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From Farm to Forest: Factors Associated with Protecting and Planting Trees in a Panamanian Agricultural Landscape

Photo 1.
Agricultural land encroaching on Cerro Hoya National Park.
Photograph U. Nagendra.

RÉSUMÉ

DE LA FERME À LA FORÊT: FACTEURS ASSOCIÉS À LA PROTECTION ET LA PLANTATION D'ARBRES DANS UN PAYSAGE AGRICOLE DU PANAMA

Les fragments résiduels de forêt sèche sur la péninsule d'Azuero au Panama sont représentatifs d'un des types forestiers les plus menacés à l'échelle de la planète, et qui a quasiment disparu au Panama. Dans de telles zones de production agricole et d'élevage, les arbres hors forêt sont indispensables à la connectivité du paysage, à la survie des espèces autochtones et au maintien des services écosystémiques associés à ces fragments forestiers résiduels. Les enquêtes que nous avons menées auprès de gestionnaires terriens dans la province de Los Santos au Panama montrent que les agriculteurs dans cette région protègent et plantent des arbres pour des motifs différents. Alors qu'ils protègent les arbres pour plusieurs raisons (comme source de bois, de fruits, de fourrage et d'ombre, et pour leur protection de l'eau), ils en plantent surtout pour produire du bois et des fruits, qui leur assurent des revenus tangibles. Par ailleurs, dans cette région, les sites où les arbres sont plantés sont plus diversifiés et plus spécifiques que les sites où les arbres sont protégés. Six essences sont fréquemment utilisées pour la création de haies vives au Los Santos, et les propriétaires de ces haies gardent souvent des arbres utiles pour le fourrage et le bois à proximité. La gestion coopérative des haies vives pourrait ainsi devenir un moyen efficace pour augmenter la connectivité des paysages dans cette région où ils sont fortement fragmentés. Nos résultats indiquent que les agriculteurs de Los Santos plantent des arbres ou les protègent dans leurs terres productives pour des raisons très différentes. Ces différences entre leurs motivations ont des implications importantes qui doivent être prises en compte dans les approches visant à accroître la couverture forestière dans la région. Les projets visant à promouvoir la régénération naturelle des forêts encouragent les agriculteurs à protéger les arbres sur leurs terres, et pourraient mieux réussir en mettant l'accent sur les services écosystémiques intangibles tels que la protection de l'eau à moindre coût. À l'inverse, les projets visant à promouvoir la plantation d'arbres doivent en démontrer les bénéfices économiques tangibles.

Mots-clés : reboisement, régénération, haie vive, agriculteurs, pâturages, eau, bois, fruits, Panama.

ABSTRACT

FROM FARM TO FOREST: FACTORS ASSOCIATED WITH PROTECTING AND PLANTING TREES IN A PANAMANIAN AGRICULTURAL LANDSCAPE

The small forest patches of tropical dry forest that remain on the Azuero peninsula of Panama represent part of one of the most critically endangered forest types worldwide and one that has been almost entirely eliminated in Panama. In a productive agricultural and cattle-ranching landscape, trees outside the forest are essential to increasing the connectivity of the landscape, the survival of native species, and the ecosystem services provided by these remaining small forest patches. Based on surveys conducted with land managers from Los Santos province, Panama, we conclude that farmers in this region protect and plant trees on their productive land for different reasons. While farmers protect trees for a wide range of reasons (including timber, fruit, animal fodder, shade and water protection), they plant them primarily for timber and fruit, both uses that produce a tangible economic benefit. Land managers from Los Santos also plant trees in a more diverse and specified set of places than those in which they protect them. Six tree species are commonly used for live fences in Los Santos, and many live fence owners allow trees useful for timber or animal fodder to grow near the fence. Cooperative live fence management may be a feasible way to increase landscape connectivity in the highly fragmented landscape of the region. Our results indicate that the reasons why land managers in Los Santos plant trees are very distinct from the reasons why they protect trees within their productive land. These differences in reasons for protecting and planting trees have important implications that should inform the approaches of programs hoping to increase regional forest cover. Projects promoting natural forest regeneration encourage farmers to protect trees on their land and may be successful through emphasizing intangible ecosystem services such as low-cost water protection strategies. In contrast, projects that promote the planting of trees must demonstrate their tangible economic benefits to land managers.

Keywords: reforestation, regeneration, live fence, farmers, pasture, water, timber, fruit, Panama.

