Connecting local realities with global policy processes: participatory forest biomass monitoring and scenario-based planning in Panama

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List of Abbreviations

AGB	Aboveground biomass
ANAM	Autoridad Nacional del Ambiente de Panamá (now Ministry of Environment)
ANATI	Autoridad Nacional de Administración de Tierras de Panamá
ANCON	Asociación Nacional para la Conservación de la Naturaleza
ANOVA	Analysis of Variance
APAP	Asociación de Productores de Agropecuarios de Platanilla
AR	Afforestation/Reforestation
AUCPP	Asociación Unión de Campesinos de la Provincia de Panamá
BAU	Business-as-usual
BCI	Barro Colorado Island
BP	Best practices
C	Carbon
CDM	Clean Development Mechanism
CEF	Centre d'Étude de la Forêt
CO_2	Carbon dioxide
COONAPIP	Coordinadora Nacional de Pueblos Indígenas de Panamá
COP	Conference of the Parties
CV	Coefficient of variation
DBH	Diameter-at-breast-height
DPSIR	Driver-Pressure-State-Impact-Response
EDF	Environmental Defense Fund
EPA	US Environmental Protection Agency
FAO	Food and Agriculture Organization of the United Nations
FCPF	Forest Carbon Partnership Facility
FPIC	Free, prior and informed consent
GIS	Geographic information system
GOFC-GOLD	Global Observation for Forest and Land Cover Dynamics
GPS	Global positioning system
INEC	Instituto Nacional de Estadística y Censo de Panamá

INFC	Inventario Nacional Forestal y de Carbono de Panamá
IPCC	Intergovernmental Panel on Climate Change
JA	Jurisdictional approaches
LiDAR	Light Detection and Ranging
LO	Learning objectives
MRV	Measuring, reporting and verifying
NbS	Nature-based solutions
NEL	Neotropical Ecology Laboratory of McGill University and the Smithsonian Tropical Research Institute
NEO	Neotropical Environment Option, MSc and PhD Program of McGill University and the Smithsonian Tropical Research Institute
NGO	Non-governmental organization
OJEWP	Organización de Jóvenes Emberá y Wounaan de Panamá
ORKUM	Organización Kuna de Madungandi
RED	Reducing Emissions from Deforestation
REDD+	Reducing Emissions from Deforestation and Forest Degradation in developing countries
SD	Standard deviation
SES	Socio-ecological system
SESYNC	The National Socio-Environmental Synthesis Center
SNA	Support to National REDD+ Action: Global Programme Framework
STRI	Smithsonian Tropical Research Institute
UNDP	United Nations Development Programme
UNESCO	United Nations Education, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UN-REDD	United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
VCF	Vegetation Continuous Fields tree cover layers of Landsat
VCS	Verified Carbon Standard (now Verra)
WHRC	Woods Hole Research Center
WWF	World Wide Fund for Nature (formerly, World Wildlife Fund)

Abstract

The loss of tropical forests continues at an alarming rate, threatening two-thirds of the world's biodiversity, compromising the livelihoods of forest-dependent peoples, and contributing to climate change. In recent times, two forest policy innovations with implications for Indigenous peoples (IPs) have garnered significant international attention, namely Reducing Emissions from Deforestation and Forest Degradation in developing countries (REDD+), and the devolution of forests and their management to local communities as part of land tenure reforms. Indeed, much of the world's tropical forests are stewarded by IPs, yet these groups remain underrepresented in REDD+, and generally disengaged in forest planning once land tenure is secured. Thus, this thesis examines how IPs can participate fully and effectively at the local level in policy processes of global concern, such as REDD+ and devolved forest management, which aim to arrest forest loss and contribute to international climate and biodiversity targets. In Chapter 1, I present a novel field-based forest biomass monitoring method I devised for REDD+ monitoring, reporting and verification (MRV), which was tested with Emberá, Wounaan and Guna Indigenous technicians in eastern Panama. I reveal that the method is statistically robust, and much faster and more cost-effective than other commonly employed methods. I also confirm the scientific rigor of the community-generated data, and put forward a blueprint for forest biomass monitoring in Indigenous territories. In Chapter 2, I present the results of the aforementioned study, revealing that Darién's undisturbed forests contain the highest known aboveground biomass (AGB) per hectare in the Neotropics, and among the highest tree species richness. The study elucidates high variation in AGB across these forests, explained by disturbances resultant from traditional land use. AGB variation, however, is not discernible with readily-available remote sensing techniques, making the case for the continued and complementary use of field-based methods. Capturing AGB variation is key for establishing reference emissions levels against which carbon gains or losses can be compensated through nature-based solutions (NbS), such as REDD+. Shifting to the second policy innovation, i.e., devolved forest management, I introduce in Chapter 3 the Upper Bayano Watershed in eastern Panama, a pluralistic, multifunctional socio-ecological system experiencing strong deforestation pressures due to territorial conflicts between IPs and colonist farmers. In this chapter, I reveal the positioning of the groups concerning REDD+, and the tensions amongst them and governmental authorities

around land tenure and security, cultural identity, and power imbalances. Key to REDD+ and other NbS, is understanding how the forest estate may change over time. Computer-based models are commonly used to elucidate potential forest futures based on known drivers of deforestation. These studies, albeit valuable, do not consider the aspirations and needs of those who inhabit these landscapes. In response, in Chapter 4, I share the results of a participatory scenario-based planning study that examines potential forest futures in Indigenous territories in the Upper Bayano Watershed under business-as-usual and desired scenarios. The study reveals the Guna and Emberá's perceptions of impending significant forest loss under the former scenario, in contrast to forest accruals in the latter. As part of the study, both groups devised a series of strategies to achieve their desired vision of land use. This study reveals how facilitated processes of social learning catalyzed decisions by the Emberá and Guna to course correct future land-use trajectories, and concludes by examining the prospects for REDD+ in the region. The results from this chapter are particularly relevant in light of recent heightened interest in the inclusion of IPs in NbS.

Résumé

La disparition des forêts tropicales se poursuit à un rythme alarmant, menaçant deux tiers de la biodiversité mondiale, compromettant les moyens de subsistance des personnes dépendantes des forêts et contribuant aux changements climatiques. Récemment, deux innovations en matière de politique forestière ayant des implications pour les peuples autochtones ont retenu l'attention de la communauté internationale, à savoir la réduction des émissions issues de la déforestation et de la dégradation des forêts dans les pays en développement (REDD+) et la dévolution des forêts et de leur gestion aux communautés locales dans le cadre des réformes du régime foncier. En effet, une grande partie des forêts tropicales sont gérées par des peuples autochtones, pourtant, ces groupes restent sous-représentés dans le programme REDD+ et sont généralement désengagés dans la planification forestière une fois que la propriété foncière est assurée. Ainsi, cette thèse examine comment les peuples autochtones peuvent participer pleinement et efficacement au niveau local à des processus politiques d'intérêt mondial, tels que REDD+ et la gestion forestière décentralisée, qui visent à arrêter la perte de forêts et à contribuer aux objectifs internationaux en matière de climat et de biodiversité. Dans le premier chapitre, je propose une méthode de surveillance de la biomasse forestière sur le terrain que j'ai conçue pour le suivi, le rapportage et la vérification (MRV) de REDD+, qui a été testée avec des techniciens autochtones Emberá, Wounaan et Guna dans l'est du Panama. Je démontre que la méthode est à la fois statistiquement robuste et plus rapide et rentable que d'autres méthodes couramment employées. Je confirme également la rigueur scientifique des données générées par la communauté et je propose un modèle de surveillance de la biomasse forestière dans les territoires autochtones. Dans le deuxième chapitre, je présente des résultats qui révèlent que les forêts non perturbées de Darién ont la biomasse aérienne (BA) par hectare la plus élevée connue dans la région néotropicale, et parmi la plus grande richesse en espèces d'arbres. L'étude met en évidence la haute variation de la BA dans ces forêts, expliquée par les perturbations résultant de l'utilisation traditionnelle des terres. Cependant, la variation de la BA n'est pas perceptible par des techniques de télédétection facilement disponibles, ce qui plaide en faveur de l'utilisation continue et complémentaire des méthodes sur le terrain. La saisie de la variation de la BA est importante pour établir des niveaux d'émissions de référence par rapport auxquels les gains ou les pertes de carbone peuvent être compensés par des solutions basées sur la nature, telles que REDD+. Passant à la deuxième

