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Tropical Forest Gain and Interactions amongst Agents of Forest Change

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Abstract: The tropical deforestation literature advocates multi-agent enquiry in recognition that key dynamics arise from inter-agent interactions. Studies of tropical forest-cover gain have lagged in this respect. This article explores the roles and key aspects of interactions shaping natural forest regeneration and active reforestation in Eastern Panama since 1990. It employs household surveys of agricultural landholders, interviews with community forest-restoration organisations, archival analysis of plantation reforestation interests, satellite image analysis of forest-cover change, and the consideration of State reforestation policies. Forest-cover gain reflected a convergence of interests and land-use trends amongst agents. Low social and economic costs of sustained interaction and organisation enabled extensive forest-cover gain, but low transaction costs did not. Corporate plantation reforestation rose to the fore of regional forest-cover gain via opportunistic land sales by ranchers and economic subsidies indicative of a State preference for autonomous, self-organising forest-cover gain. This reforestation follows a recent history of neoliberal frontier development in which State-backed loggers and ranchers similarly displaced agriculturalists. Community institutions, long neglected by the State, struggled to coordinate landholders and so effected far less forest-cover gain. National and international commitments to tropical forest restoration risk being similarly characterised as ineffective by a predominance of industrial plantation reforestation without greater State support for community forest management.

Keywords: reforestation; forest regeneration; forest transition; smallholder; tropical forest; deforestation; community forest management; plantation

1. Introduction

Tropical forest-cover gain is increasingly manifest at large scales following decades of deforestation. Some 13 tropical countries have undergone forest transitions since 1990 according to the 2015 Global Forest Resources Assessment [1], as have other tropical regions and countries according to various satellite estimates, particularly in Latin America [2–6]. Tropical forest-cover gain has entailed new forest geographies reflecting the changing drivers, agents, and contexts of forest-cover change [3,7,8]. These geographies are the physical manifestations of intangible processes by which different agents and trends of land-cover change interact to collectively form a single landscape. The tropical deforestation literature has long recognised that key dynamics arise from inter-agent interactions [9–15] and so advocated multi-agent, multi-scalar enquiry stretching beyond the domain of any single agent, e.g., smallholders, loggers, communities, and financiers [12,16,17]. Yet the literature on tropical forest-cover gain has lagged in this respect and the well-known interactions underlying deforestation are unlikely to apply [18,19].

Forest-transition theory presents a leading theoretical framework of tropical forest gain [20] that has largely neglected the role of interactions within landscapes undergoing forest-cover gain. Accounts of tropical forest-cover gain are typically reduced to aggregate tallies of forest change coincident with large-scale economic change [3,6]. Interactions underlying forest-cover gain in turn are generally presented as abstract core-periphery interactions treating the peripheral zone of forest-cover gain as a single entity, e.g., migrations of smallholders from rural peripheries to economic centres [21,22]; regional transitions from rural agricultural to urban wage employment [3]; or industrial reforestation in rural peripheries following demand from economic centres [23,24]. Accordingly, this framework emphasises the removal of landholders from the landscape while overlooking the fact that different agents therein control and (re)use lands differently [25] so that, depending on their interactions, they effectively negotiate, and even retard or reverse, the apparent forest-cover gain spurred by wider changes [26]. In neglecting this agency of forest-cover gain, aggregate accounts remain uncomfortably superficial, selective, and poorly differentiated from each other [20,27].

An alternative theoretical framework of forest-cover gain emphasises shifts in the distribution land-use/cover "rent" and similarly neglects interactions within landscapes [28,29]. Effectively, this framework orders a gradation of land use/covers ranging from intensive agriculture to semi-forested ranching to extensively managed forests concentrically in terms of market proximity, with each land-use/cover having the greatest rent in a given concentric zone. Forest-cover gain is envisaged as occurring when the concentric zones shift inwards towards the market, with outer zones partially overtaking inner-zones, typically as the result of either increased demand for ecological services (increasing the rent of outer forested zones) or agricultural intensification in inner zones (reducing the rent of middle agricultural zones) [28,30,31]. Crucially, rent as well as opportunity costs are treated as inherently private to the landholder and interactions effecting land-use/cover choice as intangible teleconnections communicated via the market. The fidelity of this framework declines upon allowing for non-market interactions and related institutions (e.g., land tenure, land-use norms), which have significant mediating effects, including on how or whether rent may be captured. In relatively settled contexts, for example, well established local institutions may spatially invert the concentric zones of forest and agricultural cover [32,33] while, in relatively peripheral regions, the unchecked pursuit of rents generates the very economic externalities that stimulate countervailing institutions [34]. In Panama, forest-cover gain has concentrated in the so-called relative periphery where agricultural land-use rents are higher than elsewhere [3], while in absolutely peripheral contexts, such as the agricultural margins, the role of rent in land-cover change is discounted by weak markets and institutions, uncertain potential rents, and risk aversion [35–38].

The literature on multiple-use forest management and conservation (MUFMC) offers richer insights on how tropical forest-cover gain may reflect multi-agent, multi-scalar interactions. Following conservationists' championing of state entities [39], communities [40,41], and smallholders [42] individually over recent decades, MUFMC has found its greatest efficacy in hierarchical networks of agents with diverse, complementary motives that need not explicitly pursue conservation *per se* [43,44], e.g., community institutions, agricultural collectives, NGOs. Effectively "comparative advantages" amongst agents plug the institutional and economic "gaps" through which typically more powerful forces for deforestation and forest degradation might gain traction. Parallels with tropical forest-cover gain are evident: the persistence and expansion of new forest cover may similarly entail interactions deflecting agricultural forces from re-clearing reforested lands [18,26]. To date, such interactions have been studied largely in contexts of mature tropical forest management so it is uncertain whether interactions promoting forest-cover gain would be comparably explicit and purposeful or rather inadvertent and serendipitous, given the lesser economic and ecological value of secondary forests. The onset of a forest transition has however been asserted as a fundamental criterion for successful interactions insofar as it precipitates a re-evaluation of forests' multiple goods and services, as well as a reconfiguration of specialised and general-use forests in the landscape [45] (pp. 1473–1474). Other key criteria for successful interactions are low transaction costs, the active involvement of the public sector,

secure land tenure and land devolution for collective institutions, and equitably-shared benefits [45,46], though again their applicability to forest-cover gain remains untested.

This article describes forest-cover gain in Eastern Panama as outcomes of interactions between landholders, community institutions, commercial plantation entities, and the State. A conceptual framework is presented highlighting key factors unifying sets of interactions according to their effect on the facility and geography of forest-cover gain. The framework underscores the organisational costs of retaining new forest cover, the degree of State support, and the distribution of the benefits forest-cover gain as key factors shaping interactions and in turn the extent and nature of forest-cover gain. The case study suggests that interactions leading to large-scale plantation reforestation have certain advantages in these respects and that, in the absence of greater State support for community forest management, plantation reforestation may predominate within numerous multi-lateral forest restoration initiatives, such as The Bonn Challenge [47], The 20x20 Initiative [48,49], The New York Declaration [50], and the Sustainable Development Goals [51].

The following section discusses the study context and methods. Section 3 discusses interactions amongst agents of forest change. Section 4 concludes by synthesising observations and drawing implications for multi-lateral tropical forest-cover restoration initiatives. Throughout this article, regeneration refers to natural forest succession and reforestation to tree planting, excluding home gardens, which are rare in the study context. Forest-cover gain refers to the localised expansion of forest cover due to either of these processes.

2. Experimental Section

2.1. Study Context

The study area is the Bayano-Darién Region of Eastern Panama. This region is bound by Bayano Lake in the west, Villa Darién in the east, the southern extent of forest in the indigenous Comarcas Madugandí and Wargandí in the north, and the Serranía de Majé in the south (Figure 1). However, an archival plantation registry discussed below pertains instead to The Greater Bayano Region, defined similarly as the area between Chepo in the west and the Darién provincial border in the east, with the same north–south boundaries as the Bayano-Darién Region. A tropical lowland humid forest biome characterises the setting, which receives 1600–2400 mm of rain annually, mostly during its wet season of April–December.