RESUMEN

DE LA FINCA AL BOSQUE: FACTORES ASOCIADOS CON LA PROTECCIÓN Y LA SIEMBRA DE ÁRBOLES EN UN PAISAJE AGRÍCOLA DE PANAMÁ

Los pequeños parches de bosque seco tropical que quedan en la península de Azuero, Panamá, representan parte de una de las clases de bosque en mayor peligro crítico de extinción a nivel mundial y que ha sido casi eliminada en Panamá. En un paisaje productivo agrícola y ganadero, árboles fuera del bosque son esenciales para incrementar la conectividad del paisaje, la sobrevivencia de especies nativas, y los servicios ecosistémicos que provienen de estos pequeños parches remanentes. A través de una encuesta de agricultores en la provincia de Los Santos, Panamá, este estudio indica que los agricultores en Los Santos protegen árboles y los siembran fuera del bosque por razones distintas. Mientras que los agricultores protegen árboles por una gran variedad de razones, (incluyendo madera, fruta, forraje para animales, sombra y conservación de agua), principalmente los siembran para madera y fruta, usos que producen un beneficio económico tangible. Los agricultores santeños también siembran árboles en sitios más diversos y especificados que los lugares en que los protegen. Seis especies de árboles son usados frecuentemente para cercas vivas en Los Santos, y muchos dueños de cercas vivas permiten que árboles útiles para madera o forraje de animales crezcan junto a la cerca. La administración cooperativa de cercas vivas puede ser una estrategia factible para incrementar la conectividad del paisaje altamente fragmentado de la región. Las diferencias entre las razones por proteger y sembrar árboles tienen implicaciones importantes que deberían ser consideradas en las estrategias de los programas que procuran aumentar la cobertura arbórea regional. Los proyectos que incentivan la regeneración natural de árboles y estimulan a los agricultores a proteger sus árboles pueden obtener mejores resultados al poner énfasis en beneficios intangibles tales como las estrategias de protección de aguas a bajo costo. Por el contrario, los proyectos de siembra/reforestación deben demostrar beneficios económicos tangibles a los agricultores.

Palabras clave: reforestación, regeneración, cerca viva, agricultores, pastos, agua, madera, fruta, Panamá.

Introduction

Tropical dry forests are critically endangered on a global scale because they are highly desirable habitat for human colonization and exploitation. Only 2% of Central American tropical dry forests remain and in Panama, this forest type has been almost entirely eliminated (Miles *et al.*, 2006; Deago and Pérez, 2001). Within Panama, Los Santos province, like many tropical dry forest environments, has a long history of deforestation that has left a very low percentage of forest cover (Deago and Pérez, 2001). With 1,600-1,700 mm of average annual rainfall, the province has one of the driest climates in Panama, with a long history of serious droughts (Contraloria, 2001; Heckadon-Moreno, 2009). The eastern part of the province forms part of "El Arco Seco" or the "dry arc" that at one time was part of a Panamanian dry forest ecoregion that differed dramatically from the mangrove forests along the coast and the wet tropical evergreen forest in Cerro Hoya National Park (photo 1; Olson *et al.*, 2001). After centuries of human exploitation, virtually no primary dry forest exists in Los Santos, and large contiguous patches of secondary regrowth are scarce (photo 2).

The forest transition theory of land use suggests that although economic growth initially causes deforestation, as development and technological advances in agriculture occur, countries will urbanize, and this decrease in rural population density on marginal land should produce less deforestation (Wright and Samaniego, 2008). Therefore, forest regrowth should occur first on marginal land in wealthy nations. Forest that regrows after a forest transition can encompass everything from agroforestry to monocultures of exotic forestry plantations to secondary successional forest regrowth (Hecht and Saatchi, 2007). The combination of nutrient-poor, marginal land and a high level of economic development are indicators that Los Santos province is a region at this transition point with high potential to revert back to forest in coming years. When the Spanish colonists arrived in eastern Los Santos province in the 16th century, they likely found a deforested environment that had been occupied and altered by humans for almost 3,000 years (4405 BP), but deforestation intensified in the late 19th and early 20th centuries, in part due to government land tenure policies and the increasing demand for beef from the canal zone (Cooke and Ranere, 1992; Heckadon-Moreno, 2009). As of 2008, Los Santos was one of the most heavily deforested and nutrient-poor provinces in Panama, one of the wealthier countries in the Central American region (Wright and Samaniego, 2008; Conalsed, 2008; World Bank, 2008). Los Santos is also the province with the third highest human development index (0.710) in Panama, with the two most developed provinces being the main urban centers on either side of the Panama Canal (Conalsed, 2008).

Los Santos province has recently experienced a slight increase in tree cover. A previous analysis (Metzel, 2010) shows that from 1990-2009, forest cover in the province increased by 4.4%. The decision to maintain forest is associated with larger land-holding size, having a secondary occupation, and having inherited all of one's land (Metzel, 2010). The two most common reasons forest owners mention for leaving forest on land are water protection (38.5%) and providing shade for cattle during the dry season (23.1%; Metzel, 2010).

However, much of the tree cover that has grown back in Los Santos province in recent decades is outside of forests, and land managers in the province protect forest, protect trees and plant trees for different reasons and in different places. These decisions about why and where to protect and plant trees can ultimately lead to different sets of tree species located in distinct parts of the agricultural landscape. There-

Photo 2.
A mural in a Las Tablas, Los Santos high school depicting deforestation in Los Santos.
Photograph R. Metzel.

fore, strategies of reforestation projects that depend on collaboration with land managers must incorporate an understanding of the differences behind the motivations that cause land managers to increase tree cover in these different ways. Decisions about whether to reforest, protect, or plant trees are made with limited financial resources in a cultural context that has historically emphasized the importance of tangible agricultural productivity (photo 3; Heckadon-Moreno, 2009).

In the past two decades, foreign residents and tourists have increasingly populated the coastal areas of Los Santos province. From 1990-2000, the foreign-born population in Los Santos province increased by 66% but still made up a small 0.5% of the total registered Los Santos population (Contraloria, 2000). It is unclear what role the foreign-born community or recent coastal tourism development is playing in the changing environment and ecology of the province. Currently, tourism development is largely confined to the province's coast, while much of the increased tree cover visible in recent satellite imagery analyses is regenerating in the interior of the province (Metzel, 2010). The arrival of this foreign demographic, added to the two historically influential populations – small-scale subsistence farmers and large-scale landowners – already on the peninsula, creates a complex environment for designing reforestation policies that successfully appeal to all landowners in Los Santos.

