 6*: 946-953.

Fahrig, L., Baudry, J., Brotons, L., Burel, F.G., Crist, T.O., Fuller, R.J., Sirami, C., Siriwardena, G.M. and Martin, J. (2011) Functional landscape heterogeneity and animal biodiversity in agricultural landscapes. *Ecology Letters, 14*, 101-12.

FAO (Food and Agriculture Organization of the United Nations). (1984). *Improved production systems as an alternative to shifting cultivation*, FAO Soils Bulletin No.53, FAO, Rome.

FAO (Food and Agriculture Organization of the United Nations). (2010). *Global forest resources assessment 2010*. Global Tables. Available online: http://www.fao.org/forestry/fra/fra2010/en/

FAO (Food and Agriculture Organization of the United Nations). (2010). *The second report on the state of the world's plant genetic resources for food and agriculture*. Commission on Genetic Resources for Food and Agriculture. Available at: http://www.fao.org/agriculture/seed/sow2/en/.

Fearnside, P. M. (2001). Soybean cultivation as a threat to the environment in Brazil. *Environmental Conservation* 28 (1): 23–38.

Feder, G. (1980). Farm size, risk aversion and the adoption of new technology under uncertainty. *Oxford Economic Papers 3*: 263-283.

Frankel, O. H. (1974). Genetic conservation: our evolutionary responsibility. *Genetics 78*: 53-65.

Galluzzi, G., Eyzaguirre, P., and Negri, V. (2010). Home gardens: neglected hotspots of agro-biodiversity and cultural diversity. *Biodiversity and Conservation, 19*(13): 3635-3654. DOI: 10.1007/s10531-010-9919-5.

Galluzzi, G., van Duijvendijk, C., Collette, L., Azzu, N., Hodgkin, T. (Eds). (2010). *Biodiversity for food and agriculture: Contributing to food security and sustainability in a changing world: Outcomes of an expert workshop held by FAO and the Platform on Agrobiodiversity Research from 14–16 April 2010 in Rome, Italy*. Platform for Agrobiodiversity Research and Food and Agriculture Organization of the United Nations. Available online at: http://agrobiodiversityplatform.org/files/2011/04/PAR-FAO-book_lr.pdf

Gaviria, J. G. (Ed.) (2004). *Recuperando vida: Guías para la recuperación de las semillas y la soberanía alimentaria en situaciones de conflicto en Colombia*. Fundación Swissaid.

Gergel, S.E., Turner, M.G., Miller, J.R., Melack, J.M. and Stanley, E.H. (2002) Landscape indicators of human impacts to riverine systems. *Landscape Ecology, 64*: 118- 128.

Gibson, R. W. (2009). A Review of Perceptual Distinctiveness in Landraces Including an Analysis of How Its Roles Have Been Overlooked in Plant Breeding for Low-Input Farming Systems. *Economic Botany, 63*(3), 242-255.

Godoy, R.A. (2001). *Indians, markets and rainforests: theory, methods, analysis*. New York, NY. Columbia University Press.

Godoy, R., Franks, J., Alvarado, M. (1998). Adoption of modern agricultural technologies by lowland indigenous groups in Bolivia: The role of households, villages, ethnicity, and markets. *Human Ecology 26*(3): 351-369.

Golley, F.B., McGinnis, J.T., Clements, R.G., Child, G.I., and Duever, M.J. (1975). *Mineral Cycling in a Tropical Moist Forest Ecosystem*. Athens, Georgia: University of Georgia Press.

Goodenough, W. H. (1981). *Culture, language, and society*. (Rev. 2nd Ed.). Redwood City, CA: Benjamin-Cummings.

Granovetter, M. (1985). Economic action and social structure: the problem of embeddedness. *American Journal of Sociology 91*(3): 481. DOI:10.1086/228311.

Graves, W. and J. F. Shupe. (1992). *Spain in the Americas*. Map. Cartographic Division of the National Geographic Society. Washington, D.C., February 1992.

Guarino, L. and Hoogendijk, M. (2004). *Microenvironments. homegardens and agrobiodiversity.* In Ezyaguirre, P. B. and O. F. Linares (Eds.) Washington, DC, Smithsonian Books: 31-40.

Hamlin, C.C. and Salick, J. (2011) Yanesha agriculture in the Upper Peruvian Amazon: Persistence and change fifteen years down the 'road'. *Economic Botany, 57*: 163-180.

Hammond, D. S., Dolman, P. M., and Watkinson, A. R. (1995). Modern Ticuna swidden-fallow management in the Colombian Amazon: Ecologically integrating market strategies and subsistence-driven economies? *Human Ecology, 23*(3), 335-356. DOI: 10.1007/BF01190136.

Hance, J. (2011). Bolivian road project through Amazon reserve canceled. Mongabay.com, October 23, 2011. Available online at: http://news.mongabay.com/2011/1023-hance_bolivia_road.html

Harlan, J. R. (1975). *Crops and man.* Madison, Wisconsin: American Society of Agronomy and Crop Science Society of America.

Heady, E. O. (1952). *Economics of agricultural production and resource use*. Englewood Cliffs, New Jersey: Prentice-Hall.

Heckadon-Moreno, S., and McKay. A. (Eds.). (1984). *Colonización y destrucción de bosques en Panamá: Ensayos sobre un grave problema ecológico*. Panama City, Panama: Panamanian Association of Anthropology.

Heckadon-Moreno, S., Herrera, F., and Pastor, A. (1984). Breve estudio de los grupos humanos de Darién. In Heckadon Moreno, S., and A. McKay (Eds.), (1984). *Colonización y destrucción de bosques en Panamá: Ensayos sobre un grave problema ecológico* (pp. 81-103). Panama City, Panama: Panamanian Association of Anthropology.

Heckadon-Moreno, S. (1997). Spanish rule, independence, and the modern colonization frontiers. In Coates, A. G. (Ed.). *Central America: A natural and cultural history* (pp. 177-214). New Haven, Connecticut: Yale University Press.

Henrich, J., Heine, S. J., and Norenzayan, A. (2010). The weirdest people in the world? *The Behavioral and brain sciences, 33*(2-3), 61-83. DOI: 10.1017/S0140525X0999152X.

Herlihy, Peter H. (1986). *A cultural geography of the Embera and Wounaan (Choco) Indians of Darien, Panama, with emphasis on recent village formation and economic diversification.* Ph.D. Dissertation. Baton Rouge, Louisiana: The Department of Geography and Anthropology, Louisiana State University.

Herlihy, P. H. (2003). Participatory research mapping of indigenous lands in Darién, Panama. *Human Organization 62*(4): 315-331.

Hernandez, A. (1970). Migración de colonos en Darién. *Hombre y cultura, 1*(2), 81-95.

Hiebert, D. (1974). Risk, learning and the adoption of fertilizer responsive varieties. *American Journal of Agricultural Economics 56*: 764-768.

Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones and A. Jarvis, 2005. Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology 25*: 1965-1978

Hodgkin, T., Rana, R., Tuxill, J., Balma, D., Subedi, A., Mar, I., Karamura, D., Valdivia, R., Collado, L., Latournerie, L., Sadiki, M., Sawadogo, M., Brown, A. H. D., and Jarvis, D. I. (2007). Seed systems and crop genetic diversity in Seed systems and crop genetic diversity in agroecosystems. In Jarvis, D. I., C. Padoch, and H. D. Cooper, (Eds.), *Managing Biodiversity in Agricultural Systems* (pp. 77–116). New York, New York: Columbia University Press.

Hoopes, J. W. and O. M. Fonseca Zamora. (2003). Goldwork and Chibchan identity: Endogenous change and diffuse unity in the Isthmo-Colombian Area. In. Quilter, J. and J. W. Hoopes (Eds.) 2003. *Gold and power in ancient Costa Rica, Panama, and Colombia*, (pp. 49-90). Washington, DC: Dumbarton Oaks.

Horvath, R. J. (1964). Von Thünen's Isolated State and the Area around Addis Ababa, Ethiopia. Annals of the Association of American Geographers. 59: 313.

Howe, J. (1974). *Village political organization among the San Blas Cuna*. Ph.D. Dissertation, Philadelphia, PA: University of Pennsylvania.

Howe, J. (1998). *A People Who Would Not Kneel: Panama, the United States, and the San Blas Kuna*. Washington, DC, Smithsonian Institution.

Howe, J. (2002). *The Kuna Gathering: Contemporary Village Politics in Panama*. Tucson, AZ: Fenestra Books.

Howe, J. (2004). Door of the Seas and Key to the Universe: Indian Politics and Imperial Rivalry in the Darien, 1640-1750. (Review). *Ethnohistory 51*(4):846-848.

Howe, J., and Chapin, M. (1975). *Notes on the environment and subsistence patterns of the San Blas Cuna.* Working Papers on Peoples and Cultures of Central America (p. 69).

Humphries, S. (1993). The intensification of traditional agriculture among Yucatec Maya farmers: Facing up to the dilemma of livelihood sustainability. *Human Ecologist 21*: 87–103.

Hvalkof, S. and K. S. Saavedra. (2007). *Informe: Evaluación de término final del proyecto: "Tierras Colectivas de los Emberá y Wounaan en Darién, Tercera Fase."* Panama and Copenhagen: Nepenthes. Available: http://www.nepenthes.dk/files/resource_2/Dokumenter/Panama/Informe_Panama_Final_A4.pdf

IDIAP (Instituto de Investigación Agropecuaria de Panamá). (2006). *Zoonificación de suelos de Panamá por niveles de nutrientes*. Panama City, Panamá.

IAASTD (International Assessment of Agricultural Knowledge Science and Technology for Development). (2008). *Agriculture at a crossroads: Global report.* McIntyre, B. D., H. R. Herren, J. Wakhungu, and R. T. Watson (Eds.) Washington: Island Press.

IUCN (International Union for the Conservation of Nature). (1986). Tropical countries from the IUCN list. In IUCN. (1986). *Plants in Danger: What do we know*? Available online: http://www.nhm.ac.uk/hosted_sites/bbstbg/tropctry.htm

IUCN (International Union for Conservation of Nature). (2010). *The IUCN Red List of Threatened Species.* Accessed: October 2010. URL: http://www.iucnredlist.org/about/red-list-overview.

Isakson, S. R. (2011). Market provisioning and the conservation of crop biodiversity: An analysis of peasant livelihoods and maize diversity in the Guatemalan Highlands. *World Development*, 39(8), 1444-1459. doi:10.1016/j.worlddev.2010.12.015.

Jackson, J. E. and Warren, K. B. (2005). Indigenous movements in Latin America, 1992-2004: Controversies, ironies, new directions. *Annual Review of Anthropology 34*: 549-73.

Jaramillo Uribe, J. (1963). Esclavos y señores en la sociedad colombiana del siglo XVIII. *Anuario Colombiano de Historia Social y de la Cultura 1*(1): 5-76.

Jarvis, J. I., Brown, A. H. D., Cuong, P. H., Collado-Panduro, L., Latournerie-Moreno, L., Gyawali, S., Tanto, T., ... Hodgkin, T. (2008). A global perspective of the richness and evenness of traditional crop-variety diversity maintained by farming communities. *Proceedings of the National Academy of Sciences of the United States of America, 105*(14), 5326-31. DOI: 10.1073/pnas.0800607105.

Jarvis, D. J., Myer, L., Klemick, H., Guarino, L., Smale, M., Brown, A. H. D., Sadiki, M., Sthapit, B., and Hodgkin, T. (2000). *A training guide for in situ conservation on-farm*. Rome, Italy: IPGRI.

Johns, T. and Sthapit, B. R. (2004). Biocultural diversity in the sustainability of developing country food systems. Food and Nutrition Bulletin 25(2):143-155.

Juma, C. (1989). *Biological diversity and innovation: conserving and utilizing genetic resources in Kenya.* Nairobi, Kenya: African Centre for Technology Studies.

Just, R. E. and Zilberman, D. (1983). Stochastic structure farm size and technology adoption in developing agriculture. *Oxford Economic Papers 35*: 307-328.

Kane, S. (1986). *Emberá (Chocó) village formation: The politics and magic of everyday life in the Darién forest.* Ph.D. Dissertation . Austin, Texas: Department of Anthropology, University of Texas at Austin.

Kane, S. (1990). Shamans Reconsidered: The Emberá (Choco) in Darien, Panama. In Stephen, L. and J. Dow, (Eds.), *Class, politics and popular religion in Mexico and Central America.*

Society for Latin American Anthropology Publication Series, 10 (Jeffrey David Ehrenreich, Series Editor). Washington, DC: American Anthropological Association.

King, A., and Smale, M. (2005). Targeting Conservation Policy. *Research at a glance, Brief 18*. Washington: International Food Policy Research Institute.