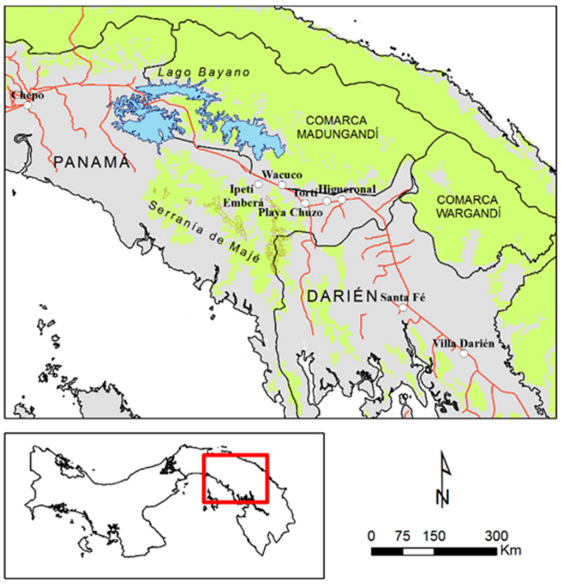

Figure 1. The Bayano-Darién Region. Note: forest cover is for 2007.

The Bayano–Darién Region is an "old frontier" that in many respects no longer resembles the open-access agricultural frontier it once was. During the 1970s and 1980s it was spontaneously settled by Mestizo colonists or "colonos" from Los Santos province and the greater Azuero Peninsula – a population of mixed Spanish-indigenous ethnicity with strong adherence to inherited Spanish customs, including ranching. Though colonisation was initially confined to the areas around the communities of Chepo and Tortí (Figure 1) it ultimately became unregulated, widespread, and concentrated along the highway [52,53]. For the Emberá and Kuna indigenous peoples, now minorities in the region, colonisation entailed resettlement into permanent communities, with a concomitant loss of assets (e.g., orchards) amongst the Kuna but gains in land rights amongst the Emberá [52]. Since then, many Emberá have adopted some of the land-use practices of Mestizo colonos [54], though they remain relatively poor. The Kuna have adopted Mestizo practices to a lesser extent, and are poorer still, preferring instead their traditional agro-forestry and relative isolation for cultural and environmental reasons. Kuna agro-forestry is much more confined than during the 1970s due to the Kuna's relocation to less suitable lands and extensive Mestizo settlement [52].

Deforestation was widespread over the 1980s and 1990s but has since slowed as farms have become more established and forest scarcer and less accessible. While forest remains abundant and accessible in the semi-autonomous Kuna Comarca Madungandí (Figure 1), recent agreements between colonos and the Kuna have slowed colono incursions. Ranches still dominate the landscape, but by the 1990s ranching contributed less to average household incomes than wage labouring and was the purview of a minority [55]. Further, since the passing of national legislation in 1992 to subsidise reforestation (Law 24 of 1992), forest plantations have rapidly covered many pastures in the region. More recently, in response to the drying of natural springs many locals have ascribed increasing value to the remaining forest cover. Lobbying and outreach by a local Catholic mission and American Peace Corps have precipitated Water Committees in each community to coordinate forest restoration and conservation in local watersheds. More recently still, the government has begun formally and freely titling landholdings to permanently delimit their extent in efforts to stem incremental expansion into the forest. Together, these trends describe a region that is more diverse, commercialised, conservation-minded, and organised than previously.

Due to this transformation, landholders, communities, commercial interests, and government have increasingly diverse interests, fostering, in turn, increasingly dynamic interactions. The theoretical frameworks previously discussed anticipate a variety of potential interactions underlying forest-cover gain. Landholders interacting with employers for wage incomes could withdraw from relatively unprofitable agricultural activities and revert their marginal landholdings to forest. Such interactions may be effectively costless and so theoretically extensive, assuming three conditions: namely, that landholders maximise wage incomes and allocate labour off-farm accordingly; that such labour allocations actually preclude continued, extensive agriculture; and that other landholders endure the significant opportunity costs of not reclaiming disused lands. Community entities, in interaction with withdrawing landholders, might organise to bear these costs in order to protect scarce forest environmental services, such as water provision. However, community organisation presumes perhaps optimistically that the benefits of protecting even increasingly scarce environmental services will offset ongoing organisational costs—a tenet dependent on effective institutions, clear rights to land and resources, and a widespread valuation of secondary forests [34,56]. Reforestation subsidization would increase the rent and thus "benefit" of planted forests and in turn extend them to more central situations in the landscape subject to community influence as well as landholders traditionally unaligned with forest management. Whether and how reforestation would be practiced in such situations would reflect negotiations between landholders, communities, and established forestry interests. In some instances these may indeed centre on rent maximisation, but in the risk-adverse frontier setting other instances may favour arrangements minimising the costs of plantation establishment. Arrangements may also reflect political-ecological legacies favouring relatively powerful agents who disproportionately "capture" benefits from resource exploitation.

2.2. Methods

This article considers the actions of and interactions amongst the following agents of forest change: (i) settler households concerned with livelihoods; (ii) community institutions concerned with forest restoration and conservation; and (iii) forest plantation interests concerned with commercial reforestation. The role of the State is also considered as its policies and actions bear upon these agents. Collectively these agents account for virtually all forest-cover change in the region and represent its micro, meso, and macro-scale dynamics, respectively. They are observed via household surveys and census microdata analyses of settler households, in-depth interviews with community institutions, archival analysis of plantation establishment, and mapping forest-cover change since 1990.

The analytical approach here is purposefully broad, inclusive, and exploratory. This is in keeping with our relative ignorance of the landscape dynamics underlying tropical forest-cover gain [57], with the notion of tropical forest-cover gain as a collective trend, and with the understanding that salient elements of its dynamic are likely to be apparent only against the complex backdrop of the local context [17,58]. In this way the approach adopts a key recommendation of Global LUCC Science Implementation Strategy to "move from [spatial] pattern to social process" when examining relatively unknown dynamics [59]. Each method of observation is separately discussed below.

2.2.1. Plantation Archive Analysis

Since 1992, when the Panamanian government began subsidising reforestation, owners of subsidised plantations have inscribed in a national registry. This registry, maintained by the Forest Service of the National Authority for the Environment (ANAM) (recently supplanted by the Ministry of Environment), contains data on the owners, area, year of establishment, and location of approximately 1700 forest plantations established between 1992 and 2008, in addition to ancillary files on forest-management plans and land titles and transfers. As effectively all plantations are subsidised, this Forest Registry presents a reliable record of national reforestation trends. To describe trends in reforestation as a function of the type of plantation owner within The Greater Bayano Region, I used an Analysis of Variance (ANOVA) to test for differences in mean plantation area between three groups of plantation owner: (a) domestic or international timber corporations; (b) reforestadoras (*i.e.*, smaller domestic commercial enterprises that establish, sell, and service plantations as investments) or a non-forestry commercial interests (*i.e.*, clients of the reforestadoras, such as banks); and (c) individuals. Given the potential for error in classifying registrants as either a timber corporation or a reforestadora I also merged classes (a) and (b) to form a general "commercial interests" class for comparison with the individual-owner class.

2.2.2. Community Interviews

Due to the widespread deforestation of watersheds and increasing demand for potable water, Water Committees (WCs) have formed in Mestizo communities to organise forest regeneration and conservation in watersheds, maintain aqueducts, and collaborate with The Ministry of Health on matters of water provision. Existing governance institutions in Amerindian Emberá communities have similarly refocused on forest restoration and conservation. Repeated semi-structured interviews with eleven community WCs furnished data on WCs' interactions with landholders (e.g., land acquisitions and social conflicts), plantation interests (e.g., collaborations and reforestation impacts), and the State (e.g., direct and indirect support), as well as on other challenges of expanding and conserving forest cover. The WCs interviewed represent the greater part of regional WC activity. Those interviewed were amongst the most prominent in the region and ranged from the very successful to the very unsuccessful, thereby constituting a cross-section of experiences. Similar interviews were also conducted with community leaders and reforesting landholders of the Amerindian community of Ipetí Emberá, the largest and most active Emberá community in the realm of forest restoration.