innovation politique, à savoir la réforme de la gestion forestière décentralisée, je présente dans le troisième chapitre une étude de cas basée sur le bassin versant du Haut Bayano dans l'est du Panama. Ce système socio-écologique pluraliste et multifonctionnel subit de fortes pressions de déforestation dues à des conflits territoriaux entre les peuples autochtones et les agriculteurs coloniaux. Dans ce chapitre, je révèle le positionnement des groupes en termes de REDD+, et les tensions entre eux et les autorités gouvernementales autour des questions de régime foncier et de sécurité, d'identité culturelle et de déséquilibres de pouvoir. La clé de REDD+ et d'autres solutions basées sur la nature est de comprendre comment le patrimoine forestier peut évoluer dans le temps. Les modèles informatiques sont couramment utilisés pour élucider l'avenir potentiel des forêts sur la base de facteurs connus de déforestation. Ces études, bien que précieuses, ne tiennent pas compte des aspirations et des besoins de ceux qui habitent ces paysages. En réponse, dans le quatrième chapitre, je partage les résultats d'une étude de planification participative basée sur des scénarios qui examine les futurs forestiers potentiels dans les territoires autochtones du bassin versant du Haut Bayano dans le cadre de scénarios de maintien du statu quo et de scénarios souhaités. L'étude révèle les perceptions des Guna et des Emberá quant à l'imminence d'une perte importante de forêts dans le premier scénario, par opposition à une accumulation de forêts dans le deuxième. Dans le cadre de l'étude, les deux groupes ont conçu une série de stratégies pour réaliser leur vision souhaitée de l'utilisation des terres. Cette étude révèle comment les processus facilités d'apprentissage social ont catalysé les décisions des Emberá et des Guna pour corriger les trajectoires futures d'utilisation des terres, et conclut en examinant les perspectives de REDD+ dans la région. Les résultats de ce chapitre sont particulièrement pertinents à la lumière de l'intérêt récemment accru pour l'inclusion des peuples autochtones dans les solutions basées sur la nature.

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Contributions to Original Knowledge

Chapter 1 presents a new, field-based, participatory forest biomass monitoring method developed in response to global calls for more rapid and cost-effective methods, and the full and effective participation of local communities, including Indigenous peoples, in Reducing Emissions from Deforestation and Forest Degradation (REDD)+. The study was carried out with 24 Indigenous technicians in the remote forests of Darién in eastern Panama and, therefore, also examines the reliability of community-generated data. After testing for various potential sources of error in forest inventories, including instruments, topography and human, the method proved to be statistically robust in estimating plot-level above-ground biomass (AGB), as well as faster and more cost-effective than other well-tested methods currently employed in Panama and around the world. The study also contributes to further dispelling existing prejudices against community-generated data, as it revealed that well-trained Indigenous technicians gather data with the same level of quality and rigor as professionally trained technicians and scientists. Furthermore, following the principles of free, prior, and informed consent (FPIC), the study presents, to the best of our knowledge, the first step-by-step blueprint for culturally appropriate aboveground biomass monitoring efforts in Indigenous territories, which allows for site-specific contextual adjustments in other geographies around the world. Finally, the results contribute to ongoing discussions regarding the role, risks and advantages for local communities engaging in REDD+, in this case, by showcasing the benefits accrued by Indigenous peoples from taking part in this fully participatory study. Benefits included community and human resource development (including temporary employment and income-generating activities); “teaching moments” from elders to youth about Indigenous worldviews about forests; spaces for collective reflection regarding ongoing deforestation in the region; and greater visibility and exposure in national, regional, and international forums regarding the plight of forests under Indigenous stewardship and their role in REDD+.

Chapter 2 presents the results of the forest biomass inventory carried out in Darién, as described in Chapter 1. Notably, the study reveals that undisturbed forest sites in Darién have the highest AGB (436 Mg) per ha in the Neotropics, in comparison to other well-studied forest sites across the region. Similarly, Darién’s forests rank second in terms of tree species richness, with high beta diversity explained primarily by spatial turnover versus nestedness. The results highlight the importance of Darién's forests for climate change mitigation and biodiversity conservation, and the critical role that the region's Indigenous peoples play in its protection and management following customary practices. The study also reveals large variations in AGB in forests under Indigenous stewardship. Tests for sources of variation (i.e., relative density of large versus small trees, forest types, forest state, and combinations of these) confirm that anthropogenic activities, which result in disturbed forest areas, is the key determinant of AGB variation in these forests. However, when AGB variation is examined employing remote sensing technologies, differences are not discernible. These results reinforce the critical need for the continued use of field-based biomass inventorying methods in tandem with remote sensing technologies, particularly in areas where forest disturbance may not result in perceptible changes to forest canopy structure due to cultural land-use norms and practices. Establishing evidence-based reference emissions levels (i.e., aimed at reducing uncertainties) based on these types of inventories, against which carbon losses or gains can be monitored and compensated, is key in the context of investments in nature-based solutions (NbS), such as REDD+.

Chapter 3 shifts from the pristine forests of Darien, and introduces the abutting Upper Bayano Watershed in eastern Panama, its inhabitants, and their complex social interactions, which are both driven and manifested through land-use dynamics that are resulting in the loss of the region's forests. The chapter also introduces the REDD+, a primary NbS, and explains the evolution of discussions taking place in Panama regarding the mechanism. Importantly, the chapter elucidates and clarifies, based on research carried out with the key actors of the region, the positioning that the Emberá, Guna, and colonist farmers take on REDD+, on how this policy instrument, and those promoting it—i.e., the Ministry of Environment of Panama—are considered through the lens of their world visions. Given the case-study approach of the chapter, it uses a hypothetical town hall meeting in which participants are expected to role play the positions of the different groups (Emberá, Guna, colonist farmer and government agency) and decide whether REDD+ is a viable instrument for conserving and sustainably managing the Bayano's forests and improving the livelihoods of its inhabitants. Complex elements related to REDD+ are explored including land tenure and security, power asymmetries, and social justice. This chapter serves as an introduction to the Upper Bayano Watershed and sets the stage for the participatory scenario-based planning exercises described in Chapter 4.

Chapter 4 advances participatory scenario-based planning as an alternative and complementary method to traditional forms of land-use planning, including computer-based modeling, to elucidate potential forest estate futures in complex, pluralistic socio-ecological systems. Revealing these potential futures, based on the aspirations of communities for their territories, natural resources, and livelihoods, is key for designing appropriate land-management strategies, policies, investments, and development plans, including NbSs such as REDD+. Using the Upper Bayano Watershed as a case study, the power of participatory scenario-based planning in fomenting social learning, and thus enabling Emberá and Guna Indigenous peoples to envision and chart a path forward for a different future for their lands, in which forests are protected and restored in culturally-appropriate manner, is revealed. Through the study, a more granular understanding of the value that Emberá and Guna Indigenous people attach to their forests is elucidated, along with the pernicious effects that both groups believe result from deforestation and non-traditional forms of agriculture on their territories. Based on these results, both the Emberá and Guna devised a series of strategies to achieve their ideal vision for the future of their territories and forests. The methods and tools employed, as well as the outcomes of this study, contribute to a growing body of knowledge on socio-ecological systems, in particular, to addressing the challenges of devising integrative approaches for analyzing, explaining and guiding the management of complex coupled human-environment systems.