Kirby, K.R., Laurance, W.F., Albernaz, A.K.M., Schroth, G., Fearnside, P.M., Bergen, S., Venticinque, E. M. and da Costa, C. 2006. The future of deforestation in the Brazilian Amazon. *Futures*, Special issue: *The Future of Bioregions and Bioregional Planning* 38(4): 432-453.

Klein Goldewijk, K., and Ramankutty, N. (2004). Land-cover change over the last three centuries due to human activities: The availability of new global data sets. *GeoJournal, 61*(4), 335-344. DOI: 10.1007/s10708-004-5050-z.

Kramer, D.B., Urquhart, G. and Schmitt, K. (2009) Globalization and the connection of remote communities: a review of household effects and their biodiversity implications. *Ecological Economics 68*: 2897–2909.

Kundermann, B. (2000). *Managing Agrobiodiversity in disaster situations: Determinants of animal and plant genetic resource loss and options for its mitigation*. Eschborn, Germany: Deutsche Gesellschaft für Technische Zusammenarbeit.

Lamont, S. R., W. H. Eschbaugh, and A. M. Greenberg. (1999). Species composition, diversity, and use of homegardens among three Amazonian villages. *Economic Botany 53*(3): 312–26.

Langebaek, C. H. (1991). Cuna Long Distance Journeys: The Result of Colonial Interaction. *Ethnology, 30*(4): 371-380.

Lasgorceix, A., Kothari, A. (2009). Displacement and Relocation of Protected Areas: A Synthesis and Analysis of Case Studies. *Economic and Political Weekly XLIV* (49): 37-47. December 5, 2009.

Lastarria-Cornhiel S. and Melmed-Sandjak, J. (1999). *Land tenancy in Asia, Africa and Latin America: A look at the past and a view to the future*. Land Tenure Center, University of Wisonsin, Madison.

Laurance, W.F., Ferreira, L.V., Rankin-de Merona, J.M. and Laurance, S.G. (1998) Rain Forest Fragmentation and the Dynamics of Amazonian Tree Communities. *Ecology, 79*: 2032-2040.

Laurance, S.G. (2005) Clearing width and movements of understory rainforest birds. *Ecology, 37*: 149-152.

Legendre, P. and L. Legendre. (1998). *Numerical Ecology*. (2nd English ed). Amsterdam, Netherlands: Elsevier Science.

Lewis, M. Paul (Ed.) (2009). *Ethnologue: Languages of the world* (Sixteenth ed.) Dallas, Texas: SIL International. Online version: http://www.ethnologue.com/.

Li, D. and Pritchard, H.W. (2009). The science and economics of ex situ plant conservation. *Trends in plant science, 14*: 614-21.

Littlefield, D.C. (1981). *Rice and Slaves: Ethnicity and the Slave Trade in Colonial South Carolina*. Baton Rouge: Louisiana State University Press, 1981.

Loewen, J. (1972). El cambio cultural entre los chocó de Panamá. *America Indígena. Vol XXXII* (1): 159-168.

Losonczy, A. (2006). *La trama interétnica*. I.C.A.N, IFEA, Bogota. (Translation into Spanish of 1997, Les Saints et la forêt. Rituel, société et figures de l'échange entre Noirs et Indiens Emberà (Choco, Colombie), L'Harmattan, Paris, with new preface by the author).

Louette, D. (1997). Seed exchange among farmers and gene flow among maize varieties in traditional agricultural systems. In Serratos, J. A., M. C. Willcox, and F. Castillo (Eds.), *Gene flow among maize landraces, improved maize varieties, and teosinte: Implications for transgenic maize* (pp. 56-66) Mexico, D. F.: CIMMYT.

MacFarquar, N. (2010). African farmers displaced as investors move in. New York Times, December 21, 2010. Available at: http://www.nytimes.com/2010/12/22/world/africa/22mali.html?pagewanted=all.

Maffi, L. (2007) Bio-cultural diversity for endogenous development: Lessons from research, policy, and on-the-ground experiences. In, Haverkort, B. and S. Rist (Eds.), *Endogenous development and biocultural diversity: The interplay of worldviews, globalisation and locality* (pp. 56-66). Leusden, The Netherlands: COMPAS.

Maffi, L., and Woodley, E. (2010). *Biocultural diversity conservation: A global sourcebook.* London: Earthscan.

Manne, L. L. (2003).Nothing has yet lasted forever: current and threatened levels of biological diversity. *Evolutionary Ecology Research 5*: 517-527.

McGrath, D. G., 1987. The role of biomass in shifting cultivation. *Human Ecology 15*(2):221-242.

McElreath, R. (2004). Social learning and the maintenance of cultural variation: An evolutionary model and data from East Africa. *American Anthropologist, 106*: 308-21.

Mendez, T. E. (2004). *El Darién: Imagen y proyecciones*. (Rev. 2nd ed.). Panama City, Panama: Instituto Nacional de Cultura.

Mertens, B., & Lambin, E. F. (2000). Land-cover-change trajectories in Southern Cameroon. *Annals of the Association of American Geographers*, 90(3), 467-494.

Mertz, O., Padoch, C., Fox, J., Cramb, R. A., Leisz, S. J., Nguyen, T. L., and Vien, T. D. (2009). Swidden change in Southeast Asia: understanding causes and consequences. *Human Ecology 37*(3): 259-264. DOI:10.1007/s10745-009-9245-2.

Mintz, Sidney W. (1985). From Plantations to Peasantries in the Caribbean". In Mintz, S. W. and S. Price (Eds.), *Caribbean contours* (pp. 127–153). Baltimore: The Johns Hopkins University Press.

Moore, J. L., Manne, L., Brooks, T., Burgess, N. D. and Davies, R. (2002). The distribution of cultural and biological diversity in Africa. *Proceedings of the Royal Society of London, B. 269*:1645-53.

Moran, E. F. (1993). Deforestation and land use in the Brazilian Amazon, *Human Ecology 21* (1) (1993) 1–21.

Nasser Baco, M., Biaou, G., and Lescure, J. (2007). Complementarity between Geographical and Social Patterns in the Preservation of Yam (Dioscorea sp.) Diversity in Northern Benin. *Economic Botany, 61*(4), 385-393.

Nepstad, D. C., C. M. Stickler, and Almeida, O. T. (2006). Globalization of the Amazon soy and beef industries: Opportunities for conservation. *Conservation Biology* 20: 1595–603.

Nickerson, N. H and Covich, A. P. (1966). A collection of maize from Darien, Panama. *Economic Botany 20*(4): 434-440.

Nieman, A. L., Kamp, K. (2009). Guide to biodiversity in the farmscapes of Lao PDR. Vientiane: IUCN Laos and Laos, National Agriculture and Forestry Research Center.

Nordenskiold, E. (1938). *An historical and ethnological survey of the Cuna Indians*. Wassen, H. (Ed.). Goteborg, Goteborgs Museum, Etnografiska Avdelningen, 27.

Norris, K. (2008). Agriculture and biodiversity conservation: opportunity knocks. *Conservation Letters, 1*(1), 2-11. DOI: 10.1111/j.1755-263X.2008.00007.x.

OAS (Organization of American States, Secratariat of). (1978). *Proyecto de desarrollo integrado de la región oriental de Panamá-Darién.* Estudio realizado por la Unidad Técnica del Proyecto Panamá-Darién durante el periodo 1975-1978, Gobierno de la República de Panamá, Programa de Desarrollo Regional. Washington: General Secretariat of the Organization of American States.

Okafor, J.C. and Fernandes, E.C.M. (1987). Compound farms of southeastern Nigeria: a predominant agroforestry homegarden system with crops and small livestock. *Agroforestry Systems 5*(2): 153-68.

Oksanen, J., Kindt, R., Legendre, P., O'Hara, B., Simpson, G. L., Stevens, M. H. H. and Wagner, H. (2008). *The vegan Package: Community Ecology Package, version 1.13-1*. URL: http://vegan.r-forge.r-project.org/.

Oldfield, M. L., and J. B. Alcorn. (1987). Conservation of traditional agroecosystems. *BioScience 37*:199–208.

Pacheco R., E. and Velasquez Z., J. J. (1993). Relaciones Interétnicas de los Emberá del Bajo Chocó. In Correa, R., F. (Ed.), *Encrucijadas de Colombia Amerinidia* (pp. 269-285). Bogotá: Instituto Colombiano de Antropología.

Padoch, C. and W. de Jong. (1992). Diversity, variation, and changes in ribereño agriculture. In K. Redford and C. Padoch (Eds.), *Conservation of Neotropical forests: Working from traditional resource use* (pp. 158-174). New York, NY: Columbia University Press.

Padoch, C., and Pinedo-Vasquez, M. (2010). Saving Slash-and-Burn to Save Biodiversity, 42(5), 550-552. *Biotropica 42*(5): 550–552. DOI: 10.1111/j.1744-7429.2010.00681.x

Pagnini, L. A. (1970). *The agricultural systems of the Chucunaque-Tuira Basin in the Darien Province, Panama*. Ph.D. Dissertation. Gainesville: Department of Geography, University of Florida.

Patiño, V. M. (1956). El maíz chococito: Noticia sobre su cultivo en América ecuatorial. *América Indígena, Mexico XVI*(4), 309-346.

Patiño, V. M. (1993). Especies vegetales promisorias del litoral pacífico insuficientemente conocidas. In Leyva, P. (Ed.), *Colombia Pacifico: Tomo II* (pp. 683-691). Santa Fe de Bogotá: Fondo para la Proteccion del Medio Ambiente "Jose Celestino Mutis".

Pavia R., Barbagiovanni, M. I., Strada, G.D., Piazza, M. G., Engel, P., Fideghelli, C. (2007) Autochthonous fruit tree germplasm at risk of genetic erosion found in home gardens in the region of Latium (Italy). In Bailey, A., P. Eyzaguirre, and L. Maggioni (Eds.), *Proceedings of a Workshop, 3-4 October 2007, Ljubljana, Slovenia*. Rome, Italy: Bioversity International.

Perafán, C. and Nessim, H. (2002). *Community consultation: The case of Darien*. Washington, D.C: Inter-American Development Bank, Sustainable Development Department, Best Practices Series.

Perales, H. R., Benz, B. F., and Brush, S. B. (2005). Maize diversity and ethnolinguistic diversity in Chiapas, Mexico. *Proceedings of the National Academy of Sciences of the United States of America, 102*(3), 949-54. DOI: 10.1073/pnas.0408701102.

Peregrine, P. N. (2001). Darién: 1200-500 B.P. In Peregrine, P. N. and M. Ember, (Eds.), *Encyclopedia of Prehistory Volume 5: Middle America* (pp. P. 246-253). New York, NY: Kluwer/Plenum.

Perfecto, I., Vandermeer, J., and Wright, A. (2009). *Nature's matrix: Linking agriculture, conservation and food sovereignty*. London: Earthscan.

Peroni, N., and Hanazaki, N. (2002). Current and lost diversity of cultivated varieties, especially cassava, under swidden cultivation systems in the Brazilian Atlantic Forest. *Agriculture, Ecosystems, and Environment 92*: 171–183.

Perrault-Archambault, M. (2005). *Who manages home garden agrobiodiversity? Patterns of species distribution, planting material flow and knowledge transmission along the Corrientes river of the Peruvian Amazon*. M. A. Thesis. Montreal, QC: Department of Geography, McGill University.

Perrault-Archambault, M., and Coomes, O. (2008). Distribution of agrobiodiversity in home gardens along the Corrientes river, Peruvian Amazon. *Economic Botany, 62*(2), 109–126.

Perreault, T. (2005). Why chacras (swidden gardens) persist: Agro-biodiversity, food security, and cultural identity in the Ecuadorian Amazon. *Human Organization 64*: 327–339.

Polanyi, K. (1944). *The great transformation*. New York: Rinehart.

POTLATCH Consulting Group. (1998). *Dinámica socio-demográfica y tenencia de la tierra: Informe 2 - documento de análisis*. Report prepared by POTLATCH consultants for the Programa de Desarollo Sostenible de Darién. Panama City, Panama.

Pretty, J. N., Antholt, C., Bawden, R. (1995). *Regenerating agriculture*. Earthscan, London.

Pretty, J., Noble, A. D., Bossio, D., Dixon, J., Hine, R. E., Penning De Vries, F. W., Morrison, J. I. (2006). Resource conserving agriculture increases yields in developing countries. *Environmental Science and Technology 40*(4): 1114-1119.

PRONAT (Programa Nacional de Administración de Tierras). (2008). *Evaluación social: Financimiento adicional*. Panama City, Panama: PRONAT AF.