Our research further explores how the factors that determine why and where land managers *protect* trees in non-forest areas of their land differ from the factors that determine why and where they *plant* trees within non-forest areas, and how the tree species that are protected versus planted on farms differ accordingly. These differences between natural regeneration and planting practices can help reforestation projects that collaborate with land managers to understand the motivations that may lead to higher local participation in regional reforestation initiatives.

This study builds on the work of Garen *et al.* (2011) showing that cattle ranchers and agriculturalists in Panama's tropical dry forest environment have diverse reasons for maintaining trees outside of forests, including cattle fodder and shade, and timber for diverse uses. Our study builds upon their previous work by focusing exclusively on one of the sites examined by Garen *et al.* (2011), located in Los Santos province, and surveying land managers in two sites, Pedasi and Macaracas, within that province. While Garen *et al.*'s study compared participants in the Smithsonian Tropical Research Institute's Native Species Reforestation Project (PRORENA) to non-participants within the same site, our current study expands this analysis by comparing land managers with and without existing forest on their land in a larger study area within Los Santos. While our results agree with Garen *et al.*'s conclusions related to Los Santos farmers' high use of live fences, our study suggests a high prioritization of planting of fruit trees by farmers in Los Santos, when compared to other uses, and provides details on the locations where farmers choose to protect or plant trees within their agricultural land.

Photo 3.
Deforestation from a homestead. How farmland is cleared in Los Santos.
Photograph R. Metzel.

Methods

Study Site: Los Santos, Panama

Los Santos province, Panama is situated between 7°13'32" and 8°00'05" N and 80°37'50" and 80°22'21" W on the Central American isthmus. The province encompasses the southeastern third of the Azuero Peninsula, stretching from the forested fringes of Cerro Hoya National Park in the southwest to the coastal urban centers of La Villa de Los Santos and Las Tablas in the northeast (figure 1). Although all of the peninsula is often classified as tropical humid forest in climate classifications (Kottek *et al.*, 2006), the Eastern half, including much of Los Santos province, falls within Sánchez-Azofeifa *et al.* (2005)'s description of tropical dry forests as "a vegetation type typically dominated by deciduous trees where at least 50% of trees present are drought deciduous, the mean annual temperature is › 25°C, total annual precipitation ranges between 700 and 2,000 mm, and there are three or more dry months every year (precipitation ‹ 100 mm)". With 1,600-1,700 mm of average annual rainfall, Los Santos experiences a 5 month dry season (December-April) and a bimodal rainy season (May to November with a short dry period in June; Love and Spaner, 2005; Heckadon-Moreno, 2009).

Land Managers Survey

To determine factors related to individual land manager decisions to maintain forest, a 46-item standardized, cross-sectional survey was developed with closed and open-ended questions in four categories; family history and personal characteristics, land management practices, farm or land holding costs and gains, and questions about wildlife and local culture. The survey was administered in an oral interview to 85 Panamanian land managers from Macaracas (43) and Pedasí (42) districts of Los Santos province in August-September 2009 and January 2010. Survey participants are called "land managers", a term that encompasses owners, paid administrators, and family members most actively responsible for managing the land.

Survey questions asked participants to specify which tree species they protected and planted in the non-forested parts of their land and contained separate questions to distinguish these two practices. In addition to the questions on protecting and planting trees on their land, participants were also asked a series of questions specifically about live fence species. Because the survey was conducted through home interviews, it forced participants' memory-based naming of tree species and recall of their uses. The species named through this technique are thought to correspond with those species of greatest importance and interest to survey participants, but may not represent the total number of tree species present on each participant's land (Love and Spaner, 2005).

Survey participants were selected from the land managers present at the time of the community visit, and from a list of landowners provided by technicians at MIDA, Panama's agricultural development agency. Interviews varied in duration from 40-120 minutes and were conducted by one of the authors and a university student from Los Santos province. The socioeconomic and demographic characteristics of participants were similar across both districts (table I; Metzel, 2010).

Data Analysis

The participants were classified into 4 survey groups in the data analysis based on their residential district and whether or not they stated that they left forest on their land: Pedasí residents with forest, Pedasí residents without forest, Macaracas residents with forest, and Macaracas residents without forest. Categories of answers to why and where participants protected/planted trees on their land were delineated based on participants' responses to open-ended questions and are thus descriptive of their decisions and perspectives. Reported percentages for the reasons and locations participants protect or plant trees represent the number of participants that mentioned a reason or location out of the number of participants that stated that they protect or plant trees, not the total number of participants surveyed. Two-tailed Fisher exact tests were used to determine if the likelihood of protecting or planting trees, or of protecting tree species along live fences, was significantly different between survey participants with and without forest. A z-test was used to determine if the percentage of survey participants who plant trees on their land was significantly different from those who protect trees (Snedecor and Cochran, 1989). A Welch test was used to determine if the mean number of tree species planted in live fences was significantly different between survey participants with and without forest (Snedecor and Cochran, 1989).

Figure 1.
Map of Los Santos province in Panama.