Preface & Contribution of Authors

This is a manuscript-based thesis consisting of a collection of papers of which I am the primary author. Chapters 1, 2 and 3 have been published already, while Chapter 4 is being prepared for submission. The manuscripts and associated journals are as follows:

Chapter 1

Mateo-Vega, J., Potvin, C., Monteza, J., Bacorizo, J., Barrigón, J., Barrigón, R., López, N., Omi, L., Opua, M., Serrano, J., Cushman, K.C., Meyer, C., 2017. Full and effective participation of indigenous peoples in forest monitoring for reducing emissions from deforestation and forest degradation (REDD+): trial in Panama's Darién. *Ecosphere* 8, e01635-n/a

Chapter 2

Mateo-Vega, J., Arroyo-Mora, J.P., Potvin, C., 2019. Tree aboveground biomass and species richness of the mature tropical forests of Darién, Panama, and their role in global climate change mitigation and biodiversity conservation. *Conservation Science and Practice* 1, e42.

Chapter 3

Mateo-Vega, J., Spalding, A.K., Hickey, G.M., Potvin, C., 2018. Deforestation, Territorial Conflicts, and Pluralism in the Forests of Eastern Panama: A Place for Reducing Emissions from Deforestation and Forest Degradation? *Case Studies in the Environment*, 1-12.

Chapter 4

Mateo-Vega, J., Potvin, C., Cunampio, R., Cunampio, G., Guillemette, M., López, A., Mancilla, L., Martínez, L., Martínez, M., Matos, O., Omi, L., Omi, S., Pacheco, B., Ventocilla, J., Participatory visioning and pathways for forest conservation and restoration in Indigenous lands: elucidating potential future states. *In preparation*.

I am the primary author of all the studies conducted in this thesis. I formulated the hypotheses and questions, proposed the methods, collected the data (in some cases with the collaboration of others, as detailed below), completed the qualitative and quantitative data analyses, and wrote the manuscripts. Catherine Potvin supervised the conceptual frameworks, methods, interpretation of the results, and writing of all the manuscripts in this thesis.

For Chapter 1, K.C. Cushman provided valuable support with “R” code to run bootstrapping analyses on plot and sub-plot level aboveground biomass.

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For Chapter 4, M. Guillemette afforded me access to the three-dimensional model that he created with Indigenous and farmer youth and women, which was used during the participatory scenario-based planning exercises.

Statement on Research Ethics

All research included in this thesis was conducted in full compliance with research ethics norms, including: Scientific Permit SE/P-4-13 from the National Environmental Authority (now Ministry of Environment) of the Republic of Panama; Resolution No. 03-13/DNPH of the National Institute of Culture of the Republic of Panama; Research Ethics Board (REB) File #: 24-0615 from McGill University; and Protocol Numbers: HS13015 and HS15034-02 from the Smithsonian Institution Human Subjects Institutional Review Board (IRB).

General Introduction and Literature Review

Despite a slowdown in the global rate of deforestation since 1990, between 2015 and 2020, the world lost on average 9.28 million hectares of tropical forest per year (FAO, 2020), an area roughly the size of Portugal. The continued precipitous decline in the extent and condition of tropical forests not only threatens 40–60% of the world's terrestrial biodiversity (Bradshaw et al., 2009; Alroy, 2017), but could undermine efforts to limit the global average temperature increase to well below 2°C above preindustrial levels (Houghton and Nassikas, 2018), a goal set by 196 countries at the 2015 United Nations Climate Change Conference in Paris, France (UNFCCC, 2015). Recent studies (Potapov et al., 2017; Watson et al., 2018a; Goldstein et al., 2020) have highlighted the exceptional value of intact, old-growth forests—i.e., those that have been spared from significant anthropogenic impact—in providing fundamental ecosystem services, supporting cultural diversity, and improving human health. Similarly, it has been demonstrated that regenerating secondary forests also provide key ecosystems services, including a disproportionately high capacity to sequester carbon dioxide (CO_2) (Bongers et al., 2015; Chazdon et al., 2016), and maintain high species richness, even though community composition may differ from original undisturbed forests (Phillips et al., 2017). As such, the imperative to sustainably manage, restore, and protect tropical forests, both intact and regenerating, remains high in the global agenda (Edwards et al., 2019), including in the 2030 Agenda for Sustainable Development (FAO, 2018), Post-2020 Global Biodiversity Framework, Bonn Challenge, and climate change discussions (UNFCCC) (UNFCCC, 2021), among others. Indeed, forests figure prominently as one of the principal Nature-based Solutions (NbS) to climate change (also known as natural climate solutions) (Seddon et al., 2020). The concept of NbS is gaining traction in science, policy, and practice (Nesshöver et al., 2017), as a set of actions and approaches for protecting, restoring and sustainably managing ecosystems to address climate change and biodiversity loss. Recent studies suggest that the single largest and most cost-effective individual pathways for tropical countries to meet their climate mitigation goals, as outlined in their National Determined Contributions (NDC) in the context of the United Nations Framework Convention on Climate Change (UNFCCC), is avoiding forest loss, which also offers robust biodiversity and ecosystem services benefits (Griscom et al., 2020).

Increasingly, Indigenous peoples are being acknowledged as key actors in forest-based climate change mitigation efforts (Walker et al., 2014; WHRC and EDF, 2015; Blackman et al., 2017; Blackman and Veit, 2018), biodiversity conservation (Garnett et al., 2018), and the ecological restoration of degraded forest areas (Reyes-García et al., 2019). Although estimates vary, of the 370 million self-identified Indigenous peoples in 70 countries around the world (IFAD, 2012), up to 350 million are forest dependent (Chao, 2012). Along with local communities, they hold under customary tenure systems 25–65% of the world's land area (Wily, 2011; Garnett et al., 2018), although only 12–18% is formally recognized under statutory law (Stevens et al., 2014; RRI, 2015). In the case of forests, two studies (Garnett et al., 2018; Ginsburg and Keene, 2018) suggest that Indigenous peoples and local communities are stewards, legally own, or have legally designated rights to 14–23% of the global forest estate. Noteworthy, are the findings of Watson et al. (2018b) that ~36% of intact forest landscapes are owned or managed by Indigenous peoples. And with regards to forest carbon, from a sample of 52 tropical and subtropical countries, it is estimated that 22% of stocks are stored are under the stewardship of Indigenous peoples, but at least a third of these are on lands in which they lack formal tenure rights (Frechette et al., 2018). In the case of Mesoamerica, this figure ascends to 50% of aboveground forest carbons stocks, but governments do not legally recognize more than one fifth of these (WHRC and EDF, 2015).

Much of the recent and growing interest in the role of Indigenous peoples in forest conservation and management stems from two inter-related policy innovations that have garnered widespread attention in academia, and among policymaker and practitioners, alike, over the past decade and a half. First, in 2007, parties to the UNFCCC affirmed "the urgent need to take further meaningful action to reduce emissions from deforestation and forest degradation in developing countries [REDD+]" (UNFCCC, 2008). REDD+ emerged in response to the recognition that land-use and land-use change, including deforestation and forest degradation, account for ~10.6% of anthropogenic CO_2 emissions globally (Le Quéré et al., 2018). REDD+ has now evolved into a UNFCCC-sanctioned climate change mitigation mechanism (UNFCCC, 2011), and one of the principal NbS policy instruments, under which tropical forests under demonstrable threat of deforestation may ostensibly become a more valuable economic alternative to other land uses (Kanninen et al., 2007; Eliasch, 2008; Pistorius, 2012). Through REDD+, developed countries aim to partially offset their CO_2 emissions by financially compensating, on a performance basis, developing countries for avoiding forest loss, as well as conserving, sustainably managing and enhancing forest carbon stocks (Olander et al., 2012). Central to the architecture of REDD+ has also been the realization of non-carbon co-benefits, namely biodiversity conservation, sustainable livelihoods for local communities, and the opening and strengthening of green markets (Visseren-Hamakers et al., 2012; Luttrell et al., 2013; Turnhout et al., 2017).