Ranganathan, J. and Daily, G.C. (2007). Biogeography of rural landscapes: opportunities for rural conservation in Mesoamerican landscapes managed by people. In: Harvey, C. and J. Saenz (Eds.), *Conservation of Biodiversity in Fragmented Landscapes in Central America*. Santo Domingo de Heredia, Costa Rica: INBIO.

Rerkasem, K., Lawrence, D., Padoch, C., Schmidt-Vogt, D., Ziegler, A. D., Bruun, T. B. (2009). Consequences of swidden transitions for crop and fallow biodiversity in Southeast Asia. *Human Ecology, 37*(3), 347-360. DOI: 10.1007/s10745-009-9250-5

Reyes-García, V. (2001). *Indigenous People, Ethnobotanical Knowledge, and Market Economy: A Case Study of the Tsimane' Ameridians in Lowland Bolivia*. Gainesville: University of Florida.

Reyes-García, V., Vadez, V., Martí, N., Huanca, T., Leonard, W. R., Tanner, S. (2008). Ethnobotanical knowledge and crop diversity in swidden fields: A study in a native Amazonian society. *Human Ecology, 36*(4), 569-580. DOI: 10.1007/s10745-008-9177-2.

Ricardo, D. (1821). *On the Principles of Political Economy and Taxation*. (3rd Ed., originally published in 1817) London, England: John Murray. Full text available at: http://www.econlib.org/library/Ricardo/ricP.html

Rico-Gray, V., Garcia-Franco, J.G., Chemas, A., Puch, A., and P. Sima. (1990). Species composition, similarity, and structure of Mayan homegardens in Tixpeual and Tixcacaltuyub, Yucatan, Mexico. *Economic Botany 44*(4): 470-487.

Rice, R.A. (2003). Tropical agricultural landscapes. In Vandermeer, J. H. (Ed.), *Tropical agroecosystems*, (pp. 195-218). Boca Raton, Florida: CRC Press.

Rist, L., Feintrenie, L., and Levang, P. (2010). The livelihood impacts of oil palm: smallholders in Indonesia. Biodiversity and Conservation 19:1009-1024. DOI 10.1007/s10531-010-9815-z.

Romoli, Kathleen. (1987). *Los de la lengua de Cueva: Los grupos indígenas del istmo oriental en la época de la conquista española*. Bogotá: Instituto Colombiano de Antropología, Instituto Colombiano de Cultura (Ediciones Tercer Mundo).

Ross, N. J. (2011) Modern tree species composition reflects ancient Maya "forest gardens" in northwest Belize. *Ecological Applications 21*:1, 75-84.

Salick, J., N. Cellinese, and S. Knapp. (1997). Indigenous Diversity of Cassava: Generation, Maintenance, Use and Loss among the Amuesha, Peruvian Upper Amazon. *Economic Botany 51*:6–19.

Salonen, M., Toivonena, T., Cohalanb, J.-M., Coomes, O. T. (2011). Critical distances: Comparing measures of spatial accessibility in the riverine landscapes of Peruvian Amazonia. Applied Geography. 32(2), 501-513. doi:10.1016/j.apgeog.2011.06.017.

Samberg, L. H., Shennan, C., and Zavaleta, E. S. (2010). Human and Environmental Factors Affect Patterns of Crop Diversity in an Ethiopian Highland Agroecosystem. *The Professional Geographer, 62*(3), 395-408. DOI: 10.1080/00330124.2010.483641.

SAS Institute Inc. (2008). SAS Statistical Software. Cary, NC, USA.

Scherr, S.J. (1999). *Soil degradation: a threat to developing-country food security by 2020?* International Food Policy Research Institute (IFPRI). Food, Agriculture and the Environment Discussion Paper 27.

Schneider, J. (2004) Toward an analysis of home garden cultures. On the use of sociocultural variables in home garden studies. In: Eyzaguirre, P. B., Linares, O. (eds) *Home gardens and agrobiodiversity* (pp. 41-55) Washington: Smithsonian books.

Settle, W.H., Ariawan, H., Astuti, E.T., Cahyana, W., Hakim, A.L., Hindayana, D. and Lestari, A.S. (2011) Managing Tropical Rice Pests Through Conservation of Generalist Natural Enemies and Alternative Prey. *Ecology 77*: 1975-1988.

Shepherd, C. J. (2010) Mobilizing Local Knowledge and Asserting Culture. *Current Anthropology, 51:* 629-654.

Sloan, S. (2007). *Reforestation amidst deforestation in the Bayano-Darién frontier, eastern Panama: Variations on the forest transition thesis*. M.A. Thesis, Montreal, QC: Department of Geography, McGill University.

Soemarwoto, O. (1987). Homegardens: a traditional agroforestry system with a promising future. In Steppler, H.A. and Nair, R. (Eds.) *Agroforestry a decade of development*. Nairobi: International Council for Research in Agroforestry.

Smale, M., Just, R. E., and Leathers, H. D. (1994). Land allocation in HYV adaption models: an investigation of alternative explanations. *American Journal of Agricultural Economics 76*: 535-546.

Smale, M., Bellon, M. R., and Aguirre Gómez, J. A. (2001). Maize diversity, variety attributes, and farmers' choices in southeastern Guanajuato, Mexico. *Economic Development and Cultural Change 50*: 201-225.

Smale, M. (2006). Concepts, Metrics and Plan of the Book. In Smale, M. (Ed.), (2006). *Farmers, gene banks and crop breeding,* (pp. 1-16). Boston: Kluwer Academic Publishing.

Smithson, J. B. and Lenné, J. M. (1996). Varietal mixtures: A viable strategy for sustainable productivity in subsistence agriculture. *Annals of Applied Biology 128*:127–158.

Soler, L. D., Escada, M. I. S., and Verburg, P. H. (2009). Quantifying deforestation and secondary forest determinants for different spatial extents in an Amazonian colonization frontier (Rondonia). Applied Geography, 29(2), 182-193.

Soleri, D. and D. A. Cleveland. (1993). Hopi Crop Diversity and Change. *Journal of Ethnobiology 13*:203–231.

Spencer, J. E. (1966). *Shifting cultivation in southeastern Asia*. Berkeley and Los Angeles, CA: University of California Press.

Steinberg, M. K. (1999). Maize diversity and cultural change in a Maya agroecological landscape. *Journal of Ethnobiology 19*:127–139.

Stier, F. (1976). *Bananas: an account of environment and subsistence on Playon Chico, San Blas*. Working papers on peoples and cultures of Central America.

Stier, F. (1979). *The effect of demographic change on agriculture in San Blas, Panama*. Ph.D. Dissertation. Tucson, AZ: Department of Anthropology, University of Arizona.

Stier, F. (1982). Domestic economy: land, labor, and wealth in a San Blas community. *American Ethnologist, 9*(3), 519-537. DOI: 10.1525/ae.1982.9.3.02a00050.

Stipek, G. (1974). Interethnic relations and boundary maintenance in the Colombian Chocó. *Actas del XLI Congreso Internacional de Americanistas III*: 87-92.

Stone, G. (2007). Agricultural deskilling and the spread of genetically modified cotton in Warangal. *Current Anthropology, 48*(1), 67-103. DOI: 10.1086/508689.

Stromberg, P., Pascual, U., Bellon, M. (2010). Seed systems and farmers' seed choices: The case of maize in the Peruvian Amazon. *Human Ecology 38*(4): 539-553. DOI: 10.1007/s10745-010-9333-3

Sutherland, W. J. (2003). Parallel extinction risk and global distribution of languages and species. *Nature, 423*: 276-279. DOI: 10.1038/nature01607.

Tengö, M., Johansson, K., Rakotondrasoa, F., Lundberg, J., Andriamaherilala, A., Rakotoarisoa, J., Elmqvist, T., Johansson, K., Rakotondrasoa, F. and Lundberg, J. (2007) Taboos and forest governance: Informal protection of hot spot dry forest in Southern Madagascar. *AMBIO: A Journal of the Human Environment, 36*(8): 683-691.

Thrupp, L. A. (2000). Linking agricultural biodiversity and food security: the valuable role of agrobiodiversity for sustainable agriculture. *International Affairs 76*:2 283–297.

Toledo, V. M., Alarcón-Cháires, P., Moguel, P., Olivo, M., Cabrera, A., and Rodríguez-Aldabe, A. (2002). Mesoamerican ethnoecology: A review of the state of the art. In Stepp, J. R., F. S. Wyndham, and R. Zarger (Eds.), *Ethnobiology and biocultural diversity* (pp. 561–574). Athens: University of Georgia Press.

Tschakert, P., Coomes, O., Potvin, C., (2007). Indigenous livelihoods, slash-and-burn agriculture and carbon stocks in Eastern Panama. *Ecological Economics 60*: 807–820.

Tweddle, J.C., Dickie, J.B., Baskin, C.C. and Baskin, J.M. (2003) Ecological aspects of seed desiccation sensitivity. *Journal of Ecology, 91*: 294-304.

UN (United Nations), Department of Economic and Social Affairs, Population Division. (2011). World Population Prospects: The 2010 Revision, CD-ROM Edition.

UNDP (United Nations Development Programme). (2010). Human Development Report 2010 - 20th Anniversary Edition. The Real Wealth of Nations: Pathways to Human Development. Available online: http://hdr.undp.org/en/reports/global/hdr2010/chapters/

UNESCO (United Nations Educational, Scientific and Cultural Organization). (2006). *The Slave Route* (Map). The Coordination of the Slave Route Project. Accessed March 2011. URL: http://portal.unesco.org/culture/en/ ev.php - URL_ID=5467andURL_DO=DO_TOPICandURL_SECTION=201.html.

Vadez, V., Reyes-Garcia, V., Godoy, R. A., Apaza, V. L., Byron, E., Huanca, T., Leonard, W. R., Pérez, E., and Wilkie, D. (2004). Does integration to the market threaten agricultural diversity? Panel and cross-sectional data from a horticultural-foraging society in the Bolivian Amazon. *Human Ecology, 32*(5): 635-646. DOI: 10.1007/s10745-004-6100-3.

Van Dusen , E. (2000). *In situ conservation of crop genetic resources in the Mexican Milpa system*. Ph.D. Dissertation, Davis, CA: University of California at Davis.

Van Dusen, E. and Taylor, J. E. (2005). Missing markets and crop diversity: evidence from Mexico. *Environment and Development Economics 10*: 513-531.

Van Etten, J., and de Bruin, S. (2007). Regional and local maize seed exchange and replacement in the western highlands of Guatemala. *Plant Genetic Resources: Characterization and Utilization 5*(2); 57–70. DOI: 10.1017/S147926210767230X

Vargas, P. (1991). Una interpretación sobre las relaciones entre los Embera y los Cuna. In *Memorias Simposio Sobre Cultura Embera, V Congreso de Antropología, El Peñol, October 12 -15* (pp.207-230). Medellin, Colombia: Organización Indígena de Antioquía.

Velásquez Runk, J. (2005). *"And the creator began to carve us of cocobolo": Culture, history, forest ecology, and conservation among Wounaan in eastern Panama.* Doctoral

dissertation, School of Forestry and Environmental Studies and Department of Anthropology, Yale University and the New York Botanical Garden.

Velásquez Runk, J., Ortíz Negría, G., Quintero García, W., and Quiróz Ismare, C. (2007). Political economic history, culture, and Wounaan livelihood diversity in eastern Panama. *Agriculture and Human Values, 24*(1), 93-106. DOI: 10.1007/s10460-006-9035-z.

Velásquez Runk, J., Ortíz Negría, G., Peña Conquista, L., Mejía Peña, G., Peña Cheucarama, F., Cheucarama Chiripua, Y. (2010). Landscapes, legibility, and conservation planning: Multiple representations of forest use in Panama. *Conservation Letters 3*(3): 167–176. DOI: 10.1111/j.1755-263X.2009.00093.x

Velez, M. A. (2011). Collective titling and the process of institution building: The new common property regime in the Colombian Pacific. *Human Ecology* 39:117–129. DOI 10.1007/s10745-011-9375-1.

Ventocilla, J. (2004). *Pueblos indígenas, bosques y ambientes marinos de Panamá.* Map. Center for the Support of Native Lands, Instituto Smithsonian de Investigaciones Tropicales, Cooperación Técnica Alemana, Fundación Dobbo Yala.

Vigouroux, Y., Glaubitz, J. C., Matsuoka, Y., Goodman, M. M., Sanchez G., J., Doebley, J., (2008). Population structure and genetic diversity of New World maize races assessed by DNA microsatellites. *American Journal of Botany, 95*(10), 1240-1253. DOI: 10.3732/ajb.0800097.