2.2.3. Household Data

A survey of the land-use histories and socio-economic traits of 55 Mestizo colono households in 2006/2007 provides data for statistical analysis of historical household land-cover change. Most colonos are descendants of pioneering families originating from "interior" provinces, though some are older "first-generation" colonos or recently-arrived settlers. Respondents were selected at random in the prominent Mestizo communities of Tortí, Playa Chuzo, Higueronal, and Río Seco–Wuacuco (Figure 1). The sample captures 10% of households in these communities as of 2000, or more if omitting non-agricultural households from consideration, and is comparable with other samples for similar household analyses [60,61].

Rather than reconstruct land-use histories retrospectively using seasonal, rotational, or other cropping "scripts", I proceeded from the year the settler acquired his land and worked forward to 2006. This accounted for the "linear" manner in which settlers processed their land from input states (usually intact forest) to intermediate states (usually fallow) to final states (usually pasture). Such reconstructions of household land use have been verified as highly reliable where households follow such simple, regular scripts, e.g., crop-fallow sequences [60,61]. To aid respondents' recall, I employed a system of cards representing either land uses/covers (forest (monte or bosque virgin), regrowth (rastrojo bajo or rastrojo alto), pasture, and agriculture) or the numbers of hectares allocated to each land use/cover, with respondents re-allocating the later cards among the former cards as lands were "processed" annually (Figure 2). A validation of the actual areas of agriculture, pasture, and regrowth on 32 properties of 15 households in 2006 using a GPS found only minor discrepancies with the reported areas for 2006 (Table 1). Interviews also furnished socio-economic data on changes to cattle herds and other assets, the sale of farm produce and cattle, household composition, migrations, income sources, and employment over 2000–2006 (Table S1).

Figure 2. Cards Denoting Land Use/Covers (Red) and Number of Hectares (Yellow) Used to Reconstruct Household Land-Use Histories. Note: in this photo, the columns of cards indicate that there were 38 hectares in forest (bosque), two hectares in fallow (barbecho rastrojo), and a sum of 11 hectares in pasture (pasto) for the year in question. The notable accumulation of multiple small-denomination cards under the pasture card is indicative of the fact that, in any given year, only one or two hectares would typically have been taken from forest for subsistence agriculture (cultivos de corto plazo), which would subsequently be passed to fallow (as shown) and then ultimately to pasture, where it would remain.

Table 1. Discrepancies between self-reported and measured areas of Household Agricultural Land Uses.

Discrepancy	Pasture	Agriculture	Regrowth
Mean Discrepancy (ha)	2.1	0.5	0.9
Standard Deviation (ha)	0.9	0.7	1.1
Percentage Discrepancy [a]	4	9	8

Notes: [a] Calculated as mean discrepancy/mean area of the relevant land use in sample × 100%.

Using these data I developed a logistic regression model of the likelihood of household forest regeneration as functions of socio-economic change over 2000–2006. Household regeneration is defined as either an increase in forest regrowth or a decrease in pasture and/or agriculture area by ⩾2 ha (excluding land sales) over 2000–2006. This definition captures the dynamism of the point at which regeneration overtakes deforestation better than static definitions of regeneration as the mere presence of secondary forest (e.g., [21]). The threshold of ⩾2 ha serves to exclude spurious land-cover change and ensures that the identified drivers of change are spatially as well as statistically significant. None of the sampled households practiced active reforestation.

Census "microdata" describing 579 Mestizo and Emberá households in nine communities complement these survey data (Table S1). Microdata are the "raw", respondent-level records from the 2000/2001 national population and agricultural censuses and cover all relevant aspects of land use and agricultural livelihoods. They have no sampling error, as all members of the select communities were enumerated.

2.2.4. Forest-Cover Maps

Forest-cover maps for 1990, 2000, 2007, and 2012 integrate observations of households, communities, and plantation interests by illustrating the type and distribution of forest-cover change caused by each. The maps were derived from Landsat (1990 and 2000), ASTER and Landsat (2007/08), and RapidEye (2012) satellite imagery by ANAM [62–64]. The maps differentiate between forest plantations, agro-pastoral cover, and various forest-cover classes (Table 2). The 2012 map features a finer spatial resolution than the earlier maps, with nominal minimal mappable areas of 5 ha and 25 ha, respectively [65], though the earlier maps frequently delineate smaller features in practice. A national accuracy assessment of the 2012 map entailing comparison with visual interpretations of aerial photography and high-resolution satellite imagery indicate an overall classification accuracy of 88%–93% [64]. Similar accuracy assessments for the 2007 map [62] indicate an accuracy of ~90 per cent [66]. For the 1990 and 2000 maps, similar accuracy assessments indicate a "very low margin of error" [63] but no quantitative measure was published. However, the 2000 ANAM map compares very well with Sloan's [67] year-2000 map of the Bayano-Darién Region, having 90% accuracy. The plantation class of Sloan's [67] map, which was delimited manually using 1:5000 air photos of 2000 reaching as far east as Santa Fé (Figure 1), is combined with the ANAM plantation class of 2000 in order to capture smaller plantations.

The timing and extent of incremental plantation expansion is observed over 1990–2012 by delineating the planation class of a given year alongside those of subsequent years. Due to the difficulties of detecting immature plantation stands using satellite imagery, particularly Landsat imagery, the apparent timing of plantation expansion should be viewed as potentially temporally lagged by approximately five years. Thus, many of the plantations that become apparent in 2012 may have actually been established just before 2007. Similarly, the apparent extent of plantations in 2000 may be an under-estimate because relatively many stands in 2000 would have still been young.

Table 2. Mapped forest-cover classes.

Mapped Class	Successive State	Description
Mature Forest	Primary forest	Climatic in maturation or nearly so, with little alteration
Cativo Forest (Mixed and Homogeneous)	Primary forest	Mixed or homogenous stands of *Prioria copaifera*, climatic or nearly so, intervened by fire or timber extraction
Intervened Forest	Primary and (fragmented) secondary forest	Primarily intervened primary forest, with fragmented secondary forest.
Secondary Forest	Late secondary forest	Late successive growth, transitioning into primary forest
Plantation Forest	-	Stands are generally 5–20 year old monocultures, depending on the year of observation, typically of teak (*Tectona grandis*) with no understory.
Pioneer Forest	Early secondary forest	Early successive growth, approximately five years old, and no more than 10 years old, including shrubby regrowth and fallows.

Source: After [63] (p. 28).

3. Results

The interactions underlying forest-cover gain vary systematically in terms of transaction and organisation costs as well as the equity of benefits amongst interacting agents. This variation strongly influences the extent, distribution, and nature of regional forest-cover gain (Figure 3). Here transaction costs denote the monetary and non-monetary costs of obtaining the means to realise forest-cover gain (e.g., land costs, social acceptance) while organisation costs pertain to the monetary and non-monetary costs of coordinating, maintaining or reinforcing activities required to continue forest-cover gain thereafter (e.g., labour arrangements, maintaining community organisation).