To date, however, REDD+ has generally fallen short of expectations (Fletcher et al., 2016; Angelsen et al., 2017). Despite the mechanism facilitating progress on improving forest monitoring systems, governance and policy, and stakeholder engagement in many countries (DiGiano et al., 2020), tropical deforestation and degradation, and concomitant biodiversity loss, remain unchecked; results-based payments are uncommon; and carbon markets have performed well below projections (Duchelle et al., 2018; Massarella et al., 2018). The UNFCCC has also called for the full and effective participation of rural communities, including Indigenous peoples, in REDD+ (UNFCCC, 2010, 2011), but countries have been afforded discretionary power as to how to do this with little guidance. The effective inclusion of communities and Indigenous peoples in REDD+ remains subpar to date (Potvin and Mateo-Vega, 2013; Suiseeya, 2017). Concerningly, despite strong support by REDD+ proponents for benefits to flow to Indigenous peoples and local communities (UNFCCC, 2011), this has rarely been the case (DiGiano et al., 2016; Dawson et al., 2018). Furthermore, in some instances, projects under the guise of REDD+ have ignored critical social safeguards, ultimately exacerbating social injustices (Suiseeya, 2017) and failing to respect Indigenous peoples' rights, consider their world views, or follow the principles of Free, Prior and Informed Consent (DiGiano et al., 2020).

Notwithstanding these shortcomings, REDD+ continues to garner the attention of policy-makers and practitioners alike working in the NbS space (Asiyanbi and Lund, 2020), both as stand-along projects or as part of jurisdictional approaches to low-emissions rural development (Nepstad et al., 2013; Boyd et al., 2018; Seymour, 2020). This is likely due to the fact that at the core of REDD+ lie three of the most important and cost-effective NbS pathways for mitigating climate change, namely reforestation, avoiding forest conversion, and natural forest management (Griscom et al., 2017). Given the preponderant role that Indigenous peoples play as stewards of significant portions of the global forest estate and carbon stocks, their territories will remain a primary target for REDD+ implementation and other NbS to climate change. Ensuring their full and effective participation remains a vexing challenge that warrants greater attention (Suiseeya, 2017; Lofts et al., 2021).

Second, the preoccupation with the net amount and proportion of land, forests and carbon stocks under Indigenous stewardship, whether legally recognized or under claim, has resulted from a growing body of work surrounding the effects of land tenure reform (Robinson et al., 2014; Robinson et al., 2018), and security (Ding et al., 2016; Vergara-Asenjo et al., 2017; Gebara, 2018), on forest conservation and management, and therefore climate change mitigation and biodiversity conservation. As a special report from the Intergovernmental Panel on Climate Change highlights (IPCC, 2019), insecure land tenure limits land-use decisions from local peoples that can contribute to climate change mitigation and adaptation. A significant proportion of the world's remaining forests are located in low and middle-income countries experiencing strong deforestation pressures (Stevens et al., 2014; FAO, 2016), and subject to weak governance and land tenure and security systems (Larson and Petkova, 2011; Karsenty and Ongolo, 2012). Evidence suggests, albeit not universally (Liscow, 2013; Buntaine et al., 2015; Yin, 2016), that in these contexts, devolving and formally recognizing land and forest rights to Indigenous peoples and local communities may curb forest loss and degradation (Ceddia et al., 2015; Ding et al., 2016; Blackman et al., 2017; Holland et al., 2017; Ginsburg and Keene, 2018; Watson et al., 2018b), and thus cut CO_2 emissions (Stevens et al., 2014; Walker et al., 2014; Blackman and Veit, 2018) and avoid biodiversity loss (Garnett et al., 2018).

Although understanding the challenges, opportunities and enabling conditions for land tenure reform and security in support of improved forest management is key (Gebara, 2018), scant attention has been paid to understanding what happens, or could happen, to devolved forests, in terms of extent and condition, under de facto or legal Indigenous management. In the case of potential futures, there are exceptions, however. For example, Walker et al. (2014) conducted a spatially explicit risk assessment of forests in Indigenous territories and protected areas in the Amazon region, spanning nine countries. Using a Geographic Information System (GIS), they examined current and near-term threats from transportation, oil and gas, mining, and deforestation (based on published governmental development plans) and determined that more than half (i.e., 53%) of the region is at risk, and that 43% of that area is within the boundaries of

Indigenous territories and protected areas. In another study, Vergara-Asenjo et al. (2017) modeled potential forest loss in Indigenous territories in the Bayano region of eastern Panama, driven primarily by land invasions from colonist farmers. Using predictors of deforestation including slope, elevation, distance from roads, and previous deforested areas, the authors found that Indigenous territories would likely lose on average ~553/ha of forests per year between 2015–2024.

These studies have played a key role in elucidating the potential fate of forests in Indigenous territories, which is necessary for understanding implications on climate change, biodiversity, and Indigenous peoples' culture and livelihoods. They are also central to exploring trade-offs, devising policies, and taking actions that achieve the greatest positive impact for people and nature. However, modeling the future of forests without considering the aspirations, needs and desires of those who are ultimately responsible for the fate of these ecosystems, such as Indigenous peoples and local communities, results in an incomplete exercise (Peltier, 2018). Indigenous peoples are among the most marginalized groups in the world (UNDP, 2017), and are often stripped of their rights to self-determination, limiting their ability to plan and manage their traditional lands and natural resources according to their own needs and aspirations (Carson *et* al., 2018). By excluding Indigenous peoples from defining their own future through processes of co-creation of knowledge, land-use visioning, planning and management, not only are opportunities to enrich policy, decision-making and on-the-ground actions foregone, but their livelihoods, health, cultural norms, traditions, and natural resources are oftentimes compromised (Zentner et al., 2019).

This thesis explores the question of how Indigenous peoples can participate fully and effectively at the local level in policy processes of global concern, such as REDD+ and devolved forest management, which aim to arrest forest loss and contribute to international climate and biodiversity targets. Importantly, it contributes to a growing body of knowledge around the conceptual framework of "social-ecological systems" (SES), which has gained traction among scholars and practitioners seeking an integrative approach for analyzing, explaining and guiding the management of human-dominated, multifunctional landscapes (Martínez-Fernández et al., 2021). This framework recognizes the strong interconnections and co-evolving dimensions of human and natural systems (Folke, 2007; Sayer et al., 2013) and provides a platform with which to study and manage adaptive complex coupled human-environment systems. Progress has been made in the use of SES as a theoretical framework to explore the resilience of systems to changing conditions (Walker et al., 2006), how groups may self-organize around a common resource problem (Ostrom, 2009), and how environmental changes affect ecosystems, the services they render, and therefore, human well-being (Millennium Ecosystem Assessment, 2005; ICSU-UNESCO-UNU, 2008; Carpenter et al., 2009). Challenges remain, however, on how to operationalize key elements of SES theory into research including the need to: (1) consider systems at multiple spatial, temporal, and organizational scales, (2) integrate multidisciplinary approaches from the natural and social sciences, (3) account for feedback mechanisms among social and ecological systems, (4) manage systems adaptively and based on continual learning, (5) incorporate all relevant stakeholders, (6) build resilience and robustness in systems, and (7) harness, instead of eliminate, complexity (Anderies et al., 2004; Berkes and Turner, 2006; Folke, 2006; Armitage et al., 2009; Martínez-Fernández et al., 2021). Using eastern Panama as a case study site, the thesis touches upon all of the aforementioned elements of SES and advances ways to incorporate them in research and practice. The thesis is structured around four chapters, of which the first three have been published, while the final one is in preparation for submission to a journal:

Chapter 1: *Full and effective participation of indigenous peoples in forest monitoring for reducing emissions from deforestation and forest degradation (REDD+): trial in Panama's Darién*. This chapter presents the results and confirms the statistical validity and cost-effectiveness of a culturally appropriate participatory forest carbon monitoring method devised and tested with Emberá, Wounaan and Guna Indigenous peoples in five territories distributed in the remote forests of Darién, Panama. The benefits for research and Indigenous peoples from this fully participatory method are discussed.