Von Thünen, J.H. (1966). *Von Thünen's Isolated State: An English translation of Der Isolierte Staat*. (Originally published in 1826). C.M. Wartenberg (Trans), P. Hall (Ed.). Oxford: Pergamon Press.

Wali, A. (1989). *Kilowatts and Crisis: Hydroelectric Power and Social Dislocation in Eastern Panama*. Boulder, Colorado: Westview Press.

Wali, A. (1993). The transformation of a frontier: State and regional relationships in Panama, 1972-1990. *Human Organization, 52*(2): 115-129.

Watson, J. W. and Eyzaguirre, P. B. (Eds). (2002). Homegardens and in situ conservation of plant genetic resources in farming systems. *Proceedings of the Second International Homegarden Workshop, 17-19 July 2001, Witzenhausen, Gemany*. Rome, Italy: International Plant Genetic Resources Institute.

West, R. C. (1957). *The Pacific lowlands of Colombia*. Ph.D. Dissertation. Baton Rouge, Louisiana: Louisiana State University.

Willemen, L., Scheldeman, X., Soto Cabellos, V., Rafael Salazar, S., and Guarino, L. (2007). Spatial patterns of diversity and genetic erosion of traditional cassava (Manihot esculenta Crantz) in the Peruvian Amazon: An evaluation of socio-economic and environmental indicators. *Genetic Resources and Crop Evolution, 54*(7), 1599-1612. DOI: 10.1007/s10722-006-9172-7.

Wood, D., and Lenné, J. M. (Eds.) (1999). *Agrobiodiversity: Characterization, utilization and management*. Wallingford: CABI.

Yongneng, F., Huijun, G., Aiguo, C., and Jinyun, C. (2006). Household differentiation and on-farm conservation of biodiversity by indigenous households in Xishuangbanna, China *Biodiversity and Conservation*, 3, 347-363. DOI: 10.1007/978-1-4020-5283-5_19.

Zaldivar, M. E., Rocha1, O. J., Castrol, E., and Barrantes, R. (2002). Species Diversity of Edible Plants Grown in Homegardens of Chibchan Amerindians from Costa Rica. *Human Ecology 30*(3): 301-316.

Zimmerer, K. S. (1991). Managing diversity in potato and maize fields of the Peruvian Andes. *Journal of Ethnobiology 11*:23–49.

Zimmerer, K. S. (2007). Agriculture, livelihoods, and globalization: The analysis of new trajectories (and avoidance of just-so stories) of human-environment change and conservation. *Agriculture and Human Values 24*(1): 9-16.

Appendix 1: Overview of research process and community responses to research

This appendix is meant to provide a general overview of the research process, as well as descriptions of some of the responses I received from communities over the course of my research. I have tried to include a number of photographs to help illustrate the methods and to make the chapter as accessible as possible to community members who may read it in the future.

Personal introduction to the study region

I became fascinated with the diverse agricultural systems of Eastern Panama as a master's student in 2003. At the time, I was working with the community of Ipetí-Emberá to quantify carbon storage in the community's *tierra colectiva* (collective lands). My academic training was mainly in ecology, and my interest, initially, in tropical forests. Yet I soon became interested in the array of fruit trees, tubers, and grains that were cultivated by families in the community. I was also intrigued by the cultural context: as its name implies, Ipetí-Emberá is an Emberá community. It is located on the west bank of the Ipetí River, on the edge of the Pan-American Highway. A stone's throw away are the Kuna community of Ipetí-Kuna and the *Latino* community of Ipetí-Colono. Despite their proximity, differences in the identities of each community's inhabitants are proclaimed by differences in dress and house construction. I would often encounter members of each community returning home from work in the fields with a load of agricultural produce on their backs. I began to wonder to what extent less salient aspects of each community's practices differed. Regional discourse surrounding agriculture provided few clues: while imagery promoting forest and wildlife conservation often highlighted the region's cultural diversity, emphasizing the roles of local peoples in conservation, agricultural imagery seemed to focus only on "modern" *Latino* farmers. While I didn't realize it at the time, my

interest in these topics would provide a jumping-off point for the development of my PhD research.

Overview of research methods

The research described in this dissertation was carried out in three main phases: (1) establishment of research agreements and selection of study villages (2006-2008); (2) collection of data in 13 villages, usually over the course of multiple stays in each village (2007-2008); and (3) return visits to all villages to verify data from and present preliminary results, with requests for community feedback (2009). The second and third phases relied on a combination of ecological, ethnobotanical and ethnographic methods. The methods used to obtain particular datasets are described in detail in Chapters 3-5. Here I briefly describe my ethnographic methods, and then provide a general overview of the research process and some responses of community members to it. While these responses differed among individuals, there were some general differences in responses by cultural group, between indigenous and Black communities, and among highway and remote villages.

Ethnographic methods

Throughout the dissertation, I draw not only on quantitative data to interpret results but also on observations made over the course of my research in eastern Panama, and on comments and anecdotes from recorded interviews or field notes. My observations are based on many months of regular interaction and casual conversation with farmers and residents of eastern Panama. Much time was spent walking or boating to fields, and traveling (or waiting to travel) between villages, and much of this time was filled with discussion of local experiences. In

selecting quotes and anecdotes to include in the text, I have tried to communicate views that I regularly encountered, or where indicated, that are especially illustrative of a particular point. Nevertheless, the final product is my construction. All interviews providing quotes were carried out with the consent of interviewees. They were generally recorded, then transcribed in Spanish (when original interviews were in Dulegaya, they were simultaneously transcribed and translated by Domingo Diaz). I translated interviews from Spanish to English.

Establishment of research agreements with indigenous communities

My work with Emberá and Kuna communities began with my contacting regional indigenous congresses that represented various groups of Kuna or Emberá and Wounaan communities in Eastern Panama. Each of the five congresses that I contacted responded favourably to my initial research proposal, and I therefore began developing research agreements with each congress, using as a model a research agreement prepared by Dr. Julie Velásquez Runk for her doctoral work with Wounaan communities (Velásquez Runk 2005). In three cases, once a draft research agreement had been completed, congress leaders asked me to present my research in person at a regional congress meeting, where my research was debated and possible research sites (villages) discussed. In two cases, regional congress leaders pre-approved my proposed research, deciding that it could be included in a briefing of ongoing work at the next regional congress and did not warrant my presence at the meeting. Once approved by the regional congress, I presented my research to village-level congresses where it was again discussed and either approved or rejected (in all but one case the research was approved by village-level congresses). With different congresses, the research proposal and approval process lasted from 1 month to over a year.

Figure A1.1 Discussing and signing research agreements in community and regional congress meetings

Several topics emerged consistently during discussions of my proposed research with regional and local congresses. First, the research theme was generally acknowledged as an important one, and meeting participants spoke of the need for more research addressing crop diversity as a form of cultural heritage. However, at almost all meetings, concerns were also raised surrounding perceived benefits and risks of my proposed research. In terms of benefits, the value of a study ("estudio") was often questioned. Meeting participants argued that what was really needed was a project ("proyecto") that would benefit all of the communities under the umbrella of the congress and fund action on perceived agricultural problems. The benefits I

outlined in my proposal and tentative research agreements (which included preparation of summary reports and educational materials for communities and community schools, support in identifying sources of funding to pursue additional work on this theme, and training and wages for local research crews), were seen as short-term and short-reaching. Some critics pointed out that I would get a doctorate (and perhaps become rich) from this research, while communities would get nothing in the long run.

In terms of risks, two main themes emerged. The first surrounded biopiracy and the possibility that my true interests lay in medicinal plants or in mineral prospecting[40,41]. These concerns were generally assuaged by congress leaders who knew I had already agreed to exclude medicinal plants[42] from the surveys, and who did not believe that I was interested in minerals[43]. The second concern was raised in three remote communities, one Emberá and two Kuna. In all cases the speakers repeated almost the same story and question: the survey methods I was proposing were very similar to a survey carried out by the Spanish [i.e., when Panama was still a Spanish colony], in which people were asked to count their family members, fruit trees, and animals. The Spanish left with this information, and later came back and killed everyone. How could they know that I would not do the same?

---

[40] Interestingly, the possibility of biopiracy surrounding local crop landraces was never raised. I think this may reflect a view of food crops as a public good, in contrast to medicinal knowledge, which is viewed as a private good.
[41] See Velásquez Runk (2005:16) for related discussion.
[42] At one meeting in a Kuna village, a local healer responded to this exchange by pointing out that almost all food crops – "even plantains!" as he said – were also medicines. He pointed out that if I were to truly leave out medicines, I would not be able to carry out the research. He argued that I had might as well be allowed to include medicinal plants, as I would have no knowledge of their uses. In the end, it was decided I would leave out plants that were "primarily" medicinal.
[43] In a community where this became a serious discussion, my research proposal was largely accepted based on the fact that another graduate student, Sarah Dalle, had collected soil samples as part of her masters work around this community almost ten years earlier. During the debate, Dr. Dalle's work was consistently held up as an example of research that had been carried out with utmost respect for local rules and regulations, and which had done no damage to the community. I am indebted to Dr. Dalle for her research ethic, which made my work possible.

The first time I was asked this question I was caught completely off guard. It was asked at the end of a long presentation of my research in a remote Emberá village. Each clause of a tentative research agreement, outlining the proposed research methodology and my commitments to the community as a researcher, had been carefully read aloud by the village president in Spanish, and then translated to Emberá Bed'ea and discussed at length. The question was asked to me by the president himself, who not only had worked with me over the last few days on the tentative research agreement, but had also been my congenial host during my stay in the community. I responded with the honest answer that this was not my intention. The community decided to approve my research.

The same story and question were later translated from Kuna during congress meetings in two Kuna communities. In one, I was refused permission to carry out my research. Three years later, I was fascinated to discover a version of this story, appearing in an early 20th century translation of "The History of the Cuna Indians from the Great Flood up to our Time" by the Kuna Chief, Nele de Kantule:

> *[The Spanish told the Kuna interpreter, Jose Vilacruz:] "You must count up for us the cocoa trees, coffee bushes and alligator pear trees. You must also count up all the fat pigs which you have and the good dogs." […] The Indians began to count up all their possessions, but Uagun [a Kuna man who later became chief because of his wisdom] said to Jose Vilacruz […]: "The Spaniards mean that we must count up our men, women and children and our chiefs so that they will know how to kill us, it is therefore that I never shall count my fruit trees." (Nordenskiöld 1937:207, see also p. 125)*

These experiences revealed the extent to which my research was placed within a long history of "research" projects (see also footnote 38), and the extent of the chasm between my assumptions

on how the research would be perceived, and the ways in which it may have been perceived by participants.

Research agreements with Black communities

In Black villages, because there was no regional leadership structure, the first presentation of my research proposal was at a village-level public meeting. In most communities there was also no clear local leadership, and I therefore organized public meetings either by going door to door the day before the meeting or in some cases with the help of local farmers' associations. At the meetings I presented an outline of my proposed research, and covered all of the topics included in the formal research agreements that I had signed with the regional indigenous congresses. In all cases my research proposal was approved at these first meetings. Local research crew members were also generally nominated at these meetings.
Demands surrounding "project" outcomes were notably absent in Black communities relative to indigenous communities. In fact, people seemed amused that I was interested in historical practices and local landraces, whereas I felt my interest in historical practices was taken for granted in the indigenous communities (though see my note on the novelty of my interest in agriculture, below).

The research agreement process in highway vs. remote communities

People in highway communities were generally more "meeting-ed out", as government and non-governmental organizations regularly visited and held meetings there. In addition, internal meetings were regularly called in indigenous highway communities to address invasions of collective lands. As such, it was harder to organize meetings in these communities. However, once held, the research was generally well received and many fewer concerns were raised surrounding benefits/risks in highway communities relative to remote communities. In most highway communities I was welcomed and treated as "one more" outsider interested in local customs (except in Black communities, where my interest in local practices was more of a novelty, see above). In contrast, in remote communities it was generally much easier to organize a meeting.

In both remote and highway Kuna communities, I presented my research in evening congress meetings. Local congress meetings were held almost every evening in most Kuna communities, and generally alternated between "traditional congresses," in which village leaders sang about Kuna history or morals, and congresses dealing with current events, which were often highly charged discussions about internal community politics or land invasions (Howe 2002). I was only able to speak on evenings when the second type of congress was being held, and at these congresses was rarely given priority to speak. As such, I often sat through one or two evenings of meetings before I was invited to present my research or research update[44]. For these

[44] This may have been in part because I was a woman; in all the nights I attended congress meetings (which were attended by the community's men, women and children) I never heard a Kuna woman speak.

reasons, I was never certain upon arriving in a Kuna community on what day I would begin or continue my research.