Results

Trees Protected on Land

Out of 85 participants, 83 reported protecting trees on their land. Survey participants with forest were not significantly more likely to protect trees on other parts of their land than those without forest patches (Two-tailed Fisher exact test, p = 1). Across all survey groups, the top five reasons for protecting trees on land were timber, fruit, animal fodder, shade, and water protection (figure 2). Only survey participants with forest mentioned biodiversity reasons for protecting trees (7%). Species protected were similar among participants with and without forest patches and across districts. *Guazuma ulmifolia* (guácimo), *Cedrela odorata* (cedro amargo), and *Anacardium excelsum* (espavé) were among the top five species protected on land mentioned by survey participants with and without forest (figure 3). Of the locations specified for protecting trees, "near water source" and "dispersed in pasture" ranked highest among participants' answers (figure 4).

Trees Planted on Land

The percentage of survey participants that plant trees on their land (71.8%) was significantly lower than the number that protect trees (97.6%; z-test, p ‹ 0.0001). Significantly more land managers with forest plant trees on the rest of their land than land managers without forest (Two-tailed Fisher Exact test, p = 0.05 (M), p = 0.005 (P)). Timber and fruit uses were the most popular reasons for planting (figure 2). When preferences were segregated on a district basis, timber ranked first in the Macaracas survey groups, while fruit ranked first in Pedasí. Both participants with and without forest mentioned water protection as the third most common reason for planting trees. Although survey participants with forest mentioned biodiversity reasons for protecting trees, no participants mentioned biodiversity reasons for planting trees. The species that ranked in the top five tree species planted by the survey groups with and without forest consisted exclusively of timber and fruit species: *Tectona grandis* (teca; timber), *Cedrela odorata* (cedro amargo; timber), *Swietenia macrophylla* (caoba; timber); and *Citrus sinensis* (naranjo; fruit), *Mangifera indica* (mango; fruit; among participants without forest), and *Persea americana* (aguacate; fruit; among participants with forest; figure 3). Survey participants most frequently mentioned planting trees near water sources, houses, and fences (figure 4), and some mentioned anecdotally that they prefer to plant timber species near fences and fruit species near houses.

Live Fence Species and Management

Although some live fence species are commonly used throughout the region, other species showed distinct geographical patterns in their use by participants. Participants with and without forest and in both districts consistently ranked *Bursera simaruba* (carate) and *Jatropha curcas* (coquillo) in the top three species used for live fences (table II). Participants in all four survey groups also used *Gliricidia sepium* (balo), *Spondias purpurea* (ciruelo), and *Spondias mombin* (jobo). In Macaracas, approximately half of participants used *Bursera tomentosa* (caratillo; used by 44% and 50% of participants with and without forest, respectively), whereas no participant in Pedasí mentioned using *B. tomentosa*. Approximately 75% of participants in Pedasí mentioned using *S. purpurea* in their live fences, while it was mentioned by approximately 25% of Macaracas participants. Reasons stated by Macaracas survey participants for not using *S. purpurea* were that it dried out, rusted and damaged the fence wire, and/or fell down often. In Macaracas and Pedasí, the mean number of tree species planted in live fences was not significantly different between survey participants with and without forest (3.84 and 3.72 (M), and 3.65 and 3.4 (P), respectively; Welch t-test, p= 0.80 (M) and p = 0.63(P)).

Land managers with forest were not significantly more likely to protect trees near live fences than those without forest patches (Two-tailed Fisher exact test, p= 0.67 (M) and 0.51(P)). The most common species protected near live fences consisted exclusively of timber and fodder species (table II). These include four timber species – *Cedrela odorata* (cedro amargo), *Pachira quinata* (cedro espino), *Cordia alliodora* (laurel), and *Tabebuia rosea* (roble) – and one fodder species, *Guazuma ulmifolia* (guácimo) (table III).

Table I.
Characteristics of survey participants (number of individuals surveyed in parentheses).

Characteristic	Macaracas	Pedasí
Mean Age, years	58.0 (43)	64.0 (42)
Mean Education, average number of years	7.1 (43)	7.0 (42)
Attended all/part of Secondary School, %	32.6 (14)	26.2 (11)
Mean Family Size, #	2.6 (43)	2.7 (42)
Mean Grown Children in Agriculture, #	0.6 (43)	0.5 (42)
Mean Grown Children in Los Santos, #	1.6 (43)	1.3 (42)
Mean Grown Children who completed high school, #	1.4 (43)	1.3 (42)
Mean Land Holding Size, ha	119.2 (43)	112.9 (42)
Mean Time Administering Land, years	26.7 (43)	27.6 (42)
Mean Time spent on Farm, hours/week	30.8 (43)	28.5 (42)
Inherited Land, %	34.9 (15)	45.2 (19)
Hold Secondary Occupation, %	30.2 (13)	45.2 (19)
Have Forest, %	62.5 (25)	42.9 (18)
Have Cropland, %	86.1 (37)	69.1 (29)
Have Pasture, %	100 (43)	88.1 (37)
Have Forestry Plantations, %	25.6 (11)	21.4 (9)