Chapter 2: *Tree aboveground biomass and species richness of the mature tropical forests of Darién, Panama, and their role in global climate change mitigation and biodiversity conservation*. This complementary chapter shares the results from the forest carbon inventory conducted in Chapter 1 and reveals the importance of Darién's forests under Indigenous stewardship to global and regional climate change mitigation and biodiversity conservation. It also confirms the importance of field-based inventories for capturing AGB variation in forest under Indigenous stewardship, given that readily available, course remote sensing technologies are unable to do so.

Chapter 3: *Deforestation, Territorial Conflicts, and Pluralism in the Forests of Eastern Panama: A Place for Reducing Emissions from Deforestation and Forest Degradation?* This chapter, prepared as a case study, serves as an introduction to the Upper Bayano Watershed of eastern Panama, including its Indigenous and colonist farmer inhabitants, and the multifaceted interactions and land-use dynamics taking place, which are shaping the future of the region's forest estate. It also introduces REDD+, a key NbS, and the complex discussions taking place in Panama regarding the implementation of the mechanism. The results of this chapter are essential for clarifying the positioning of the various groups that inhabit the Watershed with regards to the management of their forests and setting the stage for the participatory scenario-based planning exercises (i.e., *visioning* and *pathways development*) carried out by Emberá and Guna Indigenous peoples as described in Chapter 4.

Chapter 4: *Participatory visioning and pathways for forest conservation and restoration in Indigenous lands: elucidating potential future states*. This chapter builds on Chapter 3, and presents the results of culturally appropriate, participatory scenario-based planning exercises (i.e. *visioning* and *pathways development*) carried out with Emberá and Guna Indigenous peoples in the Upper Bayano Watershed to elucidate their desired future of for their forests, in contrast to possible business-as-usual outcomes. The study reveals growing concerns by the region's Indigenous peoples with their current land-use trajectories, and their desire to course correct to protect and restore remaining forests. It also examines if REDD+, as a key NbS policy instrument, is a viable option for catalyzing this desired transition from net forest loss to net forest gain.

The research carried out builds upon more than 15 years of participatory research conducted in eastern Panama with Indigenous peoples (Appendix C4), and took place during a period of increased pressure on the forests of Panama, a problem that remains in effect to this day (Rodriguez, 2021). Of the 21 countries in Latin America and the Caribbean that still house intact forest landscapes, Panama ranked fifth in terms of total loss of forests between 2000–2013 (Potapov et al., 2017). Between 2015 and 2017, the area of tree cover loss increased almost threefold, from 10.6 to 30.9 thousand hectares (ha), virtually all from natural forests, and remained high with a loss of 28,000 ha in 2018 (Global Forest Watch, 2019). Deforestation took place primarily in the eastern Panama SES. This region, which extends approximately 250 km from the Upper Bayano Watershed to the border with Colombia, is commonly referred to as Darién, named after the province that covers a sizeable portion of the area. It is a global biodiversity hotspot (part of the Tumbes-Choco-Magdalena hotspot), recognized for its ecological and cultural diversity (CEPF, n.d.). The Darién houses some of the most important remnants of "tropical moist", "pre montane wet" and "tropical wet" forests in Central America, according the Holdridge Life Zone classification system (ANAM, 2011), and is the only break in the ~30,000-km-long Pan-American Highway. These forests boast very high species richness and endemism (Herrera-MacBryde and ANCON, 1997; Myers et al., 2000) and some of the highest forest carbon stocks in the Neotropics (Asner et al., 2013; Mateo-Vega et al., 2019). However, they are under significant pressure due to colonization pressures from migrant farmers (Peterson St-Laurent et al., 2012), as well as illegal logging by local and foreign criminal syndicates (Bilbao, 2019). Due to these circumstances, the region was identified as a priority for REDD+ by the Government of Panama (ANAM, 2008).

Nota bene: Throughout the thesis, the terms "Guna" and "Kuna" are used in reference to a group of Indigenous peoples who mostly inhabit eastern Panama and northwestern Colombia. "Kuna" was the original term used both in writing and spoken language, until an orthographic reform was proposed by the Guna in 2010. This reform has not been fully embraced by all Gunas, including the inhabitants of the Comarca Kuna de Madungandí, who have opted to keep the name of their territory with its original spelling. As such, both terms are used in their appropriate context throughout the thesis, including when referring to the Comarca or capturing the voice of its inhabitants.

Linking Statement 1

In the General Introduction, the increasing global interest in the involvement of Indigenous peoples in Nature-based Solutions (NbS), including REDD+, is highlighted. However, opportunities and guidance on how to do this in a culturally appropriate manner, remains a vexing challenge in many parts of the world. Rising to the occasion of addressing this challenge, and in response to global calls for more rapid and cost-effective methods for monitoring AGB, I present in Chapter 1 a new, participatory, field-based AGB monitoring method that I developed. This method was implemented and tested with the participation of 24 Indigenous technicians across five Indigenous territories in the remote forests of Darién. I tested for various sources of error related to aboveground biomass (AGB) monitoring, and reveal that the method is statistically robust in capturing plot-level AGB. Implications of this method in terms of dispelling prejudices against community generated data, providing researchers safe access to remote forest areas, and generating direct benefits for the Indigenous peoples that participated in the study are discussed. A blueprint for conducting forest biomass monitoring in Indigenous territories, which was devised in conjunction with Indigenous traditional authorities, is presented for use in other parts of Panama and beyond, subject to contextual adjustments.

Chapter 1: Full and effective participation of indigenous peoples in forest monitoring for reducing emissions from deforestation and forest degradation (REDD+): trial in Panama's Darién

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1.1 Abstract

A primary technical requirement of the climate change mitigation mechanism, reducing emissions from deforestation and forest degradation (REDD+), is to calculate *emissions factors*, that is, the amount of CO_2 emissions or removals per hectare from land use and land-use change. *Emissions factors* are calculated from baseline estimates of the aboveground biomass (AGB) stored in different vegetation types. Ground-based methods for estimating AGB, such as forest inventories, despite being relatively accurate and necessary for calibrating remotely sensed data such as satellite or airborne Light Detection and Ranging, tend to be expensive and time-consuming. Thus, calls have been made to improve the cost-efficiency of these methods within the context of REDD+. Also as part of REDD+, there have been calls for the legitimate inclusion of indigenous peoples and rural communities in various aspects of the mechanism. To address both of these issues, we devised a participatory, rapid, forest inventorying method and tested it across the heterogeneous forest landscape of Darién, Panama. This effort took place within a project that was administratively and logistically managed entirely by an indigenous organization working in collaboration with indigenous authorities in Darién, with funding from the World Bank. A group of 24 indigenous technicians were trained on forest inventorying methods. They established and measured thirty 1-ha plots under our direct supervision. We tested for various sources of error in tree diameter and height measurements. We also tested the scalability of our tree-level biomass estimates to the plot level by comparing our results with simulations conducted on the Barro Colorado Island 50-ha permanent plot data. Results indicate that our rapid, participatory, forest inventorying method effectively captures plot-level AGB, while guaranteeing the full and effective participation of indigenous peoples. The benefits of our method in terms of cost-efficiency and access to remote forest areas are discussed, as well as those accrued by indigenous peoples.

***Keywords*:** Darién; forest above-ground biomass; indigenous peoples; Panama; participatory forest monitoring; reducing emissions from deforestation and forest degradation (REDD+).