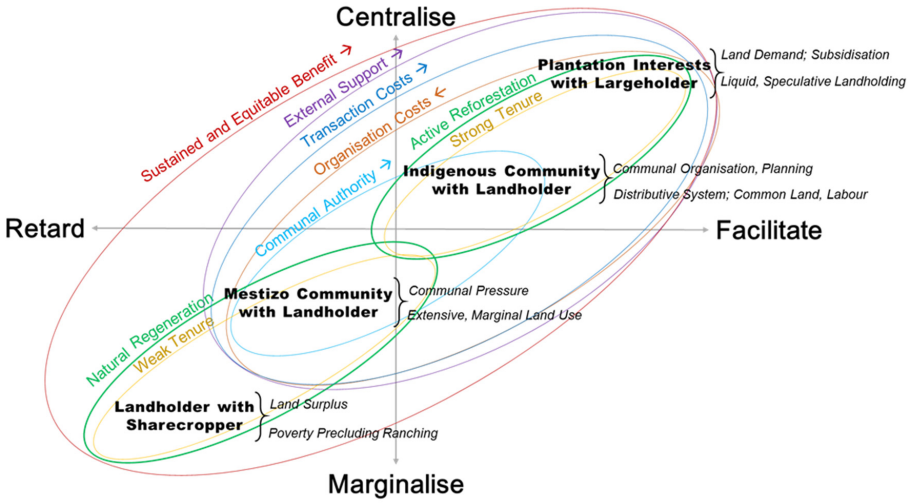

Figure 3. Key factors of forest-cover gain uniting sets of interacting agents. Arrows signify positive or negative effects of a factor on the facility and geographic centrality of forest-cover gain. Notes: the facility of forest-cover gain denotes the ease and efficiency by which interactions facilitate forest-cover gain, not the absolute area of forest-cover gain per se. Ellipses: these define key factors or traits of forest-cover gain uniting sets of interactions. Arrows pointing to the upper-right and lower-left, respectively, indicate a positive and negative effect of a factor on the facility and geographic centrality of forest-cover gain, e.g., greater external support and lower organisation costs both facilitate and centralise forest-cover gain. This schema is illustrative only, as clearly the effect of factors such as transaction costs will not maintain indefinitely at ever-higher values. Parentheses: labels indicate key, complementary traits of the primary (upper) and secondary (lower) agents of a given interaction promoting forest-cover gain.

Active reforestation is extensive at ~30,000 ha and geographically centralised because its underlying interactions entail relatively low organisation costs and equitable benefits for the actors involved. Conversely, natural regeneration is relatively limited to ~3000–5000 ha, geographically marginal and tenuous because it entails relatively high organisation costs and uncertain or unequitable benefits. Figure 3 shows the ordering of the inter-agent interactions underlying forest-cover gain along these lines as well as the key factors linking and differentiating the interactions. The following discusses these interactions in detail. Regeneration and reforestation are discussed separately but best understood here as stations along the broader spectrums of Figure 3.

3.1. Interactions Underlying Natural Regeneration

Historically, forest regeneration on Mestizos' landholdings was extensive but transitory and resultant of interactions between individual landholders. Significant forest regrowth occurred over 1990–2000 coincident with forest fragmentation (Figures 4 and 5) but this gave way to secondary-forest conversion around fragments over the 2000s (Figures 5–7). This expansion and contraction of secondary forest reflects a transitional stage of frontier development during which sharecropping and large household forest reserves—both significant predictors of household regeneration (Table 3)—transitioned from prominence to rarity.

Table 3. Logistic regression of Mestizo household forest regeneration, Bayano-Darién frontier, 2000–2006.

Variable	Coefficient
Constant	4.06
Age Household Head, 2000	−0.25°
Number of Cattle, 2001	−0.31
Number of Cattle Squared, 2001	0.005
Share Cropped, 2000–2006 (yes/no) [a]	4.87°
Per cent Landholding in Forest, 2000	0.08 *
% Cases Correctly Predicted	90
Regeneration Only	83
Pseudo R^2	
Cox and Snell	0.41
Nagelkerke	0.66

* $p < 0.05$, ° $p < 0.10$. Source: After [67]. Notes: coefficients indicate a variable's additive effect on the logged odds of regeneration. [a] Sharecropping arrangements, known as *medias* or *tercias*, refer to cases in which a landholder lets a portion of his land be cultivated by another in exchange for a share of the harvest.

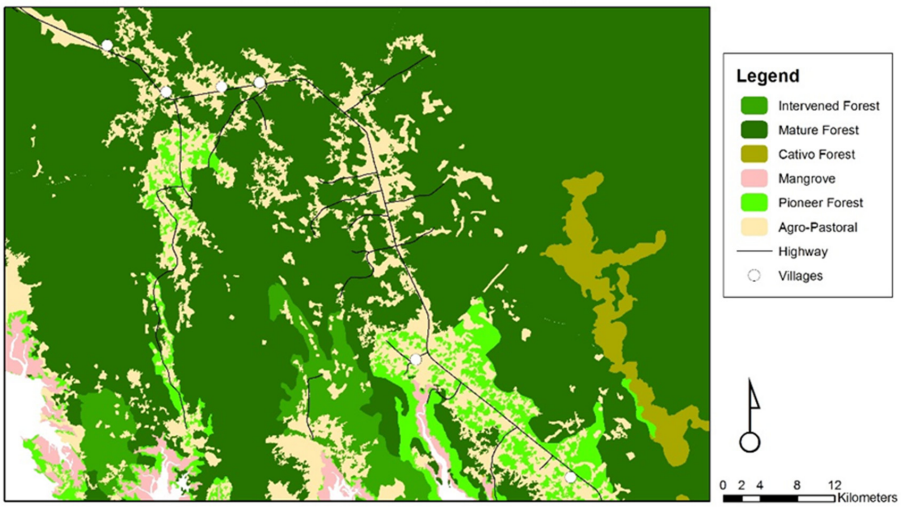

Figure 4. Land Cover in the Bayano-Darién Region, 1990.

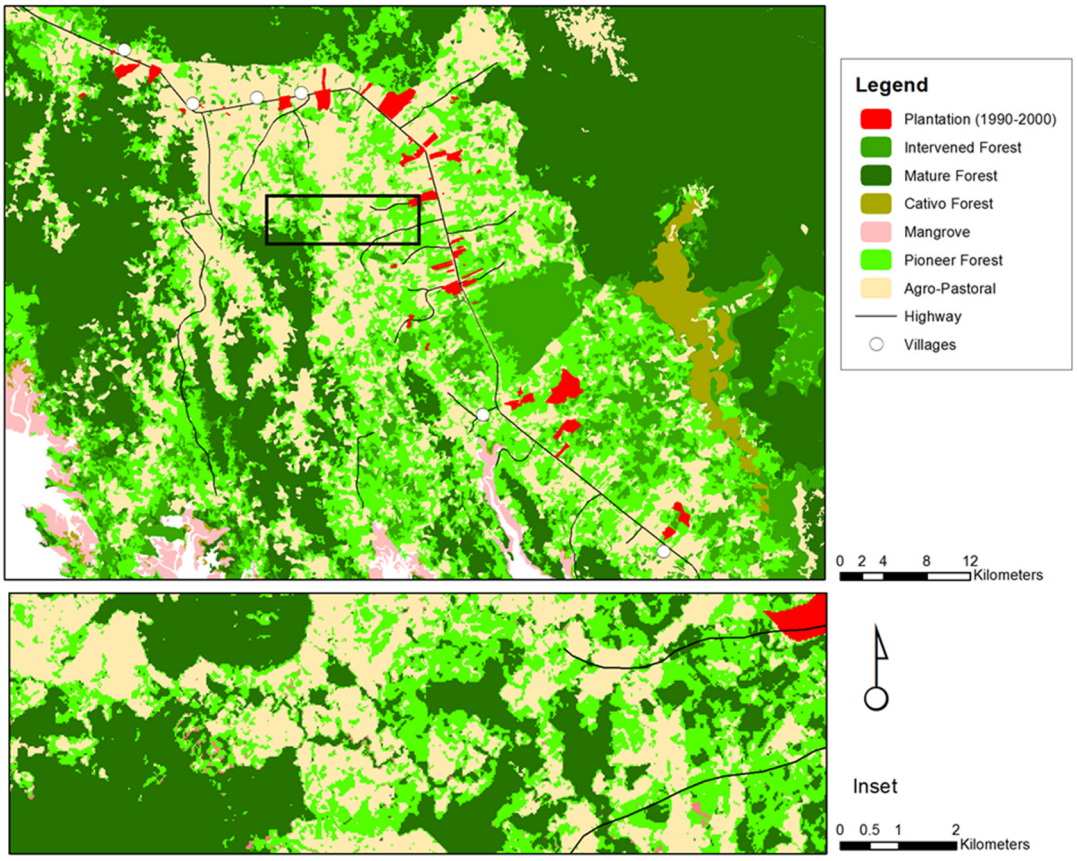

Figure 5. Land Cover in the Bayano-Darién Region, 2000. Source: Insert map after [67].