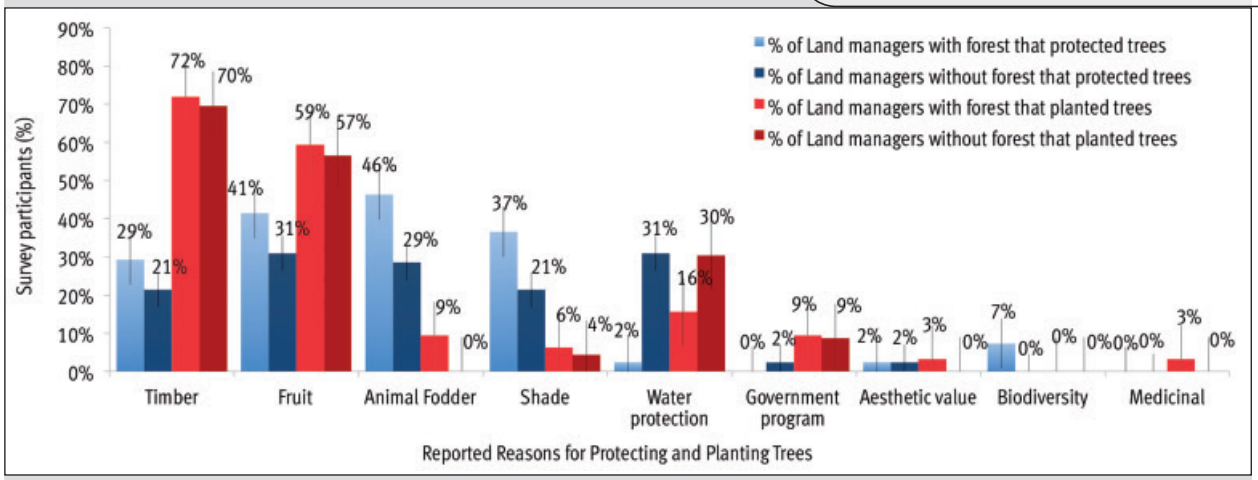

Figure 2.
Reasons survey participants with and without forest reported for protecting (blue) and planting (red) trees (excluding live fences).

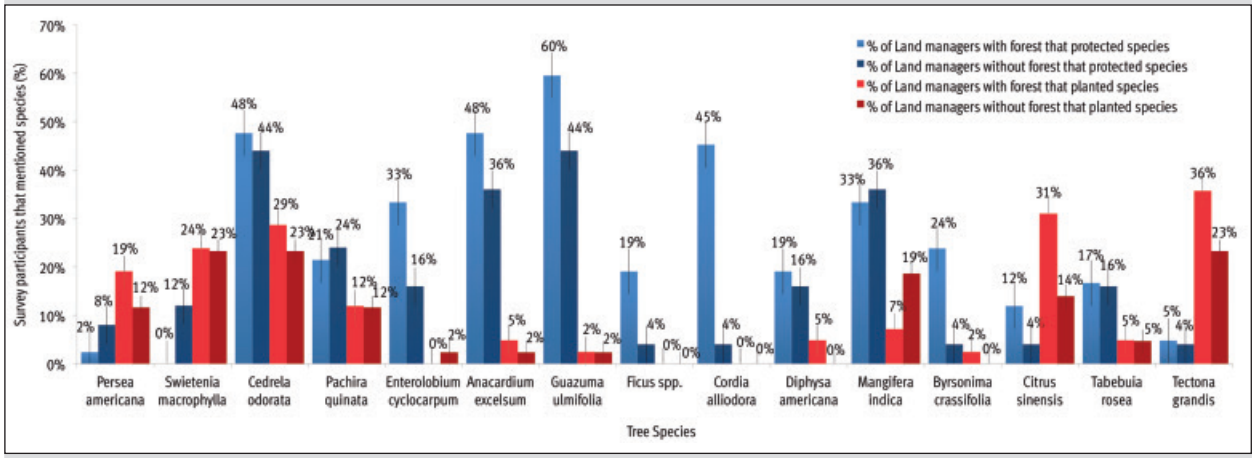

Figure 3.
Tree species that survey participants with forest and without forest reported protecting (blue) and/or planting (red) on their land, listed in alphabetical order by scientific name.
Note: The species mentioned here are species that were mentioned by at least 15% of land managers in one category. Common names and characteristics of species are found in table III.