1.2 Introduction

The adoption of the Paris Agreement at the 21st Conference of the Parties (COP 21) of the United Nations Framework Convention on Climate Change (UNFCCC) reaffirmed the importance for member states to implement policies and incentives in support of activities relating to reducing emissions from deforestation and forest degradation in developing countries (REDD+; UNFCCC 2015). Deforestation and forest degradation are the major terrestrial, land-use based source of carbon dioxide (CO_2) emissions, contributing approximately 9% of anthropogenic CO_2 emissions globally (Le Quéré et al. 2015). Through REDD+, developing countries may receive financial incentives for avoiding the loss of forests under demonstrable threat of deforestation, as well as conserving, sustainably managing, and enhancing forest carbon stocks, thus reducing atmospheric CO_2 concentrations (Pistorius 2012).

Chief among the conditions to make REDD+ operational is the need for measuring, reporting and verifying (MRV) CO_2 emissions or removals from deforestation, forest degradation, or forestation. For this, *activity data*, which refers to the area that undergoes changes, and *emission factors*, the amount of CO_2 emissions or removals per unit of activity, are key inputs (GOFC-GOLD 2015). *Emission factors* are derived from the amount of carbon stored in different forest carbon pools, including aboveground biomass (AGB), and the extent to which these change over time (IPCC 2006, Verchot et al. 2012). Different methods have been employed to estimate AGB and forest carbon stocks for REDD+ purposes, including remote sensing, such as satellite and airborne Light Detection and Ranging (LiDAR), and ground-based approaches, namely forest inventories (Asner et al. 2013, Baraloto et al. 2013). Combining approaches is the best option for reducing uncertainties surrounding estimates (Saatchi et al. 2011) as forest inventories are necessary to model, calibrate, and improve remotely-sensed data, while the latter facilitate the spatial scaling required to meet the pantropical scope of REDD+ (Mascaro et al. 2014).

This study addresses key challenges in carrying out ground-based estimates of AGB, the largest and most vulnerable pool of carbon in forests (Gibbs et al. 2007). It heeds calls for rapid and cost-effective forest inventorying methods (Baraloto et al. 2013), which is particularly important if the benefits accrued from REDD+ are to surpass the transaction and implementation costs of deploying the mechanism (Olsen and Bishop 2009). We contend that efficiencies and cost-reductions may be achieved through novel forest inventorying methods that guarantee the full and effective participation of rural communities, including indigenous peoples, as called upon by the UNFCCC (Decision 4/CP. 15 and Decision 1/CP. 16; UNFCCC 2010, 2011) . Historically, forest monitoring has been the domain of expert foresters, often as a result of prejudices against community-generated data, considered by some of lesser quality and credibility (Pratihast et al. 2013, Danielsen et al. 2014). Drawing from the experience of successful community-based forestry initiatives, however, a strong case has been made for the inclusion of local communities in forest carbon monitoring to estimate *emissions factors* for REDD+ (Dam and Trines 2011, Larrazábal et al. 2012, Balderas Torres 2014, Boissière et al. 2014). This follows other studies that have successfully engaged indigenous peoples and rural communities in biodiversity (Janzen et al. 1993, Basset et al. 2004) and environmental monitoring (Sheil and Lawrence 2004), including vertebrate population density and abundance (Luzar et al. 2011, Fragoso et al. 2016), resource use (Danielsen et al. 2014), vegetation and land-use mapping (Cummings et al. 2015, Vergara-Asenjo et al. 2015), and game harvest and plant extraction (Constantino et al. 2008, 2012), among others.

According to Skutsch et al. (2011), there is a need to assess the reliability of community-based biomass monitoring initiatives, particularly in light of the potential implications it could have in the cost-effectiveness and local acceptability of national REDD+ schemes. This latter point is particularly relevant in the case of indigenous peoples whose territories, both recognized and under claim, play a fundamental role in housing large swaths of forest (Vergara-Asenjo and Potvin 2014) and aboveground carbon reserves (Walker et al. 2014) in the tropics. Their legitimate engagement in MRV, a fundamental tenet in in respecting their human rights, would also foster their ownership of the REDD+ mechanism (Chhatre et al. 2012).

We are only aware of two studies (Walker et al. 2014, Butt et al. 2015) that have engaged indigenous communities in monitoring AGB for REDD+ purposes in complex, species-rich, multi-stratum tropical forests across broad, heterogeneous forested landscapes in the Neotropics. The study by Walker et al. (2014), which explored the contribution that indigenous territories make to storing forest carbon in the Amazon basin, relied on indigenous organizations and communities for data gathering. However, no assessment of the quality of the data taken by these groups was carried out. The study by Butt et al. (2015) also relied on data gathered by indigenous peoples in Guyana and found >92% of the data to be reliable for use in their analyses. In this study, the indigenous communities only gathered tree diameter data, without height measurements. The area sampled in forests of large stature (i.e., ≥20m) was small (approximately 3 ha). Rising to the challenge of sampling a much larger area, as well as incorporating additional variables such as tree height, we devised and assessed a rapid, participatory, field-based forest monitoring method that was executed by indigenous technicians in the remote, mature forests of eastern Panama's Darién region.

Our study focused on high-biomass areas in indigenous territories in Panama's Darién for two reasons. First, a Panama-wide survey using airborne LiDAR (Asner et al. 2013) estimated that

Darién hosts some of the highest aboveground tree carbon stocks in the country. The study, however, pooled all forests with ≥130 Mg C/ha into a single carbon density class. Elucidating the variation of this upper margin of aboveground carbon stocks, based on ground-level forest inventories, was an important consideration for conducting this current study. Second, the Government of Panama embarked on its REDD-readiness process in 2008 (ANAM 2008). As part of this effort, a national forest and carbon inventory (Spanish acronym: INFC) was conducted under the leadership of the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD; Melgarejo et al. 2015*a*). Of the thirty-seven 2-ha "sampling units" established by UN-REDD across the country, only five were established on indigenous lands (Melgarejo et al. 2015*a*). Of these, only two were set up in the Darién region, one in the *Emberá-Wounaan Comarca*, and one in *Tierras Colectivas Emberá y Wounaan* (hereafter, *Tierras Colectivas*). Our study, even though it utilizes a different sampling methodology, complements the national-level INFC by focusing on mature forests in indigenous territories in Darién and significantly increasing the sampling intensity in this region of the country.

Our aim through this study was to develop and implement a rapid forest inventory method, and:

1. evaluate the performance of the technicians that conducted the forest inventory;
2. test for common sources of error in tree measurements;
3. assess the scalability of our tree-level AGB estimates to the plot level; and
4. examine the efficiency and cost-effectiveness of our method.

Furthermore, we explored the benefits of having conducted this study under the umbrella of a project managed administratively and logistically by an indigenous organization in collaboration with traditional indigenous authorities, following a rigorous process of free, prior and informed consent (FPIC). FPIC aims to ensure that indigenous peoples or traditional communities have the right to give or withhold consent to proposed projects that may affect their customary territories, after developing a full and clear understanding of the implications of the initiative (Colchester 2010).

1.3 Methods

A collaborative grass-roots initiative

Between 2010 and 2012, the Neotropical Ecology Laboratory (NEL) of McGill University and the Smithsonian Tropical Research Institute (STRI) led an initiative to provide capacity-building on REDD+ to Panama's indigenous peoples, governmental officials, and farmers (Amado et al. 2014). Members of the *General Congress of Tierras Colectivas* (hereafter, *General Congress*) were among the most active and requested this study as a follow-up. The leaders of the *General Congress* expressed interest in further strengthening their capacity on REDD+ and elucidating the volume of carbon stocks in their mature forests across Darién. This would allow them to engage in evidence-based decision-making regarding REDD+, if they were to opt to take part in the mechanism in the future. This study is focused on their first interest.