The second phase: data collection

I began my research with stays of approximately one month in a village of each cultural group in 2007. During these visits, I participated in household and village-level activities and tried to gain an understanding of agricultural practices and cycles. Through participant observation and interviews I explored the diversity in approaches to agriculture among households, year-to-year variation in agricultural practices, and how agriculture had changed over the lifetime of the farmers with whom I worked. I also began to develop keys that would allow me to standardize crop and fruit tree varieties across villages; in particular I worked with farmers to identify traits used to distinguish among varieties, to collect voucher specimens of each new variety, and to develop a photographic field guide that would be used in subsequent surveys (I added to this guide during all phases of the research).

The second part of the active research was focused on structured surveys of annual fields and agroforests in each of 12 (and eventually 13 villages, see below). During this phase, I worked closely with Domingo Diaz, a Kuna agronomist, and one long-term field assistant (A. Clason or N. Guerrero, who at the time were undergraduate students in Canada and Colombia, respectively), who accompanied me to all villages.

In each village I also worked with local research assistants who had been nominated by community members. I generally worked with the same local research assistants during each visit to a community, and local assistants were actively involved in explaining research to

participating households, mapping fields using GPS units, plant inventories, collecting field histories and voucher specimens, and helping to develop identification keys (Fig. A1.2).

In each of the 12 participating villages, approximately ten households were invited to participate in the study through a lottery that included all known households in the community. These surveys are described in detail in Chapters 3 and 4 and so will not be discussed further here. However, one note regarding gender and segregated knowledge among members of a household is not discussed elsewhere. Field surveys were carried out in the company of one of the field's owners, and I was accompanied by a fairly even split of male and female household heads, depending on who was available to accompany me. In most cases both male and female household heads were present for household interviews before and/or after the field visits. This allowed me to clarify the names and origin of plants that the accompanying family member did not know. When necessary, I returned to households until I could confirm missing information with the pertinent family member. The only times this was not possible was when the original owner of a parcel was deceased or had moved away.

Figure A1.2 Overview of research methods including (a) creating village map of all potential households (participating households were then selected by lottery); (b) household interviews; (c) inventory of an agroforest; (d) training local crews to use GPS to map fields; (e) inventory of an annual-tuber field; (f) collecting soil samples; (g) pressing plant voucher specimens.

Another interesting note, perhaps, is that inventories were rarely as easy as walking through an agroforest and writing down the species that were present. Vegetation grows at such a rate in Eastern Panama that undergrowth that hadn't been thinned in a couple of months would often be at waist or shoulder height. We often needed machetes to reach the trees and shrubs that we were interested in inventorying, and it was often impossible to find the boundary of a

particular agroforest. As a result, it was often necessary for the landowner to walk the perimeter of an agroforest with us (preceded by a crew member with a machete and followed by a crew member with a GPS, and often by another one of us taking notes on the species growing along the edges of the field, so that this was often a slow procession). Overgrown agroforests were havens for wasps and bees (see also Herlihy 1989:198), and my insistence that we include all parts of an agroforest in the inventories resulted in many reminders of this fact.

Community responses to field surveys

To my knowledge, my work was the first in most communities to systematically document agrobiodiversity[45], and people were generally keen to share their knowledge and explain where their seeds, crops and agroforest plants and trees had come from. Many older farmers were open about their concerns surrounding the future of local agriculture and landraces. A number of people commented that this was a theme rarely touched upon by the myriad of projects initiated in the region over the last decades; instead, these projects focused either on introducing mainstream agricultural techniques and improved varieties, or on raising awareness about losses of 'wild' biodiversity, which were often blamed on local agricultural practices.

Old and young community members alike (and particularly women) were very interested in the book of photographs of fruit and crop varieties that I developed and carried with me, and

[45]Ethnobotanical surveys of the Bayano region by Duke (1968) and Bennett (1962) include information on cultivated species and may have been carried out in the study villages. In communities affected by the Bayano Dam, including Akua Yala, Icandí and Ipetí-Kuna, relocation teams did a census of farmers' agroforests in the early 1970s to assess damages prior to flooding, and Wali (1989) also documented commonly cultivated species. In Ipetí-Emberá, a number of research projects have dealt with agriculture and agrobiodiversity directly or indirectly (Sloan 2005; Tschakert et al. 2007; Kirby and Potvin 2007; Potvin et al. 2007; Coomes et al. 2007), and in 2008 undergraduate students from McGill university worked with community members to inventory gardens in the community as a class exercise (Holmes, Pers. Comm.).

conversations over the photos often yielded new information. Similarly, the collection of voucher specimens of maize and rice with which I travelled to communities as part of the process of standardizing landrace (variety) names across villages invariably drew crowds. In fact, when landraces that had been lost from a community were represented among my voucher specimens, I spent considerable energy ensuring that the specimens did not disappear as community members, excited to recuperate landraces they had known in their past, helped themselves to seeds.

Farmers' responses to being invited to participate in the study differed between remote and highway villages. In general, in highway villages and villages where fishing was an important source of income, I was "fit into" farmers' busy schedules. In one highway village in which fishing is an important source of income (Akua Yala), surveys of annual fields coincided with an increase in fish prices, and I could not find enough households willing to accompany me to their fields (most fields were accessed by motorized dugout). I therefore obtained permission from the regional congress to carry out annual field surveys in a neighbouring highway village (Wagandí, also known as Quebrada Calí Kuna), which was added in 2008 as the 13th village of the study. In contrast, in most remote communities people were keen to have the opportunity to earn a days' wage for accompanying me to their farms, and in some cases the fact that I only worked with a sample of households became a point of tense discussion in community meetings.

Third phase – verifying data from 2007-2008 and presenting initial results to communities

The third phase of the research consisted of return visits to each village in 2009. These visits had three purposes: to verify data from 2007-2008 (particularly with respect to crops and fields that might have been planted after our work in the community in 2008); to further standardize landrace (variety) data, and to present preliminary results to communities and request feedback (fig A1.3). As the first two are described in Chapters 3-5, I will briefly describe the third.

The main event of the return visits to each community was a meeting at which I presented preliminary results of the research and asked for feedback. Waterproof posters summarizing preliminary research results were left with each community and with regional organizations (Fig. A1.4), as were written reports which summarized the research program to date and initial results. We also returned information on field sizes and soil characteristics to each farmer with whom we had worked, and local research crew members were provided with certificates attesting to the technical skills they had used in the research, including mapping using GPS and the recording of ecological and social survey data.

Figure A1.3 Verifying and presenting preliminary results. Panels a, b, d, show meetings at which standardized landrace identities were discussed. Panel c shows community members looking at poster (see Fig. A1.4) and other results summaries.

Figure A1.4 Poster distributed to participating communities and local organizations. The poster listed some of the reasons farmers provided for maintaining agrobiodiversity, as well as some often provided by agrobiodiversity scientists. Photos of local crops included crop names in Spanish, Dulegaya (Kuna) and Emberá Bed'ea where possible.

Two communities requested my assistance in preparing agrobiodiversity-related project proposals based on the results of my research. In 2009 I helped the community of Nurra to prepare a proposal for a project focused on revitalizing the production of traditional cacao landraces, and the community of Condoto to prepare a proposal for a project focused on establishing markets for local landraces of rice and maize, combatting a damaging rice pest, and revitalizing the production of non-commercial crop varieties. Both projects were ultimately funded by the Small Grants Programme of the United Nations Development Programme (USD $37,000 received, in total) and at the time of writing were ongoing. Implementation is community-driven.

Appendix 2: Supplementary information for Chapter 2

Appendix 2.1 Interactions with intermediaries: Excerpt from field notes

This excerpt of my field notes was written after an early morning hike out of the remote Kuna community of Nurra with my colleague and translator Domingo Diaz. We had just spent ten days in the community, and were heading back to the city. The hike out of Nurra is gruelling – hilly and muddy. About 4-5 hours after leaving the village, the forests of the Comarca give way to the pastures of *interiorano* farmers. Another hour's walk on a skid trail through these pastures leads to a secondary road and to the hamlet of Pigandicito, which is made up of a few *interiorano* households and a store. From there it is several hours' walk to the Pan-American Highway, or a 45-minute drive by pick-up truck. However, the fee charged by the pick-up truck is sufficient to deter many Nurreños from using it.

> *This morning Domingo and I were joined by almost the entire community in our hike out of Nurra. It was an eye-opening look at the vulnerability of the community's producers. After many phone calls on the community's only pay phone over the last few days, the secretary of the village congress [one of the few fluent Spanish speakers in the community] secured an agreement last night with a potential coffee buyer. The buyer, whose name had been suggested by one of the teachers [non-Kuna] in the community, would meet community members, with their coffee, at 10 am this morning at Pigandicito. Thus, anyone interested in selling their coffee needed to have it out by that time.*
>
> *The news was announced in the congreso meeting last night and appeared to mobilize everyone in the community: most families have several hundred pounds of dried, unshelled coffee stored in bags in their houses, and are desperate to sell it in the next few weeks. The rains have just begun, and it is no longer expected that the logging company with this year's contract will uphold its promise to open a track to the community [in part, payment for the trees the logging companies remove is made by opening a track to the community. The*

track provides a short window (days to weeks) of road access to the community until the rainy season turns the track to impassable mud.]

Almost all hikes out of Nurra begin in the hours before dawn to avoid the heat of the day. Today was no exception. Domingo and I were up at 4 AM and many families had already set out, with every able family member carrying as much coffee as possible. Some hiked with flashlights, others in the dark. The scene at Pigandicito at 10 AM was one of exhaustion. By noon there was still no sign of the coffee buyer. It was a hot clear day and people were starting to get anxious about making it back to the community before dark. Many of the women and children left to hike back in. Pigandicito is outside the Comarca, and very much on the land of "others": Nurreños feel that the colonists who live around Pigandicito are slowly encroaching on Comarca lands, and the colonists feel that the Kuna are slowing the development of the area. Those waiting were reassured by the dryness of the dirt road that connects Pigandicito to the highway – it seemed very passable. In fact, the first men to arrive in Pigandicito had discovered a delivery of sugar, salt, and rice, left on the side of the road by a delivery truck. It had been ordered by a Nurreño store owner, who was hiking out with his coffee and would hike the goods back in.

Domingo and I needed to catch the pick-up truck to the highway for our trip back to the city. We left the large group and walked another 20 minutes to the small store, which is the last stop on the pick-up truck's route. The secretary of the village came with us, and from a point near the store was able to get a cell signal on my phone and call the buyer. The buyer said he had just arrived at the turn-off from the highway, but that he thought the secondary road looked muddy and he didn't want to risk getting stuck. After a heated exchange during which the secretary told the buyer that the road was totally passable, the buyer agreed to try again. At that point the pick-up truck arrived at the store, and Domingo and I got in, wishing the secretary luck. We did not pass the buyer's truck on our drive out.

After a bumpy but dry 45-minute drive we reached the highway. The buyer was stepping into his truck, about to drive off. I ran up and introduced myself and

asked if he would still be driving in to Pigandicito. He shrugged, said that the road was too risky, and that he had some other stops to make along the highway and needed to get on with his day. There was no way for the buyer to contact the community members in Pigandicito to let them know he wasn't coming. Domingo called the pay phone in Nurra, but at 5 hours from Pigandicito no one was going to hike out to tell those waiting what had happened.

[We later learned that the community members waiting in Pigandicito had given up late in the afternoon and had secured permission from a *interiorano* family to leave their coffee under their roof until they could find another seller. The coffee was eventually sold to another buyer at price much lower than had been hoped. My impression of the response of Nurreños to this event was not one of outrage or cynicism, but of resignation: as with their negotiations with the logging company, the community had little recourse when promises were broken except to work with someone else the next year. And often need was great enough that even this wasn't an option.]

Figure A2.1. Top, L-R: Coffee drying in the sun; a Nurreño, loaded with coffee and ready to head out from the village of Nurra at 4 am; a shot in daylight of part of the trail into Nurra; Bottom L-R: girls and women after dropping their loads in Pigandicito; community members awaiting the buyer: the man with the head band is sitting on a delivery of sugar and salt that would be carried back into the community, the bags in the foreground are bags of coffee ready for sale.

Appendix 2.2 Data sources and methods used to create Figure 2.6

The data used to create Figure 2.6 were drawn from the decadal National Agricultural Census (Contraloría de Panamá 1981, 1991, 2001). Data on "Total harvest" and "Total sold" (units for both were hundreds of pounds of unhulled rice or "quintales en cascara") were first summed across all River and all Highway *corregimientos* (counties), then the proportion was calculated based on the ratio. Note that, until 1990, data for indigenous farmers was presented separately; I therefore added totals of indigenous and non-indigenous farmers for 1980 prior to the calculation. Data from difficult-access areas ("*Areas Especiales"*), which is published separately, was omitted for all years. This forced me to exclude from the 2000 dataset five *corregimientos* that were considered Areas Especiales prior to 2000: Cirilo Guainora, Jingurudo, Lajas Blancas, Manuel Ortega, Río Sabalo. Including data from *Areas Especiales* would likely have further lowered the percentage of rice sold in river-accessed areas.