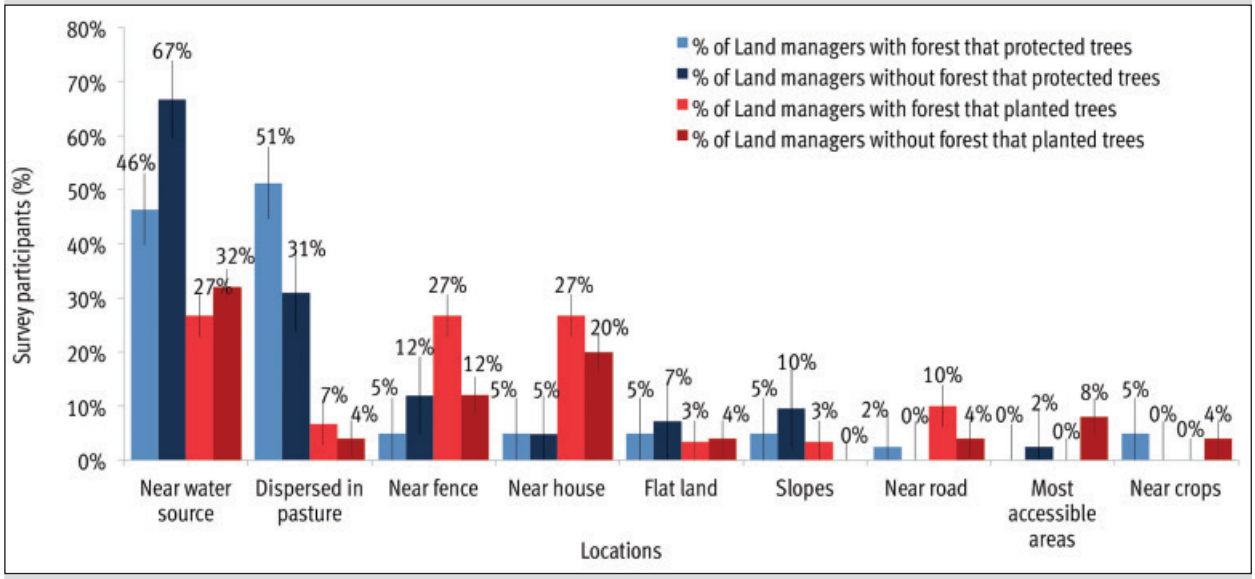

Figure 4.
Locations survey participants with and without forest reported protecting (blue) and/or planting (red) trees (excluding live fences).

Table II.
Tree species survey participants with and without forest reported using *in* and *along* live fences in Macaracas and Pedasí. Note: The species mentioned here are species that were mentioned by at least 15% of land managers in one category. Common names and characteristics of species are found in table III.

Species Planted	Macaracas		Pedasi	
	Land managers with forest (n_1=25, n_2=20)	Land managers without forest (n_1=18, n_2=16)	Land managers with forest (n_1=17, n_2=11)	Land managers without forest (n_1=25, n_2=20)
In Live Fences				
Jatropha curcas	92%	100%	71%	44%
Bursera simaruba	88%	78%	59%	88%
Spondias purpurea	32%	22%	71%	84%
Gliricidia sepium	40%	50%	47%	24%
Spondias mombin	36%	17%	53%	28%
Bursera tomentosa	44%	50%	0%	0%
Pachira quinata	0%	0%	6%	28%
Diphysa americana	0%	17%	6%	8%
Along Live Fences				
Cedrela odorata	40%	63%	27%	40%
Guazuma ulmifolia	35%	44%	18%	25%
Cordia alliodora	30%	25%	18%	10%
Tabebuia rosea	15%	25%	9%	15%
Pachira quinata	10%	6%	18%	25%
Enterolobium cyclocarpum	0%	13%	18%	5%
Anacardium excelsum	20%	6%	0%	5%
Diphysa americana	10%	0%	9%	20%
Byrsonima crassifolia	10%	19%	0%	5%
Mangifera indica	5%	6%	0%	20%
Jatropha curcas	0%	0%	18%	0%

Discussion

Factors influencing the Decision to Protect or Plant Trees

Farmers with forest in Los Santos protect and plant tree species on their land differently than those without forest. A higher percentage of survey participants with forest planted trees on their non-forested land than participants without forest, and only survey participants with forest protected trees for biodiversity reasons. The current landscape is composed of isolated patches of forest with very little connectivity among them. Trees protected and planted in non-forested land by participants with forest may increase the species diversity of their forest patches through increasing landscape connectivity. The species named through this technique are thought to correspond with those species of greatest importance and interest to survey participants, but may not represent the total number of tree species present on each participant's land (Love and Spaner, 2005).

Survey participants planted trees in a more diverse and specified set of places than those in which they protected them. Fewer survey participants planted trees than protected trees on their farms, and they planted for fewer reasons. Whereas participants protected trees for a diverse set of reasons, they planted them primarily for two tangible economic reasons: timber and fruit. Anecdotal evidence suggests that some farmers plant timber species along fences and fruit species near houses, so depending on where reforestation efforts occur, different species and their associated uses may be more or less popular. These findings from our survey are supported by results from another study in Los Santos stating that 79% of respondents plant fruit trees near their homes (Garen *et al.*, 2011). Another survey in Los Santos similarly found that wood and fruit rank first and second in tree uses reported by plantation owners, and a survey in neighboring Herrera province indicated that 80-85% of pasture owners also retain trees for wood and fruit (Love and Spaner, 2005; Garen *et al.*, 2009). Yet another survey conducted at five sites in Panama found that fruit, fuelwood, and wood were the three benefits of trees most commonly mentioned by farmers (Fischer and Vasseur, 2002). These results indicate that land managers plant trees primarily to produce a tangible economic benefit (photo 4). Thus, reforestation initiatives that encourage actively planting trees rather than simply protecting them must further demonstrate the economic benefits derived from these trees.

Table III.
Scientific and common names of species mentioned in this study. Source data: AEP, 2013; Pérez and Condit, 2014.