To carry out this study, the *General Congress* established a partnership with the Organización de Jóvenes Emberá y Wounaan de Panamá (Organization of Emberá and Wounaan Youth of Panama—OJEWP), Environmental Defense Fund (EDF), and the NEL. OJEWP received and managed the funds from the Forest Carbon Partnership Facility (FCPF) of the World Bank and handled the administration and logistics of the project, as well as communications with the *General Congress*. EDF facilitated the relationship between OJEWP and FCPF and provided outreach support, while the NEL offered scientific leadership and led the field expeditions.

Study area

Based on (1) a stratification of *Tierras Colectivas* according to forest types, (2) the spatial distribution of the territories across Darién, (3) internal decision-making by the *Caciques* (Chiefs of the General Congress) regarding territories and forested areas of particular importance to them, and (4) safety considerations given the proximity to the border with Colombia and the potential presence of guerrillas, five of the 13 territories of *Tierras Colectivas* were selected for this study, namely Arimae, Playa Muerto, Caña Blanca, Río Congo, and Balsas (Fig. 1.1).

Engaging Emberá and Wounaan people in Tierras Colectivas

Free, prior and informed consent and knowledge sharing: beyond lip service. Decision making among the Emberá and Wounaan is decentralized and takes place at three levels, namely general, regional, and local congresses (Cansari 2001). Therefore, for this study, a process of FPIC was carried forward by OJEWP, in company of the NEL, and followed with the *Caciques* of the *General Congress*, regional leaders, *Nokos* (Territory and/or Community-level Chiefs), as well as community leaders and members to obtain approval to carry out research in their forests. The FPIC process was carried out in accordance with the *McGill University—Neotropical Environment Option (NEO) Protocol for Research in Panama's Indigenous Communities* (McGill University 2006) which was developed by an inter-disciplinary team of indigenous professionals from Panama in collaboration with Canadian scholars from three universities to provide ethical guidelines for any research endeavor involving indigenous peoples and their territories.

Even though approval for the project was granted by the *General Congress*, community-level meetings were held in each territory, including regional and local authorities, to (1) address the scope and objectives of the study, (2) offer a short training on the links between forests, deforestation and climate change, and REDD+, (3) field questions and concerns, and (4) request local-level authorization to enter the forest. Each of these initial meetings lasted 3–5 h. During the study and at the end of the fieldwork, community-level meetings were held to inform about the work carried out.

Final research results, including a report, a map of forest cover and estimated AGB and forest carbon stocks, and a poster that depicts pictorially the fieldwork carried out, were also given to the *Caciques* and *Nokos*, and presented to the communities on a subsequent visit to each territory a year later, and as the occasion arose thereafter.

Building local capacity for forest inventorying and REDD+. At the beginning of the study, 22 individuals received a two-day training in the territory of Arimae on the theoretical and practical aspects of conducting forest inventories and REDD+. From these, five indigenous technicians (Emberá, Wounaan, and Kuna) from OJEWP and the territory of Arimae (co-authors NL, MO, JBar, RB, JBac), as well as one technician of *mestizo* origin from OJEWP (co-author JS), became the core team. This group was selected by OJEWP and the *Caciques* of *Tierras*

Colectivas. One of us (LO), an Emberá woman and member of OJEWP, handled communications with the traditional authorities of the *General Congress* and the territories visited, as well as managed the logistics of the expeditions. This team of seven members, along with the project lead (JM-V) and a professional field technician from STRI (JM), participated in all five expeditions.

In each territory, four to eight additional community members were assigned by the *Nokos* to take part in the study. These local technicians received a half-day training. Due to the need to read the numbers on the instruments (e.g., diameter measuring tape, ultrasonic hypsometer, clinometer, and global positioning system [GSP]) and/or read and enter data in the data collection sheets, all technicians were literate. The level of schooling among the team ranged from elementary school to university-level education.

In addition to the aforementioned core team, 24 indigenous technicians took part in the fieldwork component of the project. To carry out the fieldwork, the technicians were divided among four teams. One team comprised of two technicians was responsible for marking the limits of each plot, while two teams of three technicians were responsible for independently measuring the trees. A fourth team, comprised of a professional botanist, a "botánico" (i.e., Spanish name for botanist, which are local healers knowledgeable of plants), and an assistant, was responsible for identifying trees by their scientific and local name and collecting botanical samples.

Participatory location of plots within the territories. To improve the resolution of forest carbon stocks in the zones of high biomass identified by Asner et al. (2013), we sought to identify prospective areas where plots could be established, relying on a combination of local knowledge and scientific criteria. Within each territory, *Nokos,* elders and hunters, served as advisors. They were presented with a map of their territory and asked to identify, within the different life zones/forest types, areas that have a high density of large trees (i.e., high AGB). Through deliberations, each group reached a consensus. Sampling was carried out in as many of these areas and as wide an area as possible in each territory. In total, as part of the FPIC process, approximately 38 meetings and trainings were held with the communities prior to, during, and following the study (Table 1.1).

Plot size, shape, and establishment

Thirty plots of 1-ha each were established and measured by the indigenous technicians in *Tierras Colectivas* to capture variation in AGB and tree diversity within each territory. Half of these were established in mature forests for which there is a known history of and/or evidence of disturbance (e.g., tree stumps, nearby agriculture, trails), while the other half were established in forests that had not been disturbed.

Plot size (1 ha) was chosen as the largest possible plot (Pearson et al. 2005) that could be measured in a single day, even if hiking to and from the site required up to 4 h each way. Preliminary trials carried out in the Comarca Kuna de Madungandí, also in eastern Panama, settled on 1-ha plots. Aligning with well-established methods used in other studies (Baraloto et al. 2013) we chose square-shaped, nested plots, with four internal 12 x 12 m subplots in each corner (Fig. 1.2). The nested-plot forest inventorying approach is commonly used to sample trees in different size classes, with large trees sampled at the plot level, and smaller ones sampled in the subplots (Pearson et al. 2005). The four subplots were located in the corners to maximize the distance between these. The plots were randomly established within the areas identified by the advisory groups and within the specified life zones/forest types. The four vertices of the plot were recorded with a global position system (GPS; Garmin GPSmap® 60CSx) to a precision of 1.5 m or below.

Measuring and verifying tree diameter

At the plot level, all living trees and palms ≥50 cm dbh were measured, and in the 12 x 12 m subplots, all living trees and palms ≥10 cm dbh. The ≥50 cm dbh cut-off was selected due to the large girth of trees found in these forest types. Trees in the smaller size class were measured to estimate what we call "background" AGB: the biomass of trees ≥10 cm and <50 cm dbh in a unit area. "Background" AGB at the plot-level is calculated by extrapolating the mean subplot AGB values in each plot to a 1-ha area. Trees with <10 cm dbh were excluded from this study as they represent a marginal portion of AGB in mature forests (Brown 2002). Measurements were taken according to standard rules and considerations employed in forest inventories for both regular and irregular trees and topography (U.S.Forest Service 2012).

To quantify and reduce errors in measuring dbh (Condit 1998, Chave et al. 2004), all trees ≥50 cm dbh in 13 plots, and all trees ≥10 cm and <50 cm dbh in the subplots of seven plots (n = 464), were measured twice by different technicians. In this case, recently trained indigenous technicians took both measurements, but a professional technician from STRI (JM) closely monitored one, while the other measurement was taken unsupervised. The two sets of measurements were taken independently. The mean difference among both measurements and the standard deviation (SD) were calculated. Furthermore, we ran a Wilcoxon rank sum test to compare dbh measurements taken by both technicians, following a Shapiro-Wilk test for normality, as well as compared their coefficient of variation (CV).

Assessing and reducing errors around tree height measurements

Tree height is often ignored in forest inventories due to difficulties in taking measurements in the field (Molto et al. 2014). However, we included them in this study since they can significantly improve AGB estimates of individual trees (Hunter et al. 2013). Tree height was measured for all 1399 living trees in the 30 plots. Our sampling design quantified and aimed to reduce three sources of error that can plague height measurements: (1) instruments employed, (2) humans, and (3) topography.