The following *corregimientos* were included in each category:

River - Boca de Cupé, Brujas, Camogantí, Chepigana, Chepillo, Chimán, El Real de Santa María, Garachiné, Gonzalo Vásquez, Jaqué, La Palma, Pásiga, Paya, Pinogana, Púcuro, Puerto Piña, Río Congo, Sambú, Santa Cruz de Chinina, Setegantí, Taimatí, Tucutí, Unión Santeña, Yape.

Highway – Metetí, Agua Fría, Cañita, Chepo, Cucunatí, El Llano, Las Margaritas, Río Congo Arriba, Río Iglesias, Santa Fe, Tortí, Yaviza

Appendix 2.3 Data sources for Figures 2.9 and 2.10

2010 Population Data

The proportion of the population by ethnic group was estimated using data from the decadal National Population and Household Censuses of the Panamanian Bureau of Statistics (Contraloría de Panama). At the time of writing, only preliminary data from the 2010 population census was available online. While data on total population and total population of African descent was available at the district (sub-province level), information on the indigenous population was only available at the level of province (Contraloría de Panama 2010a, b).

Because I was interested in the indigenous populations of the districts of Chepo and Chimán in Panama province, which form the western limit of the Darien Region, I assumed that each indigenous group would represent the same proportion of the total population in these districts in 2010 as it had in 2000.

2010 Estimate of area managed by cultural group

Land ownership in Darién is highly contested, with individuals and collectives of many ethnic groups having submitted competing claims to Panama's National Program for Land Administration (PRONAT 2008). However, some indigenous territories (*comarcas*) are formally recognized by the Panamanian Government. Others (*tierras colectivas*) are physically demarcated by a cleared path of vegetation (particularly in areas where land conflicts are most serious) and have in many cases been mapped as part of ongoing land claims negotiations. The following sections describe the data sources for Figure 2.10

Indigenous *comarcas*

There are three *comarcas* in the Darien Region: Madungandí (Kuna), Wargandí (Kuna), and Emberá-Drua. (Emberá and Wounaan). Based on shapefiles obtained from the National Environmental Authority (ANAM), which include the limits of *comarcas* and *corregimientos* in Panama, 33%[46] of the Darien Region[47] is within an indigenous *comarca*.

Indigenous collective lands

A formal effort to title collective lands (*tierras colectivas*) of Emberá and Wounaan communities in Darién that are not encompassed by the Comarca Emberá-Drua is being led by the Congreso General de las Tierras Colectivas Emberá Wounaan (CGTCEW). I obtained shapefiles of Emberá-Wounaan collective lands in Darién from the CGTCEW in 2009. The shapefiles were the product of a GPS-based mapping effort from 2001 and 2007 that was mainly funded by the Danish Aid agency, Nepenthes (see Hvalkof and Saavedra (2007) for a review of the final phase of this project, as well as critique of some of the mapping methods used). A number of Emberá and Wounaan communities in Panamá Province are also seeking titles for their lands, and I obtained estimates of the areas being claimed as collective lands by these communities from a PRONAT report (2008). While I used the areas from this report for estimates of "proportion of land base used", polygons for these collective lands were digitized from a map produced by the Centre for Native Lands (2004). Together, the shapefiles and report data suggest that an additional 16% of the landscape is within the limits of Emberá-Wounaan collective lands.

---

[46] All area estimates are based on analyses done in ArcGIS v. 9.3.
[47] As defined in Chapter 1.

The Kuna, Emberá and Wounaan communities in the *corregimientos* of Paya and Pucuro in Darién National Park in the northeastern corner of the region are also fighting for collective titles for their lands; however, I did not have the mapped limits for their claims. Each community in this corregimiento was assigned a land area equivalent to the average area claimed by Emberá communities engaged in the collective land claims process (7,160 ha). It is worth nothing that previous efforts to map indigenous subsistence zones in Darién Province identified the entirety of these *corregimientos* as indigenous-use areas (Chapin and Threkeld 2001; Dames and Moore Group 2001).

Lands managed by Black communities

To my knowledge, no maps of collective land claims for Black communities are available. I therefore tried to obtain a preliminary, conservative estimate of the percentage of the region that is managed by Black communities by assuming that Black communities use an area proportional to their population (10%).

Thus, a preliminary estimate suggests that together, Black, Kuna and Emberá-Wounaan communities manage approximately 61% of the total land base of the Darien Region. I would again emphasize that these figures are estimates, and should not be used without further analysis. In particular, my estimates ignore overlap among the areas managed by indigenous and Black communities, overlap with protected areas and parks, contested borders, and land sharing. Nevertheless, they provide a starting point.

Appendix 2.4 Ethnic identities and boundaries: Notes from Tucutí

This section was written to provide insight into how ethnic identities are perceived locally. While much academic work has focused on ethnographies of the Kuna and Emberá, much less work has explored Black identities. As such, I have chosen here to present some perspectives from the predominantly Black community of Tucutí.

Tucutí is a remote community on the Rio Balsas that celebrates its Black heritage. No one in the community with whom I spoke knew when the community had been founded, but the consensus was that it was several centuries old. At different points in its history, the village has served as a base for American and French miners, Latino-run logging companies, Jamaican labourers, and Chinese merchants. The community is surrounded by Emberá and Wounaan communities, with the exception of two Black communities further downriver. As such, many residents who identify as Black also speak proudly of their mixed heritage. For example, one man in his early-40s had a Chinese-Latino maternal grandfather (he said his great-grandfather was from Canton, China), a Black *darienita*[48]-Emberá maternal grandmother, a Black *colombiano*[49] paternal grandfather, and an *interiorana* paternal grandmother. One woman explained: "The Blacks of Darien, the *darienitas*, we are different from the Blacks from other parts of Panama. We are more '*mestizada'* – a mix of Black, Indian, other. And our roots are in Colombia, not the Antilles."

---

[48] *Darienita* is still used by many in Darién to refer to Blacks born in Darién (as opposed to Colombia)

[49] Note the distinction between Panamanian and Colombian Blacks; for much of the 20th century, Black Colombian immigrants (*chocoanos*)were persecuted and considered to be of a lower class than Panamanian-born Blacks (*darienitas*). However, most Colombian migrants were male, and they generally married *darienita* women, so that the distinction has thus blurred over time (Heckadon et al. 1984:83).

Historically, the Blacks of Darien were known as *darienitas* or *libres*, a term carried over from the colonial period to describe communities of freed and escaped slaves (Velásquez Runk 2005:439-440). My impression, which echoes that of Wali (1989:150) for the Bayano region (quoted above), was that in the past, less attention was paid to ethnic titles as a source of identity. However, the rise of cultural politics in the region has made people more aware of the power such titles can provide in struggles for collective rights. The comments of one politically active Tucuteña highlight some of these tensions:

> *Nowadays, everyone wants to be a* darienita*. When I was at a land zoning meeting in Metetí [a major highway town in Darién], this* Santeña *[a Latina woman from the western Panamanian province of Los Santos] stood up, and said "I am* darienita*". She was dressed like a* Santeña*, she spoke like a* Santeña*, but because she was born in Darien now she claims to be a* darienita*.*

Sometime in the 1990s, the title '*Afrodarienita'* begins to appear in reports on the region in reference to the Blacks of Darien (e.g. POTLATCH 1998; Perafan and Nessim 2002). It is absent in reports published in the 1970s and early 1980s (e.g. Heckadon Moreno and McKay 1984). One woman, the coach of the award-winning Conjunto Folklorico de Darien, which performs dances to *Bullerengue* and *Bunde* music (traditionally Black styles of music) in national competitions, responded to my use of the term during an interview with this statement:

> *In the past, we didn't use that name,* afrodarienita*. Even today the elders don't accept it. But those women at the university, the women who study there, they say that is our history, that we're* afrodarienitas*, because we belong…because our roots are African. They say that our dances are from there, that kind of thing. So*

that's that. Before, no one tried to call us afrodarienitas, *but now they want to impose that on us.*

Today, Black Tucuteños identify politically as belonging to '*la etnia Negra'*, or the Black ethnicity. This terminology is used interchangeably with '*Afro-descendiente*' (Afro-descendant) by the Panamanian State. For example, the "Definitions and Explanations" of the 2010 Census states that respondents could specify their ethnicity as *Negro(a); Negro(a) colonial; Negro(a) antillano(a); Otro* (in English: "Black", "Colonial Black," "Antillean Black," or "Other"; Contraloría de Panama 2010c; Appendix 2.4). However, the census results are presented under the following categories: *Afro-colonial; Afro-antiliano(a); Afro-panameño(a); Afro-descendiente-No Declarado; Otro* (Contraloría de Panama 2010a). Appendix 2.5 summarizes the responses of Darién Blacks to these categories.

Maintaining boundaries: Emberá – Black relations in Tucutí

Many Blacks in Tucutí continue the tradition of acting as a godparent to Emberá children [see discussion of *compadrazgo* in Chapter 2], and Emberá families often send their teenaged children to live with Black families so that they can attend school in Tucutí[50]. From what I observed, billeted children are expected to help out around the house and in the fields, and in return are provided with food and lodging. For example, the two Emberá boys who were staying at the house I lived in in Tucutí would often head to my host's farm after school to thin the

[50] This practice of sending children to live with Black families so that they could attend school and learn Spanish was also reported among Kuna living in the Tuira river basin in 1960s (Pagnini 1970:88).

underbrush and weeds, or to harvest plantains or tubers for family meals. Otherwise, the boys used the house as though it was theirs and participated in meals as part of the family.

While most people with whom I spoke said that Black-indigenous relations had been friendly in recent memory, certain tensions were also revealed in discussions with both Emberá and Black households. These tensions seemed to relate first to the economic disparities between the two groups, and second to the national discourse surrounding indigeneity, which excludes Blacks.

From an economic standpoint, the Emberá households of Tucutí are generally poorer than the Black households. In part this reflects their shorter time of establishment in the community, and in part it reflects the longer integration of Blacks into the mainstream Panamanian economy, and the benefits this has provided in terms of salaried positions, remittances from children in the city, etc. In talking with Emberá households as part of my household surveys, several mentioned that they felt like second-class citizens in the town: "Now that we have the middle school [grades 7-9], the Emberá population is growing, but the benefits that come to the community are not shared with the Emberá. Only the Blacks with money get the benefits." However, the Black population also harbours frustration about the lack of rights afforded to them because they are not considered "indigenous". The establishment of the boundaries of Darien National Park is one example (the park extends east of Tucutí to the Colombian border, encompassing all of the upriver Emberá communities).

> *When they determined the limits of the park, the* representante[51] *[elected official] was indigenous. The indigenous groups thought the park would serve as a sort of Comarca. So rather than set the Park limits beyond the last [Tucuteño's] worked land, they made the park as big as possible and set the limits much closer to Tucutí. Nupaganti [a tributary of the Rio Balsas] is where the last parcel [of worked Tucuteño land] is, but they set the park limits at the Rio Sabalo [much further downriver].*

Frustration on the part of Blacks in Darién with regard to their exclusion from certain planning activities because they are not considered "indigenous" has been reported by others working in the region (e.g. POTLATCH 1998).

[51] A 'representante' is equivalent to a representative in the United States and is less powerful than a 'diputado' (equivalent to a U.S. senator).

Appendix 2.5 Definitions of ethnic categories from national census

The "Definitions and Explanations" section of the 2010 National Population and Household Census states that respondents of African descent were provided with the opportunity to identify their "sub-ethnic group" as *Negro(a); Negro(a) colonial; Negro(a) antillano(a); Otro* (in English: "Black", "Colonial Black," "Antillean Black," or "Other"; Contraloría de Panama 2010c; see below for definition of each category). However, the census results are presented under the following categories: *Afro-colonial; Afro-antiliano(a); Afro-panameño(a); Afro-descendiente-No Declarado; Otro* (Contraloría de Panama 2010a,b,c).

Approximately 2/3 of Blacks in the Darién Region identified as *Afro-panameño* (Afro-Panamanian) in the 2010 census (Table A2.1). Interestingly this the only category without a definition in the "Definitions and Explanations" section of the census results (Contraloría de Panama 2010c).

Table A2.1 Declared "sub-ethnic group" of Darién Blacks in the 2010 National Population and Household Census (Contraloría de Panamá 2010b).