Scientific Name	Common name	Family	Uses
Anacardium excelsum	Espavé/Javillo	Anacardiaceae	Edible, handicrafts, medicinal, timber
Anacardium occidentale	Marañón	Anacardiaceae	Edible, fence posts, firewood, medicinal
Andira inermis	Harino	Fabaceae	Firewood, fodder, medicinal, ornamental, shade, timber
Bursera simaruba	Carate	Burseraceae	Charcoal, firewood, live fence, medicinal
Bursera tomentosa	Caratillo	Burseraceae	Insect repellent, live fence, medicinal
Byrsonima crassifolia	Nance	Malpighiaceae	Edible fruits, live fence, medicinal
Calycophyllum candidissimum	Madroño	Rubiaceae	Firewood, handicrafts, live fence, ornamental, timber
Cedrela odorata	Cedro amargo	Meliaceae	Handicrafts, medicinal, timber
Citrus latifolia	Limón	Rutaceae	Edible, medicinal
Citrus sinensis	Naranjo	Rutaceae	Edible
Cocos nucifera	Palma de coco	Arecaceae	Edible, insect repellent, ornamental
Cordia alliodora	Laurel	Boraginaceae	Live fence, medicinal, shade, timber
Diphysa americana	Macano	Fabaceae	Live fence, ornamental, timber
Enterolobium cyclocarpum	Corotú	Fabaceae	Edible, fodder, handicrafts, medicinal, ornamental, shade, timber
Ficus spp.	Higuerón/Higo	Moraceae	Medicinal, timber
Gliricidia sepium	Balo	Fabaceae	Firewood, fodder, live fence, medicinal, ornamental, shade
Guazuma ulmifolia	Guácimo	Malvaceae	Fodder, medicinal
Inga vera	Guabo	Fabaceae	Firewood, timber
Jatropha curcas	Coquillo	Euphorbiaceae	Live fence, medicinal
Mangifera indica	Mango	Anacardiaceae	Edible, ornamental
Ormosia macrocalyx	Peronil	Fabaceae	Handicrafts, ornamental, timber
Pachira quinata	Cedro espino	Malvaceae	Handicrafts, medicinal, timber
Persea americana	Aguacate	Lauraceae	Edible, handicrafts, medicinal, ornamental
Samanea saman	Guachapalí	Fabaceae	Handicrafts, ornamental, shade, timber
Sciadodendron excelsum	Jobo de lagarto	Araliaceae	Fence posts, live fence
Spondias mombin	Jobo	Anacardiaceae	Edible, firewood, handicrafts, live fence, medicinal, timber
Spondias purpurea	Ciruelo	Anacardiaceae	Edible, fodder, live fence, ornamental
Sterculia apetala	Panamá	Malvaceae	Edible, fence posts, medicinal, ornamental, timber
Swietenia macrophylla	Caoba (nacional)	Meliaceae	Handicrafts, medicinal, ornamental, timber
Tabebuia rosea	Roble	Bignoniaceae	Medicinal, ornamental, timber
Tectona grandis	Teca	Lamiaceae	Timber
Zygia longifolia	Guabito	Fabaceae	Firewood, medicinal, ornamental, timber

Many reforestation initiatives distribute tree seedlings to farmers as a way to encourage tree planting. However, the results of this study indicate that farmers choose to plant and protect trees for different reasons and in different locations. Therefore, it is important for successful reforestation programs to consider whether their planting programs are aligned with farmer priorities like timber and fruit production. They should also consider initiatives that encourage farmers to protect trees on land or pursue natural regeneration strategies directed toward attaining less tangible but equally important services like animal fodder, shade and water protection. Protecting trees on land is a low-cost strategy compared to tree planting, and so assisted regeneration may be preferred over planting in cases where long-term ecosystem services are the primary reasons for reforestation.

Natural Regeneration for Water Conservation in Panama

Panama's 1994 Forestry law further expanded upon the nation's 1992 reforestation law's prohibition of destruction of trees and shrubs near water resources by requiring 100-200-meter no-logging buffer zones around river sources, lakes and natural aquifers, and 10-meter buffers around riparian zones (Articles 23-24). With these legal restrictions and a long history of droughts on the Azuero peninsula, farmers in Los Santos are highly concerned about water protection on their land. Among Los Santos farmers, water protection is the most common reason for leaving forest on land (Metzel, 2010) and according to this survey, trees are most commonly protected along a water source.

Photo 4.
Homemade wooden foldable bench constructed on the front porch of a wooden house bordering La Tronosa Forest Reserve in Los Santos, Panama.
Photograph R. Metzel.

Initiatives to promote natural regeneration should align their strategies with farmers' water concerns to expand riparian corridors and inform the public about the ecological processes through which riparian habitat restoration influences water quality and evapotranspiration in pastoral areas (Sweeney *et al.*, 2004; Jipp *et al.*, 1998). Despite the prevalence of water-related concerns in Los Santos, there seems to be surprisingly little public consciousness surrounding the connection of erosion to water protection, given that roughly one third to a half of Los Santos' soils are classified as non-arable, severely limited, and unfit for agriculture (Conalsed, 2008). According to ANAM data, two of the three watersheds in Los Santos rank in the top three most deforested watersheds in the nation, with less than 4% forest cover (Anam and Cathalac, 2008). One of these watersheds decreased in forest cover from 2000 to 2008 despite government restrictions on felling trees near water sources (Anam and Cathalac, 2008). More emphasis is needed on natural regeneration as a tool for water protection and prevention of erosion and soil degradation.

The Importance of Live Fences for Landscape Connectivity

Live fences serve as wildlife corridors and contribute to increased landscape connectivity (Harvey *et al.*, 2004; Francesconi *et al.*, 2011). Live fences add significantly to forest cover in a landscape; estimates of live fence coverage range from 140 to 340 m per hectare (ha) of pasture at sites in Costa Rica and Nicaragua (photo 5; Harvey *et al.*, 2005). Of 1195 live fences studied across four other Central American sites, 17% directly connected to forest patches or forested riparian zones (Harvey *et al.*, 2003). Although live fences may originally consist of only one or a few planted species, natural dispersal leads other plant species to colonize the fence understory. A live fence that was planted as a monoculture can evolve into a habitat for a wide variety of tree and animal species if the fence owner allows natural regeneration to proceed. Live fences house a diverse

Photo 5.
Live fence of *Bursera simaruba* (carate) in Los Santos, August 2009.
Photograph R. Metzel.

fauna, including birds, bats, butterflies, dung and carrion beetles, lizards and non-flying mammals (Estrada *et al.*, 1994; Molano *et al.*, 2002; Harvey *et al.*, 2004). Although live fence corridors are most likely used primarily by smaller mammals, large mammals, including howler monkeys, have been shown to supplement their diet substantially by feeding from live fences (Asensio *et al.*, 2009; Harvey *et al.*, 2004).