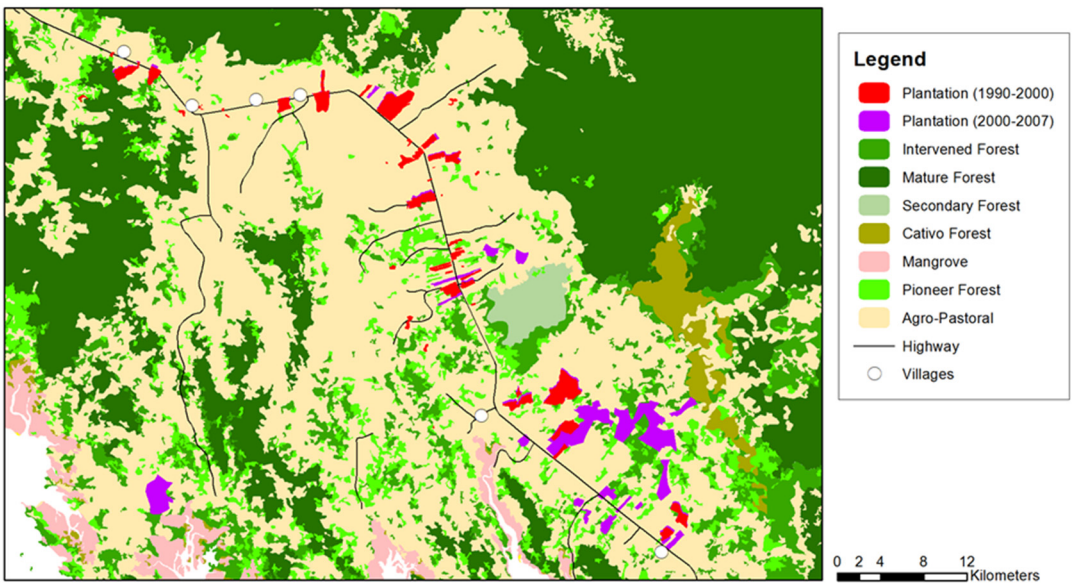

Figure 6. Land Cover in the Bayano-Darién Region, 2007.

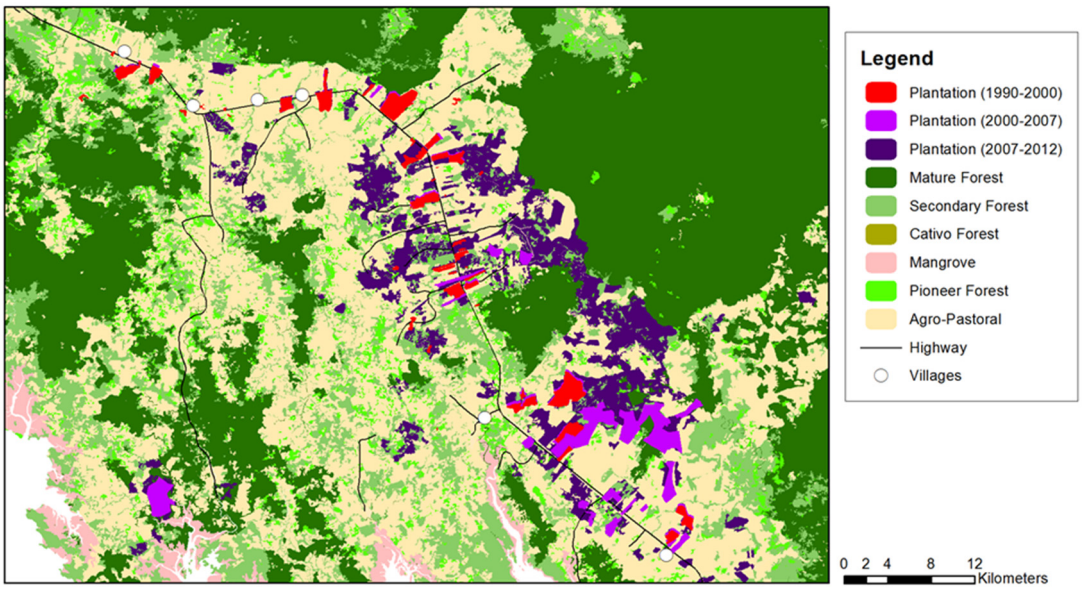

Figure 7. Land Cover in the Bayano-Darién Region, 2012.

Secondary forests were extensive during the 1990s as landholders frequently allocated portions of their still-ample forest reserves to sharecroppers, who would in turn clear and cultivate them for typically one year and leave them to regenerate. This traditional sharecropping institution is known as a *media* or *tercia* and entails a landowner letting a part of his land to a sharecropper in exchange for a portion of the harvest (typically ½ to $^{1}/_{3}$) and/or the service of land clearing and/or conversion [68] (pp. 302–303). This arrangement was often intermittently recurrent, ensuring a generally persistent cover of forest regrowth across the landscape. While interactions between landholder and sharecropper initially entailed mutual benefit and negligible transaction and organisation costs, over the long term it entailed increasing opportunity costs of foregone ranching amongst landholders as their wealth and, thus, their capacity to expand their ranches progressively grew. Accordingly, at the behest of landholders, sharecroppers progressively converted their plots to pasture over the 2000s, precluding their further cultivation and regeneration, and the practice of sharecropping became a relative rarity (Figures 4–6).

Mestizo settlers' increasing interactions with non-farm economic enterprises have not yielded further forest regeneration, contrary to expectations. Some 53% of regional Mestizo agricultural households earn the majority of their income performing non-agricultural economic activities, e.g., metal working, construction (Table S1). While such households allocating labour and capital to off-farm activities enjoy statistically significantly greater incomes and lower rates of pasture expansion than other Mestizo landholders, they expand their pasture only slightly less rapidly in practical terms (the "significant" difference in pasture expansion is <0.25 ha/year at $p < 0.05$) and do not deforest at a significantly lesser rate overall (Table 4). This reflects settlers' concern with overall personal welfare, which they maximise by combining off-farm income with slowed but ongoing on-farm activities. This, in turn, is possible by virtue of the minimal organisational costs of maintaining extensive pasture once established. This situation significantly influences the other, more complex inter-agent interactions promoting forest-cover gain.

Efforts by community WCs to restore forests have struggled as a lack of any precedent for communal institutions has heightened WCs' costs of engaging with landholders (Figure 3). In the absence of a more appropriate prior authority or communal land tenure, be it customary or decreed by the State, WCs have necessarily adapted local institutions at their disposal to pursue forest restoration. Specifically, WCs adapted the institution of *derecho posesorio*—a semi-formal land tenure by which individual landholders have historically claimed forested lands by virtue of their continued occupation

and "productive" exploitation, *i.e.*, cultivation. For instance, WCs now claim lands "occupied" by forest regrowth, a land cover not commonly recognised as "productive" amongst settlers or attributable to a given land user, much less to a collective entity. In other instances, WCs "occupy" and claim lands with aqueducts, resulting in similar disputes over the validity and authority of claims as expansionist settlers advance competing claims. Thus significant community support for forest restoration has not yet translated into a clear communal institutional authority rivalling that of the individual settler.

Table 4. T-tests on Mestizo household income (2005), rate of pasture expansion (2000–2006), and rates of deforestation (2000–2006) as determined by non-farm income held by at least one household member (2000), Bayano-Darién Region.

Mesizo Household Change	Non-Farm Income?		*T*-Value
	Yes	No	
Pasture Expansion (ha/year)	0.18	0.93	2.23 °
Income ($/month)	481	177	2.87 *
Conversion of mature forest (ha/year)	0.22	0.61	1.08
Conversion of fallow (ha/year)	0.23	0.30	0.18

* $p < 0.01$, ° $p < 0.05$. Source: After [67]. Notes: most households having off-farm income sources in 2000 maintained such income for years before and after 2000. Off-farm income does not include day labouring on another's landholding, but only paid, non-agricultural work.