Sub-region within Darien Region[1]	Total Afrodescendant population	Percent identifying as "Afro-colonial"	Percent identifying as "Afro-antillean"	Percent identifying as "Afro-panamanian"	Percent identifying as "Other"	"Not declared"
Darien Province	8,064	23%	6%	66%	5%	1%
Chepo and Chiman Districts (Panama Province)	3,327	29%	10%	55%	3%	3%
Comarca Emberá-Drua	200	18%	6%	61%	7%	9%

[1]See map of Figure 1.6 for location of each of these subregions

Excerpts from the "Definitions and Explanations" section of the 2010 National Population and Household Census (Contraloría de Panamá 2010c). I have translated the definitions into English, but include the original Spanish version afterwards for reference.

Indigenous population

An indigenous informant is one who claims to belong to an aboriginal group, independent of the locality in which they were registered. In this sense, indigenous peoples may be encountered in any geographic area of the country.

Afrodescendant population

Black or afrodescendant: refers to a social group originating in Africa, initially brought to America by Europeans, and who divide themselves into sub-ethnic groups in accordance with the different periods during which they arrived on the isthmus.

a. Colonial black: Descendant of African slaves brought to the isthmus during the Spanish Conquest. The descendants of these slaves can be found in the central provinces, in areas like Natá, Parita and Monagrillo: and in Chiriquí, in areas like Puerto Armuelles and Alanje. In Colón province in areas such as Costa Arriba and Costa Abajo. In Panamá province they are found in Pacora, San Miguel and Chepo.

b. Antillean black: Descendant of West Indian workers, French-speaking, English-speaking or otherwise, who arrived in Panama principally during the construction of the Trans-isthmian Railway, the Panama Canal at the end of the 19th century, and the North American canal. They are most often located in Panama and Colon cities and in the province of Bocas del Toro.

c. Black: Anyone with ancestors who were descendants of black slaves or colonists, and/or descendants of Antillean blacks or Afro-antilleans who spoke English, French or other

languages, migrants from the various periods of national development, who select this option for their self-identification.

d. Other: Any other black group or afro-descendant, not included in the previous categories.

[NOTE: The actual census data includes a fifth category: Afro-panameño (Afro-panamanian), which is not defined here]

Original Spanish text:

Población indigena

Se consideró como Indígena todo aquel informante que declarara pertenecer a algún grupo aborigen independientemente de la localidad donde fue empadronado. En tal sentido, se puede encontrar población indígena en cualquier área geográfica del país.

Población afrodescendiente

Negro o afrodescendiente: Se refiere al grupo social proveniente de África traídos inicialmente por los europeos a América y que se dividen en subetnias, de acuerdo con los diferentes períodos en que llegaron al Istmo.

a. Negro(a) colonial: Descendiente de los esclavos africanos traídos al istmo durante la colonización española. Se pueden identificar a los descendientes de estos últimos en las provincias centrales, en áreas como Natá, Parita y Monagrillo: y en Chiriquí, en áreas como Puerto Armuelles y Alanje. En la provincia de Colón en áreas como Costa Arriba y Costa Abajo. En la provincia de Panamá se ubican en Pacora, San Miguel y Chepo.

b. Negro(a) antillano(a): Descendiente de los trabajadores antillanos de habla francesa, inglesa, u otras lenguas que llegaron a Panamá, principalmente durante la construcción del Ferrocarril Transístmico, el Canal Francés a fines del siglo XIX, y el Canal Norteamericano. Se les localiza mayormente, en áreas de las ciudades de Panamá y Colón y en la provincia de Bocas del Toro

c. Negro(a): Aquella persona con ancestros descendientes de los negros esclavizados o coloniales, y/o descendientes de antillanos negros o afroantillanos de habla inglesa, francesa u otras lenguas, migrantes en los distintos períodos del desarrollo nacional, que seleccionó esta opción para su autoidentificación.

d. Otro: Algún otro grupo negro o afrodescendiente, no incluido en las categorías anteriores

[NOTE: The actual census data includes a fifth category: Afro-panameño (Afro-panamanian), which is not defined here]

Appendix 3: Supplementary information for Chapter 3

Appendix 3.1 Soil sampling and characterization

Soil samples were collected in one rice or maize field of each participating household in each study village, with a few exceptions due to logistical difficulties. We decided to collect samples only from fields that were planted predominantly in rice and/or maize to reduce variability resulting from the contrasting management of different field types (e.g. perennial vs. annual crop fields). Five soil samples were collected from each field using a core that was 5 cm diameter and 20 cm long. The cores were collected in five distinct areas of each field and then mixed together and stored in a bag that was left open except during transport so that the soils could air dry. Upon their arrival at the Smithsonian Tropical Research Institute in Panama City (usually within 5 days of collection), the samples were placed in trays and left to air dry indoors. Only when soils were completely dry were they sealed in bags for storage.

Analyses of pH, organic matter, and nutrient and micro-nutrient levels were carried out by the soil lab of the Instituto de Investigación Agropecuario de Panama (IDIAP), Panama's Agricultural Research Institute. Levels of phosphorus, potassium, manganese, iron, copper and zinc were determined using the Mehlich 1 method[52]. Levels of calcium and magnesium were estimated using Atomic Absorption Spectrometry, levels of aluminum through the NaOH titration method, and pH using a potentiometer. Organic matter was estimated by wet oxidation using the modified Walkley Black method. Median values for each village of each soil variable are presented in Table A3.1

[52] When used on limestone soils, Mehlich 1 may dissolve CaPO4, giving overly high P values. This may explain the high phosphorus values in these soils (B. Turner, Pers. Comm.).

One advantage of having the soils analyzed by IDIAP is that the methods of analysis were identical to those regularly used in determining the fertilizer needs for agricultural soils in Panama. The Institute's list of "Critical levels of nutrients for agriculture" are presented in table A3.2 (IDIAP 2006:4). Note that fertilizers were not used on any of the fields in which soils were sampled. IDIAP's "critical levels" provide an indication of areas in which farmers' decisions of what to plant may be most influenced by soil conditions.

Table A3.1. Median soil values from sampled annual fields in each village. Village codes correspond to those on map in Figure 1.8. See table A3.3 for agricultural relevance of these values.

Soil property	Abbre-viation	B1	B2	E1	E2	K1b	K2	B3	B4	E3	E4	K3	K4
PH	pH	6.05	6	5.6	6.75	6.5	6	5.4	6.3	6.3	6.5	7.2	6.05
Organic matter (%)	M.O.	4.45	4.6	6	4.7	4.8	5.5	4.7	5.2	4.7	7.1	6.8	5.45
Phosphorus (Mg/l)	P	24	17	24	46.5	65	11	1.125	14	2	2	14	0.25
Potassium (Mg/l)	K	196	168	196	244	274	137	82.5	184	111.5	196	184	113
Calcium (Cmol/kg)	Ca	37	30.5	18.2	40.35	32.5	34.3	16.8	30.5	31.3	17.7	37.1	19.8
Magnesium (Cmol/kg)	Mg	6	5.3	4	5.65	5.3	5.5	7.4	6.2	7.75	8	4.1	5.95
Aluminum (Cmol/kg)	Al	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Manganese (Mg/l)	Mn	27	33	49	21.5	19	34	44	35	27.5	56	43	43.5
Iron (Mg/l)	Fe	12.5	12	12	8.5	20	13	17	16	19.5	17	6	14.5
Zinc (Mg/l)	Zn	4	5	3	4	4	6	2.5	4	3	4	1	3
Copper (Mg/l)	Cu	1	1	0.25	0.625	0.25	1	2.5	1	2	1	0.25	1

Table A3.2 Critical levels of nutrients for agriculture (IDIAP 2006). Units are the same as those in Table A3.2. "Bajo" = low, "medio"= medium, "alto"= high, "muy ácido"=very acidic, "acido"=acidic, "poco acido"=mildly acidic; "neutro"= neutral; "alcalino" = alkaline.

Elemento	Valores	Interpretación	Elemento	Valores	Interpretación
P	0 – 18	Bajo	Fe	0 - 25.0	Bajo
	19 –54	Medio		25.1 – 75.0	Medio
	55 +	Alto		75.0 +	Alto
K	0 – 44	Bajo	Mn	0 – 14.0	Bajo
	45 –150	Medio		14.1 – 49.0	Medio
	151 +	Alto		49.1 +	Alto
Ca	0 – 2.0	Bajo	Zn	0 – 4.0	Bajo
	2.1 - 5.0	Medio		4.1 – 14.0	Medio
	5.1 +	Alto		14.1 +	Alto
Mg	0 – 0.6	Bajo	pH	4.0 – 5.1	Muy ácido
	0.7 - 1.5	Medio		5.2 - 5.9	Acido
	1.6 +	Alto		6.0 – 6.9	Poco acido
Al	0 - 0.05	Bajo		7.0	Neutro
	0.06 - 1.0	Medio		7.1 +	Alcalino
	1.0 - 3.0	Alto	M.O	0 – 2.0	Bajo
Cu	0 - .2.0	Bajo		2.1 – 6.0	Medio
	2.1 - 6.0	Medio		6.1 +	Alto
	6.1 +	Alto			

Analyses of soil differences among villages

To explore whether there were systematic differences in the soils of villages of different ethnic groups or with remote vs. highway access, a global test for the median values of all soil variables (pH, organic matter, P, K, Mg, Ca, Al, Mn, Zn, Fe, Cu). We used a multivariate comparison, ADONIS, in which the independent variables were village ethnicity and highway access. The test revealed significant differences in soil characteristics with village location relative to the highway (R2=0.22, p=0.04), but not with village cultural identity (R2=0.10, p=0.85). In view of this result, each soil variable was then tested for significance with village location relative to the highway using a two-sample t-test. These tests revealed that two nutrients were responsible for differences among remote and highway villages: phosphorus was significantly higher in the soils of highway villages ($t_{6.021}$= 2.930, p = 0.03), and zinc was significantly higher in the soils of remote villages ($t_{9.943}$= 2.284, p = 0.04).

Appendix 3.2 Rice, maize and *Musa spp.* landraces included in multivariate analyses

The following tables present the Pearson correlation coefficients for the proportion of households maintaining each landrace of maize, Musa spp., and rice in villages of each ethnicity and in highway vs. remote villages. Landraces are those encountered in more than one village. For each crop, we only consider relationships of landraces to independent variables that described a significant portion of the variation in that crop in PERMANOVA analyses (ethnicity for maize and Musa spp.; ethnicity and highway access for rice; Table 3.1 in Chapter 3).

While the statistical significance of the Pearson correlations should be viewed with caution because of the large number of comparisons, the value of the correlation coefficient gives an indication of a landrace's tendency to be planted by a specific cultural group or in remote vs. highway villages. Significant correlations are starred (alpha = 0.05). Correlation coefficients greater than 0.45 are highlighted in bold to draw attention to landraces that were most commonly associated with particular cultural groups or found in remote or highway villages.

Table A3.3 Pearson correlation coefficients of maize landraces included in the multivariate analyses in Chapter 3.

Crop or landrace (common names)	Villages (n)	**Pearson's r Highway villages**	**Pearson's r Black villages**	**Pearson's r Emberá villages**	**Pearson's r Kuna villages**	**Voucher specimen[2]**
Planta baja	10	0.25	0.36	-0.48	0.11	498
Calilla	10	0.26	0.01	**0.60***	-0.60*	1017, 496
Calilla x Planta baja[1]	3	0.19	0.08	0.32	-0.40	499
Tuzón	3	-0.33	**0.74***	-0.37	-0.37	1019, 1020
Blanco duro	2	-0.08	-0.31	**0.62***	-0.31	24
Purwa ob	2	-0.17	-0.29	-0.29	**0.57**	1011
Ob nunut	2	-0.25	-0.25	-0.25	**0.50**	921
Dule ob sichit	5	-0.48	-0.38	-0.27	**0.65***	1005
Dule ob coroguat	4	0.13	-0.42	-0.42	**0.84***	1006
Dule ob sipuguat	2	-0.27	-0.24	-0.24	**0.47**	1004
Dule ob parpat[1]	2	-0.18	-0.28	-0.28	**0.57**	335

[1]Crosses were treated as separate landraces if their seed stocks were managed as such. In the cases of Calilla x Planta Baja and Dule ob parpat (which is a cross of the other landraces of dule ob), farmers recognized the seeds as a cross but maintained the crossed landrace from year-to-year.

[2]Example specimen in holding at Herbarium of Universidad Nacional de Panama

Table A3.4 Pearson correlation coefficients of rice landraces included in the multivariate analyses in Chapter 3.