Increasing tree cover near live fences in Los Santos can expand provincial forest cover significantly and provide extensive habitat for animal species to migrate between the few large isolated forest patches that remain in Los Santos (photo 6). Many live fence owners in Los Santos may be open to allowing this type of live fence regeneration, particularly if the tree species that colonize the live fence can be used for timber or animal fodder. Timber and fodder trees are the species farmers most frequently protect alongside live fences. Some survey participants mentioned that they plant timber species along fences so that they can be easily extracted for sale or home use. Research indicates that Costa Rican farmers similarly allow timber species to grow within their live fences (Budowski and Russo, 1993). Through programs encouraging the planting of a timber and fruit species mix, farmers could harvest select timber trees from fence corridors, while protecting fruit and rare tree species to provide a permanent corridor for wildlife.

Due to the prevalence of cattle ranching and agriculture as income sources on the peninsula, unless forest has a tangible economic value it is unlikely that farmers will intentionally reforest large contiguous patches at the expense of pasture or cropland. Expanding live fences into wildlife corridors through joint implementation by neighbors with contiguous land parcels splits reforestation costs between neighbors. This arrangement allows each farmer to maintain more pasture proportional to the area of tree cover. For example, if two neighboring land managers make a joint commitment to each plant two rows of trees on his/her side of a live fence, together they create a corridor more than double that width. This strategy builds on the existing tendency among farmers to plant timber species and protect trees along fences. Joint implementation reinforces the commitment of both farmers to the project. Expanding live fences into wildlife corridors can greatly increase connectivity while also providing tangible economic benefits. According to some survey participants, planting trees along live fences reduces costs by protecting the live fence from moisture and wind, and eventually reduces the need to clear area around the fence for fire breaks. Challenges to cooperative fence management include the potential for plantings to initially disrupt firebreaks, the costs of protecting young trees from cattle, the maintenance of cooperative neighborly relationships, and the alteration of tree growth structure in the corridor by cattle

Photo 6.
Pastureland in Los Santos with live fences; live fences create tree corridors that greatly increase the connectivity of a landscape, January 2010.
Photograph R. Metzel

grazing. To ensure effectiveness at promoting biodiversity, more research is needed on the optimum width and species mix of the fence corridor to provide sufficient habitat to the species most prioritized for conservation in Los Santos.

In addition to planting a diverse mix of species along fences, conservation initiatives could diversify the tree species in the fence itself by developing a fence stake trading system and subsidies for using overlooked species, thus increasing fence diversity and resistance to species-specific pests. In general, a small proportion of potential live fence species account for a large percentage of live fence posts (Harvey *et al.*, 2004). In live fences studied in Costa Rica, only eight species accounted for 95% of live fence posts (Budowski and Russo, 1993). Our research in Los Santos also indicates a relatively low diversity of live fence species at the farm level. Although survey participants mentioned six common live fence species used in the region, each farmer uses an average of only 3-4 species. Despite the low diversity of live fence species used per farm when compared to the Los Santos region as a whole, Garen *et al.* (2011) found that more farmers in Los Santos plant trees as live fences compared to farmers in other parts of Panama. When asked why they did or did not use a certain live fence species, farmers in our survey would often mention availability of planting stock as a main reason. Farmer access to research on the untapped diversity of potential native live fence species could substantially increase the number of species used. Since many live fence species are propagated by cuttings that can be obtained without destroying the source fences, implementation of this program would be relatively inexpensive.

Conclusions

There are differences in the reforestation, tree-protecting and tree-planting practices of local landowners that have the potential to influence the success of reforestation projects in Los Santos. The results of this study help provide valuable information for strategically aligning reforestation efforts with the priorities of local land managers. The choice of collaborators, reforestation strategies, and locations is essential to the success of reforestation projects. Three key areas may greatly influence the success of conservation in this region: the burden on tree planting projects to demonstrate the tangible economic benefit of their project to the farmer; water as a priority for natural regeneration projects, and cooperative live fence management as a way to increase landscape connectivity. However, while land managers are willing to plant trees that provide tangible economic benefits, high up-front reforestation costs often prevent them from planting even the most valuable trees, like high-value timber. Thus, additional legal and economic incentives may be needed to overcome the up-front costs of planting economically valuable species and the opportunity costs of protecting trees to improve ecosystem services on farms.

Increases in tree cover through tree protecting and planting at a much smaller scale than that of entire farms are important to landscape connectivity in Los Santos. Having a better knowledge of the situations in which farmers protect and plant trees on their non-forested land can better align reforestation practices with the ecosystem services they seek to improve. The science and the practice of reforesting landscapes must be linked together in an effort to create viable and biodiverse habitats in these marginal areas of tree cover that blur the line between farm and forest.

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