Accordingly, while WCs enjoy negligible transaction costs in acquiring lands for restoration they suffer appreciable organisation costs to maintain them, ultimately limiting potential restoration (Figure 3). The fragility of WCs' claims obliges WCs to constantly monitor and defend them from expansionist or disgruntled landholders as well as to frequently solicit State intervention to settle individual disputes. Organisational costs are, thus, aggravated by WCs' ill-suited institutional basis, limited communal authority, and weak integration with State institutions. Importantly, the organisation costs of restoring an individual forest patch are perceived to be far more certain, immediate, and piecemeal than the communal or individual benefit that restoration may provide, given that the ultimate of benefit of water provision depends on a critical accumulation of forest regeneration across a larger watershed. As a result, progress in forest restoration has been exceedingly slow and confined to marginal lands despite significant efforts, which have tenuously reclaimed and restored ~3000–5000 ha.

3.2. Interactions Underlying Active Reforestation

Substantial reforestation in the Bayano-Darién Region has occurred at the nexus of corporate plantation interests and private landholders and, to a lesser degree, at the nexus of indigenous communities and landholders. This reflects the State's encouragement of forest-cover gain via economic incentive as well as its hesitation to devolve greater authority to Mestizo communities long involved in forest conversion. Under pressure to counter deforestation, the Panamanian government enacted the Reforestation Incentives Law 24 of 1992 to stimulate reforestation [69] while subsequently encouraging the integration of reforestation and forest carbon markets (amendments and regulations of Law 24 include: Executive Decree 89 of 8 June 1993; Article 80-C of the Executive Decree 170 of 27 October 1993; Law 1 of 1994; Law 24 of 1995; Law 1 of 1998; Resolution Number AG-0151-2000; and the Fiscal Reform of January 2005, also known as Law 6 of 2 February 2005 (*esp.* Articles 75 and 76)). State efforts to engage private, agro-pastoral landholders directly have rarely resulted in reforestation [35,70], and indeed such landholders receiving State support to reforest have simultaneously converted natural forests to pasture, again to maximise overall welfare [71] (p. 108). Rather, the reforestation that ensued reflects complementary, mutually-beneficial interactions between such private landholders and plantation interests or indigenous communities minimising the organisational costs of forest-cover gain (Figure 3).

A complementary division of resources and labour between communal and individual agents in the Emberá indigenous community of Ipetí Emberá (Figure 1) has facilitated the relative success

of 550 ha of reforestation by reducing costs and enhancing benefits (Figure 3). The organisational and opportunity costs of reforestation for the community and individual landholders are reduced by the availability of communal labour and securely titled communal land, including additional land for landholders hosting reforestation on communal lands, all of which is coordinated gratis by an existing quasi-traditional communal governance institution [35,54]. Accordingly, landholders availing of communal land and labour distribute the risks of reforestation across the wider community, in contrast to WC-landholder and State–landholder interactions for which risk and reward are relatively asymmetrically distributed. The community governance institution also increased reforestation revenues beyond expected timber revenues by arranging for forest carbon payments, a feat beyond the ability of WCs due to their relatively insecure land tenure and lesser communal authority. These carbon payments are shared with participating Emberá landholders similarly otherwise unable to individually negotiate the complex permits and forest inventories required by non-local institutions.

The forest-cover gain in Ipetí Emberá is more extensive than in most larger Mestizo communities and even many corporate plantation interests of considerably greater resources. Yet despite the organisational strength of Ipetí Emberá, reforestation there has stalled due to the difficulties of sustained collective action. Landholders and labourers have not attained the target ~200 man-days of labour per hectare per year necessary to ensure high rates of sapling survival and growth [72] largely because communal revenues are deferred some years after plantation establishment. Landholders and labourers have, therefore, gradually flouted communal directives concerning plantation maintenance and instead favoured agricultural land uses under their individual control. Under-investment in collective reforestation by individuals has in turn diminished the potential utility of further personal investment, given that reforestation revenues are shared communally and become increasingly less certain with divestment. Thus a downward spiral of declining year-on-year labour investment in reforestation is reported and the communal endeavour is increasingly discounted by its participating members.

The Panamanian government enacted Law 24 of 1992 to stimulate reforestation via economic incentive [69]. Amongst other incentives, Law 24 provided for (a) subsidised credit for the establishment of planted forests; (b) tax exoneration for direct and indirect investment in reforestation, including a 100-per-cent income tax deduction; (c) tax exoneration to processors of plantation timber; and (d) tax exoneration for properties, materials, administration, goods and services, labour, and other costs related to reforestation. Such incentives were highly attractive. Of the $313,729,620 invested in Panamanian reforestation between 1993 and 2004 by public and private entities, tax exemptions alone accounted for between $90 million (28%) and $100 million (32%) [72] (p. 40), increasing profits accordingly. The area reforested surged as a result. Prior to Law 24, Panama had 11,000 ha in forest plantations, most of which were State-owned, regionally-confined, established during the 1970s for conservation purposes, and 11 per cent of which were in teak [72]. Between 1992 and 2007, Law 24 spurred at least 40,000–46,000 ha of reforestation [73,74], rising to 75,000 ha by 2009 [75]. Private commercial interests reforested the vast majority of this area, with 77-80 per cent of the national area in teak [72,74]. In 2008 alone, commercial entities accounted for 84% of the national area reforested, with the balance attributable to communities, NGOs, and various ecological projects [76] (Table 4). Reforestation concentrated particularly in the Bayano-Darién Region [67]. By 2012 reforestation reclaimed 29,381 ha in the region according to the ANAM forest map, with the vast majority in teak.

This surge of reforestation in the Bayano–Darién Region is largely attributable to corporate timber interests and, to a lesser extent, domestic commercial investors (*reforestadoras*) (Figures 4–7). The activities of both these agents centre on interactions with private landholders but follow from the State incentives inherent to The Reforestation Incentives Law. Of the 5733 ha reforested in The Greater Bayano Region between 1992 and 2007 according to the Forest Registry, 28 timber corporations reforested 73% and commercial interests (*i.e.*, corporations and *reforestadoras*) reforested 91% (Table 5). Significant differences in the mean forest plantation area are also apparent amongst corporate interests, *reforestadoras*, and individuals, with corporations establishing plantations fifteen times greater than individuals and six times greater than *reforestadoras* on average (Tables 5 and 6).

Table 5. Distribution of forest-plantation area between corporate, local commercial and individual plantation owners, Greater Bayano Region, in hectares, 1992–2007.

	Corporations	*Reforestadora* and Non-Forestry Orientated Domestic Commercial Interests	Individuals	Total
Mean [a]	150.1	23.6	10	47.4
Area [b]	4203	1038	491	5733
Range	2.5–599	0.9–185	0.3–56	0.3–559
Std. Dev.	185	32	16	107
N	28	44	49	121
ANOVA of Plantation Area by Owner		$F_{2, 118} = 23.32$, $p < 0.001$		
		Commercial Interests (Timber companies, corporations, *reforestadoras* and investors)	Individuals	Total
Mean [a]		72.8	10	47.4
Area [b]		5241	491	5733
Range		0.9–559	0.3–56	0.3–559
Std. Dev.		132	16	107
N		72	49	121
ANOVA of Plantation Area by Owner		$F_{1, 119} = 10.87$, $p < 0.001$		

Source: After [67]. Notes: the Forest Registry contains no inscriptions for forest plantations for 1992 or 1993 for The Greater Bayano Region. The registry records 5733 ha reforested for this region over 1992–2007. [a] All calculations exclude inscriptions of 0 hectares in the Forest Registry; [b] Area is a cumulative sum of the areas of all plantations of the type in question established between 1994 and 2007.