Crop or landrace (common names)	Number of villages in which encountered	**Highway villages**	**Black villages**	**Emberá villages**	**Kuna villages**	**Voucher specimen[1]**
Colombiano	10	-0.07	0.18	**0.53**	**-0.71***	577
Ligero colorado	9	-0.22	0.22	0.26	-0.48	1040
Ligero blanco delgado	8	-0.38	0.15	0.44	**-0.58***	1037
Rexoro blanco	7	**0.68***	-0.28	0.26	0.02	537
Gallote	4	0.12	-0.20	**0.64***	-0.43	1031
Plata de 6 meses	4	-0.28	-0.40	**0.80***	-0.40	1029
Rexoro colorado	4	0.18	-0.33	0.39	-0.06	1055
Bolita	3	-0.34	-0.37	**0.74***	-0.37	1021
Mexicano	3	0.50	**0.60***	-0.24	-0.36	1058
MIDA	3	0.48	-0.34	0.08	0.27	1044
Picaporte	3	-0.30	0.49	-0.16	-0.33	1062
Burboni	2	-0.34	0.40	-0.15	-0.24	1039
Diente de gato	2	-0.24	-0.25	**0.51**	-0.25	23
Dule oros kinnit	2	-0.22	-0.27	-0.27	**0.53**	1043
Dule oros sipu	2	0.10	-0.31	-0.31	**0.61***	1042
Gwaimaderreget	2	-0.06	-0.31	0.22	0.09	928
Negro	2	-0.19	-0.28	**0.56**	-0.28	17
Niño	2	-0.36	-0.26	**0.51**	-0.26	1023
Urinda	2	-0.25	-0.25	0.50	-0.25	1035

[1]Example specimen in holding at Herbarium of Universidad Nacional de Panama

Table A3.5 Pearson correlation coefficients and descriptions of *Musa spp*. landraces included in the multivariate analyses in Chapter 3. We did not collect voucher specimens of Musa landraces, however we documented landrace characteristics with photographs. We are in discussion with the Smithsonian Tropical Research Institute's Bioinformatics team regarding the hosting of these photos on STRI's Bioinformatics website.

Crop or landrace (common names)	Number of villages in which encountered	**Highway villages**	**Black villages**	**Emberá villages**	**Kuna villages**
Primitivo	12	-0.21	-0.42	-0.17	**0.58***
Cuadrado	12	0.27	-0.29	-0.01	0.30
Guineo	12	0.09	-0.37	-0.17	**0.54**
Plátano enano	12	**0.57**	-0.21	-0.21	0.42
Platano	12	0.25	-0.21	0.37	-0.16
Quiñentón	11	0.35	-0.06	-0.07	0.13
Silip/dominico	11	-0.06	**-0.68***	0.11	**0.57**
Mata burro rojo	10	**-0.57**	-0.28	-0.30	**0.58***
Manzano	10	-0.24	-0.23	-0.34	**0.58**
Mata burro verde	10	-0.49	-0.49	-0.23	**0.72***
Guineo enano	9	-0.01	-0.19	-0.39	**0.58***
Felipillo	9	0.07	**-0.68***	-0.16	**0.83***
Plátano guineo	8	0.36	0.47	-0.04	-0.43
Dominico negro	5	-0.37	-0.31	-0.50	**0.82***
Plátano blanco	4	0.47	0.41	-0.07	-0.33
Sino purreget	4	-0.15	-0.42	-0.42	**0.85***
Plátano tallo rojo	4	-0.30	-0.41	-0.41	**0.82***
Sin-ol-lo	4	-0.13	-0.48	-0.48	**0.97***
Wayakir arat	4	-0.05	-0.50	-0.50	**0.99***
Waimadun tallo negro	4	-0.23	-0.45	-0.45	**0.90***
Keskesu	4	-0.28	-0.42	-0.42	**0.84***
Mas tukor silip	4	-0.13	-0.44	-0.44	**0.89***
Guineo pajarito	3	**-0.56**	0.13	0.26	-0.39
Siga mas	2	-0.38	-0.27	-0.27	**0.54**

Appendix 3.3 Ranking of dietary importance of food crops

We asked households in each village to rank crops based on their importance in the household diet. We used cards displaying pictures of the food portion of each crop (e.g., the tuber) and worked with household heads to arrange them from most to least important. Nine crops were included in the dietary importance ranking: rice, maize, taro, cassava, banana, plantain, *cuatrofilo*, yam, and *ñampi.* Often, there were ties among crops. In these cases we assigned the tied crops the median rank (e.g., three crops ranked by a household as most important were assigned a rank of "2").

We did not direct respondents to provide importance values for a particular time of year (e.g., dry season, rainy season pre-harvest, rainy season post-harvest), and so the rankings represent respondents' interpretation of "dietary importance". However, there was no bias in the time of year in which we worked with villages of particular ethnic groups or in remote/highway villages.

Our objective was to test whether more landraces were maintained of crops that were more important in the household diet. The landrace richness data grouped banana, plantain, and *cuatrofilo* landraces as "*Musa spp.,"* and yam and *ñampi* landraces as "yams" (discussed in Chapter 3 Methods). We did this because, in some communities, it was difficult to assign particular landraces to one category or the other, and we felt that grouping landraces in this way increased the robustness of our inter-village comparisons. As a result, it was necessary for us to assign one dietary importance rank to each of these groupings. We used the highest rank for the group (e.g., highest of banana, plantain, or *cuatrofilo*; and highest of yam or ñampi), because the importance of a food would not be reduced by including other landraces in its definition. We then calculated average ranks

for each crop in each village, and used these ranks in the Random Coefficient Regression analysis described in the Methods of Chapter 3.

The average ranks for all nine foods in villages of each ethnic group and with remote vs. highway access are presented in Table A3.6. The same data are presented in table A3.7, with foods grouped as they were for the Random Coefficient Regression analysis (Chapter 3).

Table A3.6. Average rank of nine crops in terms of their dietary importance in remote and highway villages of each ethnic group. The highest rank.is 1, lowest rank is 9.

Rank	Black		Embera		Kuna	
	Highway	Remote	Highway	Remote	Highway	Remote
1	Rice	Plantain	Rice	Rice	Plantain	Banana
2	Plantain	Rice	Plantain	Plantain	Banana	Maize
3	Cassava	Maize	Cassava	Maize	Cuatrofilo	Plantain
4	Banana	Cuatrofilo	Banana	Banana	Cassava	Cuatrofilo
5	Cuatrofilo	Cassava	Cuatrofilo	Cuatrofilo	Rice	Cassava
6	Yam	Yam	Maize	Cassava	Maize	Rice
7	Ñampi	Ñampi	Yam	Ñampi	Yam	Taro
8	Maize	Banana	Ñampi	Yam	Taro	Yam
9	Taro	Taro	Taro	Taro	Ñampi	Ñampi

Note: Banana, Plantain and Cuatrofilo are all groups of Musa spp.; Yam and Ñampi are two groups of Dioscorea spp.

Table A3.7. Average rank of six crops in terms of their dietary importance in remote and highway villages of each ethnic group. The data are aggregated from those presented in table A3.8 as follows: 'Musa' includes banana, plantain and cuatrofilo, and 'yam' includes yam and ñampi. The highest rank.is 1, lowest rank is 6.

Rank	Black		Embera		Kuna	
	Highway	Remote	Highway	Remote	Highway	Remote
1	Rice	Musa	Rice	Rice	Musa	Musa
2	Musa	Rice	Musa	Musa	Cassava	Maize
3	Cassava	Maize	Cassava	Maize	Rice	Cassava
4	Yam	Cassava	Maize	Cassava	Maize	Rice
5	Maize	Yam	Yam	Yam	Yam	Taro
6	Taro	Taro	Taro	Taro	Taro	Yam

Appendix 4 Agroforest species excluded from analyses

Ornamental species were excluded from our surveys for logistical reasons. Medicinal species were excluded from our surveys at the request of participating communities. We also excluded "variably cryptic species," or species that were more likely to be encountered in some sites than others, despite being present in all sites. In particular, some species were more cryptic in one sampling season than another (e.g. small herbs were rare in the dry season, but visible in the wet season, and we sampled in both seasons), while other species were predominantly planted outside of agroforests in some villages but not others (e.g., pineapple and sugarcane in small monoculture patches, and aromatic herbs in pots in or around peoples' homes; Fig. A4.1). The species excluded are listed in Table A4.1.

Fig A4.1. Examples of variably cryptic species and species excluded from analyses: (a) a patch of pure pineapple, that was not attached to an agroforest and therefore would have been missed in agroforest surveys (the field's owner, I. Sabugara, appears in the photograph); (b) ornamental plants, such as those in this homegarden, were excluded from surveys; (c) example of aromatic herbs being grown in an easily-surveyed "zotea", or raised bed, in a homegarden; (d) example of aromatic herbs and seedlings being grown in the space between two houses, where they might easily have been missed and therefore excluded from a homegarden survey; (e) ginger, which often loses its above-ground vegetation in the dry season.

Table A4.1. Species excluded from comparative analyses. Species indicated with a "*" were surveyed in some villages using a questionnaire; please contact the author if interested in these data.

	Species	Spanish Name	English Name	Life form	Dominant use	Origin	Place where normally cultivated
Aromatic herbs and seasonings							
	Allium sativum	Ajo	Garlic	Herb	Seasoning	Old World	Pot or *zotea* (raised bed)
*	*Allium sp.*	Cebollina	Green onion	Herb	Seasoning	Old World	Pot or *zotea* (raised bed)
	Eryngium foetidum	Culantro	Culantro	Herb	Seasoning	Neotropics	Homegarden, unmanaged areas (semi-wild)
*	*Ocimum spp.*	Albahaca	Basil	Herb	Seasoning	Old World	Homegarden
*	*Plectranthus amboinicus*	Oregano	Oregano	Herb	Seasoning	Old World	Pot or *zotea* (raised bed)
*	*Zingiber officinale*	Jengibre	Ginger	Herb	Seasoning	Old World	Homegarden, pot, monoculture patch
	NA	Poleo	NA	Herb	Seasoning	NA	Pot or *zotea* (raised bed)
Food species							
*	*Ananas cosmosus*	Piña	Pineapple	Herb	Fruit	Neotropics	Monoculture patch, homegarden
	Arachis hypogaea	Mani	Peanut	Herb	Nut	Neotropics	Agroforest
	Citrullus lanatus	Sandia	Watermelon	Herb	Fruit	Old World	Homegarden, annual field
*	*Cucumis sativus*	Pepino	Cucumber	Herb	Fruit	Old World	Homegarden, annual field
*	*Cucurbita sp.*	Zapallo	Squash	Herb	Fruit	Neotropics	Homegarden, annual field
*	*Ipomoea batatas*	Camote	Sweet Potato	Herb	Tuber	Neotropics	Homegarden, annual field
	Lycopersicum esculentum	Tomate	Tomato	Herb	Fruit	Neotropics	Homegarden, annual field
*	*Saccharum sp.*	Caña	Sugar cane	Grass	Sweetner	Old World	Monoculture patch, homegarden
	NA	Canela	Cinnamon vine	Herb	Tea	NA	Homegarden
	NA	Espinaca	Spinach	Herb	Leafy green	NA	Homegarden
	NA	Te de Monte	Forest tea	Herb	Tea	NA	Homegarden
	NA	Valeriana	NA	Herb	Tea	NA	Homegarden
Species with non-dietary household uses							
*	*Curcuma longa*	Yuquilla	Yellow dye/tumeric	Herb	Dye	Old World	Homegarden
	Mucuna pruriens	Mucuna	Mucuna	Herb	Fertilizer	NA	Homegarden
	NA	Hoja fregar	Scrubbing leaf	Herb	Scrub dishes	NA	Homegarden
*	NA	Tinta roja	Red dye	Herb	Dye	NA	Homegarden
*	NA	Tinta verde	Green dye	Herb	Dye	NA	Homegarden
Important food crops (analyzed in Chapter 1)							
	Colocasia spp.	Papa China	Taro, dasheen	Herb	Tuber	Old World	Annual/Tuber field, homegarden
	Dioscorea spp.	Ñame	Yam	Herb	Tuber	Old World	Annual/Tuber field, homegarden
	Dioscorea trifida	Ñampi	Yam, Yampee	Herb	Tuber	Neotropics	Annual/Tuber field, homegarden
	Manihot esculenta	Yuca	Cassava	Shrub	Tuber	Neotropics	Annual/Tuber field, homegarden
	Oryza sativa	Arroz	Rice	Grass	Grain	Old World	Annual field, homegarden
	Xanthosoma spp.	Otoe	Taro, malanga	Herb	Tuber	Neotropics	Annual/Tuber field, homegarden
	Zea mays	Maíz	Maize	Grass	Grain	Neotropics	Annual field, homegarden
***Included in presence/absence questionnaire**							