Table 6. *Post hoc* test on ANOVA of plantation area by corporate, local commercial and individual plantation owners, Greater Bayano Region, 1992–2007.

Pair-Wise Comparison of Type of Owner		Mean Difference in Plantation Area (ha) (A *vs.* B)	Standard Error
A	**B**		
Corporation	*Reforestadora*	126.5 *	35.32
	Individual	140.0 *	35.04
Reforestadora	Corporation	−126.5 *	35.32
	Individual	13.5°	5.45
Individuals	Corporation	−140.0 *	35.04
	Reforestadora	−13.5°	5.45

* $p < 0.01$, ° $p < 0.05$ Notes: Tanhane's *post hoc* test. This test is appropriate when group variances are unequal, which is the case here (Levene's test of homogeneity of variance = $70.14_{1, 118}$, $p < 0.001$). $N = 28$ (corporations); $N = 44$ (*reforestadoras*); $N = 49$ (individuals). See Table 5 for ANOVA.

Interactions between plantation interests and private landholders reflect well-known dynamics of frontier deforestation as well as new, less-familiar patterns of forest-cover gain. Plantation interests have bought out ranchers and consolidated their lands in the same manner in which ranchers succeeded smallholders previously [67]. Yet at least two points distinguish the Bayano–Darién from similar "neoliberal frontiers" where well-financed cattle and export-agriculture interests displace landholders further into the frontier (e.g., [36,77,78]). First, commercial timber interests in the region subsume principally the larger ranchers with extensively cleared lands, not the smaller, poorer agriculturalists. Indeed, owing to appreciation in the value of land, which most locals attribute to the plantation boom, those ranchers who might have participated in reforestation instead find it more profitable—or at least more appealing—to sell out to plantation interests. Second, as reforestation interests in the Bayano-Darién Region succeed the larger ranches they displace relatively fewer landholders deeper in the frontier, although even rare occurrences of "displacement deforestation" of ranchers flush with cash may still offset many of the environmental gains of plantation forestry. (To illustrate: suppose ten Bayano ranchers owning 50 ha of pasture each at 45 tonnes of carbon (tC) per ha [79] sell their

pasture to plantation interests for reforestation at 125 tC/ha [80], such that 40,000 tC over 500 ha is sequestered over 20 years. Then suppose that one of the ten ranchers use their proceeds of their land sale to recommence deforestation of mature forest of 335 tC/ha [79] elsewhere. Upon clearing 50 ha of mature forest anew, the rancher would have offset 16,750 tC or 42% of the 40,000 tC sequestered). Observations in the Darién frontier further east confirm that displacement deforestation has indeed occurred, though its actual extent remains uncertain.

The direct interaction between plantation interests and private landholders contrasts the complete lack of interaction between plantation interests and communities. This reflects the autonomy of neoliberal forces penetrating frontiers [8] but also the relative impotence of community institutions to influence regional land use. Plantations in the Bayano-Darién Region have concentrated in a patchwork over the most accessible pastures bordering the highway while the surrounding, partially forested marginal lands remain occupied and progressively deforesting or under tenuous communal claim (Figure 7). These plantations thus constitute a reforesting core within an expanse of expanding pasture, itself fringed by narrowing bands of regeneration beyond which communities have cordoned off fragmented areas of forest regrowth.

The traditional "policy levers" by which the State promotes forest management—namely taxes, subsidies, and permits—have inherent appeal to large-scale commercial interests and help promote them over individual or communal agents. Commercial interests were relatively responsive to the reforestation incentives in part because of their relatively unique concern over asset depreciation, relative rates of return, and taxable income. More importantly, commercial interests were responsive because the incentives lowered their long-term organisation costs of reforestation. Indeed the incentives gave rise to an entirely new industry of subsidised subcontractors that maintained plantations as investments on behalf of non-forestry commercial interests but also international corporate forestry interests, typically with the use of non-local labour. Such was the response to Law 24 that it was criticised and ultimately reformed for having attracted investment by industrial elites, investment firms, and corporations seeking to protect wealth from taxes but having little interest in reforestation per se. In contrast, subsidised transaction costs for land acquisitions and titling appear less relevant to the surge in commercial reforestation. While these subsidies certainly assisted commercial interests in acquiring large, typically informally-occupied or untitled tracts of land from marginal ranchers, the corresponding rapid appreciation of land values in the Bayano-Darién Region greatly offset these subsidies with little apparent effect (Figures 4–7).

The specialisation of corporate interests and reforestadoras in exploiting State reforestation incentives has rendered these agents and their interactions with private landholders highly sensitive to changes in State support (Figure 3). The sudden decline in the annual area reforested after 2002 in The Greater Bayano Region and nationally coincided with the onset of a progressive 20 per cent per annum curtailment in the income tax exemption for plantations established thereafter [see also ref. 82 for similar observations in Ecuador] (Figure 8). Nonetheless, apparently as a result of the fact that the costs of plantation maintenance remained subsidised after 2002 while income did not, plantations became particularly extensive in the Bayano–Darién Region by 2012 (Figure 7). Plantations first apparent in 2012 were far larger and more contiguous than those of 2000, ostensibly to achieve economies of scale (Figures 4–7). Plantations interests in turn reportedly became increasingly selective in their interactions with landholders after 2002 in order to achieve such economies.

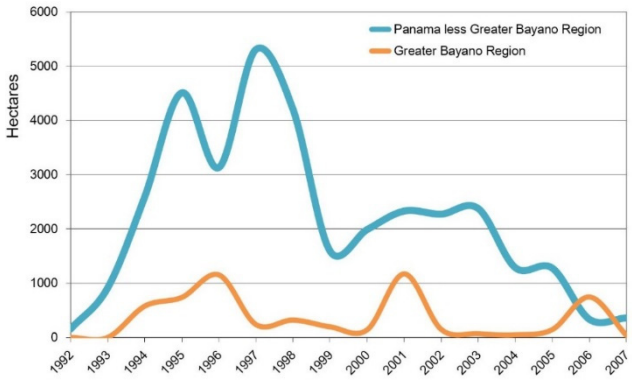

Figure 8. Annual area established in forest plantation, in hectares, for Greater Bayano Region and Panama, 1992–2007. Source: Data from Forest Registry of ANAM.

4. Discussion and Conclusion

The plantation interests, communities, and settlers of the Bayano-Darién Region have partitioned their landscape into distinct realms of forest-cover gain: the core of reforestation along the highway and on communal lands, the peripheral forest areas of regeneration and restoration, and the expanse of rough pastures fringed by regeneration, respectively. Mestizo settlers dominate the landscape both by their sheer numbers and their institutional legacies, but decreasingly so. Landholders of major Mestizo communities in the region occupied 13,707 ha in 2001 according to census records (Emberá claimed a further 5099, Table S1), which while undoubtedly much less than total deforestation regionally [63] is countered to some degree by recent forest-cover gain. Enduring forest-cover gain in the region is characterised by ~30,000 ha of reforestation, of which virtually all is attributable to plantation-largeholder interactions and the remainder to community-landholder interactions in the single indigenous community of Ipetí Emberá. Natural regeneration spans another ~3000–5000 ha and is almost entirely attributable to community-landholder interactions in the much more numerous Mestizo settlements. While landholder-sharecropper interactions spurred a greater area of regeneration over the 1990s, it was highly ephemeral in nature. Similarly, landholder-employer relationships resulted in minimal forest-cover gain despite expectations to the contrary. Thus interactions between agents, of which one explicitly sought forest-cover gain, proved critical to the nature and extent of forest-cover gain. As per the conceptual schema of Figure 3, these interactions differentially rendered a nascent landscape dynamic of forest-cover gain according to differences in the organisational and transaction costs of forest-cover gain as well as the degree of State support and the mutuality of benefit entailed by forest-cover gain.

4.1. The Costs of Forest-Cover Gain

The success of interactions promoting forest-cover gain reflected an inverse relationship between the organisation costs and transaction costs of forest-cover gain. At one extreme, relatively unsuccessful Mestizo communities assume or share regenerating lands at minimal cost but struggle with high organisational cost to maintain their position thereafter, a situation aggravated by the uncertain, cumulative, and unequally distributed benefits of regeneration. At the other extreme, relatively successful plantation interests endure high transaction costs to acquire and secure land and then enjoy low organisational costs to expand and maintain plantations forests thereafter, for which benefits are piecemeal and relatively certain and equally distributed. The community of Ipetí Emberá represents a middle-ground between these extremes, while landholder-sharecropper and landholder-employer interactions are somewhat anomalous given that they lack an agent explicitly interested in forest-cover gain.

At a fundamental level, this inverse relationship between organisational and transaction costs suggests an advantage on the part of interactions enduring higher transaction costs in order to avail of lower organisational costs. Unlike transaction costs, the ongoing nature of high organisation costs leaves forests continually vulnerable to reversion to cleared land and generally appears to be the critical limiting factor for forest-cover gain. For instance, even in Guatemalan communities freely inheriting pre-established, fully-credited agro-forestry plantations requiring communal labour to repay plantation debts with communal harvests—a situation analogous to that of Ipetí Emberá—community members increasingly divested from this lucrative endeavour for the certainty of their own plots, to the ultimate demise of the plantations [81]. Likewise, in Indonesia, mandated cooperation between foreign agro-forestry plantations interests and local landholders whereby land, labour, credit and seed were exchanged was soon ended as plantation interest withdrew due to the inefficiencies of collective organisation [82].

The inverse relationship between organisational and transaction costs bears on the form and nature of forest-cover gain that a State may promote, as to accelerate regional forest transitions in concert with REDD+ activities [30]. State policy and action, which underlie all interactions bearing on forest-cover gain [46], are highly aligned with the manipulation of transaction costs, as exemplified by Law 24. While State policy and action may also influence organisational costs, such influence is arguably more delayed, indirect and unintended. WCs' ongoing struggles with collective forest management and settler land uses echoes early State policies in the region and beyond, for instance. Settlers' predecessors from Los Santos province were historically estranged from their customary collective land-management institutions by legislation favouring "enclosures" by hacienda ranchers [83]. More recently, following the illegal colonisation of the region during the 1970s and 1980s, the State denied Mestizo settlements recognition, agricultural extension, and other services such as road access [52] (pp. 121–125). At the same time the State emasculated its environmental agency, INRENARE, ostensibly to further the economic interests of the State-controlled Bayano Corporation in the region [52], again with deleterious consequences for community forest management. Accordingly, communities were and still are relatively immature assemblages of highly autonomous settlers. Residents historically formed collectives in only a few instances to counter the harassment and spectre of eviction by the State or State-backed commercial loggers and large ranchers, and then only with the encouragement of the local Catholic mission [53]. These collectives soon deteriorated into feuding and dissolution [84]. That WCs similarly struggle today after having been established in part by exogenous interests (again, the Catholic mission) is therefore unsurprising.

Ironically, the very informal land claims and institutions of settler landholdings that frustrate WCs' institutional efforts have facilitated the expansion of commercial plantation reforestation. The incentives of Law 24 favoured large-scale industrial plantations, or at least enticed this sector most effectively, as via its attention to taxable income (Article 4), loans (Article 9), land-tax exceptions for properties reforested by >50% or >200 ha (Article 7), importations of machinery and chemicals (Article 6), and forestry investments, including in administration and mechanisation (Articles 5 and 1.2). The ascendency of corporate plantation agents follows unambiguously from the region's recent history during which large State corporations, State-backed logging interests, and ranchers similarly ousted smaller, informally-titled landholders with the implicit goal of generating badly needed foreign exchange [53] (pp. 123–124). This process describes the development of a "neoliberal agricultural frontier" in which foreign enterprises are enticed to acquire extensive landholdings and produce for foreign markets, as elsewhere in Latin American [8,36]. Whereas this process originally entailed forest destruction in Panama, it has since been rebranded as forest restoration, although the plantations have exceedingly little value in ecological terms [85].

State-backed industrial forest-cover gain in a neoliberal frontier resonates particularly with the conceptual framework of Figure 3. A limited State presence in Eastern Panama has until recently implicitly prioritised support for agents and interactions of forest restoration and management that are either relatively independent of State monitoring (e.g., indigenous forest reserves and authorities) or

otherwise able to organise (*i.e.*, finance) interactions with relative autonomy but still in compliance with State plans and regulations (e.g., the plantations interests' compliance with long-term reforestation plans and environmental assessments). In Panama, as elsewhere [86,87], forest restoration and management has in turn favoured larger, commercial agents while overlooking communities and community forests implicitly as a means of minimising organisation costs on the part of the State (Figure 3). Interestingly, the preference of corporate plantation interests for informally-titled cleared lands in the Bayano-Darién Region contrasts with the preference of comparable interests for untitled forested lands in Amazonia, the latter similarly citing lower organisation by avoiding landholders wherever possible [88]. This underscores the delicate balance that reforestation legislation must weigh between the inclusiveness and extensiveness of forest-cover gain.

4.2. Policy Implications for Large-Scale Forest Restoration

Panama's history of forest restoration, characterised by commercial plantations operating in isolation of community priorities and ecological needs, may be repeated on a massive scale nationally and internationally in the absence of greater State support for interactions favouring geographically and ecologically diverse forest restoration. Panama has recently committed to reforest 1 million hectares by 2035 via public-private partnerships under the so-called Alliance of 1 Million [89]. Numerous multi-lateral forest-restoration aspirations have similarly been recently declared, including The Bonn Challenge (150 Mha by 2020) [47], The 20x20 Initiative (20 Mha by 2020 in Latin America, a target surpassed by national commitments) [48,49], The New York Declaration (200 Mha by 2030) [50], Objective 15 of the U.N. Sustainable Development Goals [51], and various national plans (INDCs) to combat climate change under the UNFCCC [90–92]. Crucially, these aspirations entail no clear, explicit framework stipulating the type or manner of forest restoration. Rather, countries appear free to define forest restoration as best suits their interests and circumstances.

This liberty favours commercial plantation reforestation over natural forest restoration. On the one hand, natural forest restoration inclusive of varied social and geographic contexts may entail relatively complex social interactions requiring unfamiliar, challenging, and potentially costly forms of State support—for example, new communal authorities and forest restoration programmes, or new land tenure schemes for absentee landholders. On the other hand, the model of relatively exhaustive but less inclusive plantation restoration is particularly attractive to the State because of its relative simplicity, visibility, responsiveness to traditional State incentives, autonomy from State administration and amenability to State control. As but one example, investors are seeking to establish coffee plantations in Nicaragua as contributions towards its 2.7 Mha commitment under the 20x20 Initiative [93]. In contrast, Colombia's ongoing experiment with natural forest restoration via retiring old pastures has engendered social unrest due to land alienation and increased incidences of wildfire. The high visibility of plantation reforestation enhances claims by the State that restoration is "additional" while affording unambiguous credit to State policy. Similarly, the responsiveness of commercial plantation interests to economic incentives free of the social complexities and risks of natural regeneration arguably allows the State to coordinate a maximum of "forest restoration" most rapidly at minimal pubic cost, and importantly to insert such restoration into a familiar, managed landscape in which each parcel and forest patch is known to and approved by existing State institutions.

Ultimately the scope of even incentivised reforestation is limited by the predilections of commercial interests towards large, flat, inexpensive and well-situated lands and fast-growing, profitable species. However, with further government involvement there remains greater scope for community participation in commercial reforestation or that availing of carbon payments, which could increase and diversify the area reforested. In Ecuador, legislation requiring reforestation partnerships entailing temporary exchanges of community and/or individual land and labour for shares of commercial plantations established on such lands, as well as seedlings, credit, and so on, have seen reforestation occur over more varied lands and by more varied agents than otherwise likely because locals no longer struggled with upfront costs, marketing, technical unfamiliarity, and so on [94].

Regardless of the mode of reforestation, financial subsidies are critical, especially for community partnerships, considering the additional risks and costs that community organisation entails.

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