To compare performance of the tree height measuring devices, all 1399 trees were measured with a Vertex ultrasonic hypsometer (Vertex III and Transponder T3 by Haglöf), and of these, 1203 trees were also measured with a mechanical clinometer (Suunto PM-5/360 Optical Reading Clinometer). In the case of trees measured with both instruments, 379 were measured twice, and in one case, three times, resulting in 1583 independent measurements of tree height. These were stratified according to three height classes: (1) ≥40 m (emergent layer), (2) 30 m through <40 m (canopy layer), and (3) <30 m (mid- and understory layer) following Richards (1996) and based on observations of forest structure by the project lead. A Wilcoxon rank sum test was then used to compare the height measurements taken with both instruments for each forest stratum, following Shapiro-Wilk tests for normality.

To address random measurement error, 464 trees in 13 plots and 32 subplots were measured twice by different technicians, once by a recently trained indigenous technician and the second time by the professional technician from STRI. Both sets of measurements were taken independently from one another. The mean difference between both measurements and the standard deviation were calculated for the three different forest height strata, and a Wilcoxon rank sum test was also applied to test for significant differences in height measurements between technicians.

To determine whether the vantage point from which a tree is measured introduces error in height measurements, 59 trees were measured twice by the same technician using the same ultrasonic hypsometer but from two different vantage points. A clinometer was used to measure slope angle and calculate the difference in angle relative to the base of the tree with each measurement. Mean results from both measurements were compared using a paired *t*-test, following a Shapiro-Wilk test for normality.

Finally, the accuracy of height measurements taken by our field technicians in Darién was estimated in a complementary experiment carried out in Barro Colorado Island in central Panama. Barro Colorado Island, like much of Darién, is covered in lowland tropical moist forest that exhibits a similar forest structure, and thus shares the same challenges for measuring trees. Height was measured on 109 trees in closed-forest conditions from the ground with the ultrasonic hypsometer. The height for all of these trees is known for 2013 based on measurements taken from various observation towers located throughout Barro Colorado Island, following Larjavaara and Muller-Landau (2013). To compare the measurements taken with the ultrasonic hypsometer vs. the known tree height in 2013, the data were stratified into three size classes based on known height, namely <20, ≥ 20 through <30, and ≥ 30 m. The measurements taken with each modality (ultrasonic hypsometer vs. tower) for each height stratum were then compared using a paired *t*-test, following Shapiro-Wilk tests for normality.

Scaling AGB estimates

AGB for all trees was estimated using the improved pantropical allometric model developed by Chave et al. (2014). For palms (family Arecaceae), AGB was estimated using Goodman et al. (2013), assuming a mean dry mass fraction (dmf) for all palm species of 0.370.

Error in estimating forest carbon stocks originates from scaling values from small sampling units to larger spatial scales (Clark and Kellner 2012). We considered two potential sources of variation that could affect AGB estimates at the plot level and propagate to higher scales (i.e., territory and landscape). First, the presence of large trees has been shown to be a key determinant of plot-level AGB (Slik et al. 2013, Stephenson et al. 2014). We hypothesized that through density-dependence, the number of big trees in a plot might negatively impact the number of small trees. To rule out this hypothesis, we compared the mean AGB for subplots with large trees against the mean AGB for those without large trees using a Welsh two-sample *t*-test.

To corroborate our results, we also compared AGB in subplots with and without large trees in R Version 3.3.1 (R Core Team 2016; Data S1 and Metadata S1), using the 2010 census (Census 7) data from the well-studied Barro Colorado Island 50-ha plot (Condit 1998, Hubbell et al. 1999, Hubbell et al. 2010). For this, we divided the 50-ha plot into 50 individual, 1-ha units. AGB was estimated using the Chave et al. (2014) model, local wood density data (CTFS 2014), and a site-specific Weibull relationship between diameter and total tree height (Feldpausch et al. 2012, Muller-Landau, *personal communication*). We then simulated the four 12 x 12 m subplots nested in the corner of each 1-ha plot and summed the AGB of trees in the "background" size class. We then categorically separated all subplots between those with and without large trees (i.e., ≥50 cm dbh). A Wilcoxon rank sum test was then conducted, following a Shapiro-Wilk test for normality to compare both sets of subplots.

Second, we tested if our design yields "background" AGB estimates that are scalable to the plot level, also using the Barro Colorado Island 50-ha plot data. Because in Darién we sampled 30 plots, we used bootstrapping to randomly select 30 plots, 10,000 times, among the 50 simulated 1-ha plots on Barro Colorado Island. Each time, the mean AGB of the four subplots within each plot was calculated and extrapolated from a subplot area of 144 m^2, to a 1-ha area. The known "background" AGB values were also calculated for each 1-ha plot during the same bootstrapping test. The mean extrapolated and known "background" AGB values for the same plot were then compared for significant differences using a Welsh two-sample *t*-test.

1.4 Results

Study area

Of the four most prevalent forest types in *Tierras Colectivas*, we sampled three, namely Tropical Moist Forest (18 plots), Pre-Montane Wet Forest (eight plots), and Tropical Wet Forest (four plots) between April and July 2014. The plots had an average of 30 large trees (i.e., ≥50 cm dbh) per hectare, with a range of 5 to 57 large trees per hectare (Fig. 1.3). Plots in the disturbed mature forest had on average 22 large trees per hectare, while those in the undisturbed mature forest had 39 large trees per hectare (Fig. 1.3).

Plot establishment

One of the objectives of our study was to develop a rapid forest monitoring method especially for cases in which the luxury of time and resources is limited due to long travel distances and remoteness. Of the 30 plots, 20 were established and measured in a single day. Eight plots were measured in half a day, allowing for two plots to be established and sampled in a single day, and two plots were sampled over the course of 2 d due to poor weather and reduced visibility within the forest, which hindered tree height measurements.

Measuring and verifying tree diameter

The mean dbh of the 464 trees measured by the two indigenous technicians, one supervised by a professional technician and the other unsupervised, was 63.2 ± 38.6 cm and 63.5 ± 39.9 cm, respectively. The large standard deviation is due to the range of tree sizes included in both sets of measurements, 10.1–250.3 cm and 10.1–258 cm, respectively. The mean absolute difference between both sets of measurements was 2.7 ± 7.9 cm, equivalent to 4% of the mean tree dbh for both sets of measurements. The Wilcoxon rank sum test of the two sets of measurements confirmed that there were no significant differences (P = 0.78). The trees measured by the unsupervised, recently trained indigenous technician had a comparable CV to that of the technician who was supervised by the professional technician (0.63 vs. 0.61).

Assessing and reducing errors around tree height measurements

The tree height measurements (n =1583) taken with both the ultrasonic hypsometer and the clinometer were overall similar (Fig. 1.4a). For all forest strata, the mean difference in measurements was less than 1 m, equivalent to less than 4% (Table 1.2). A Wilcoxon rank sum test was used to compare measurements broken down by size classes. For trees in the emergent forest layer (≥40 m) and the mid- and understory layer (<30 m), based on the ultrasonic hypsometer, there was no significant difference between tree height measurements taken with both instruments (P = 0.42 and 0.10, respectively). For the canopy layer (≥30 and <40 m), however, the difference was statistically significant based on the ultrasonic hypsometer (P = 0.04), with the clinometer tending to provide trees measurements that are higher than the ultrasonic hypsometer (Table 1.2).

The mean difference in height measurements between both technicians for the three forest strata was in all cases under 3.5 m or less than 9% (Table 1.2). We found no significant difference in tree height measurements for the ≥40 m tree strata measurements (P = 0.064), but did find significant differences in measurements for trees ≥30 and <40 m ($P = 1.124 \times 10^{-05}$), and trees <30m in height ($P = 5.239 \times 10^{-12}$). The CV for measurements taken by both the indigenous and professional technician was virtually the same (0.41 vs. 0.40).

A comparison of the means for two separate measurements taken of 59 individual trees with a ultrasonic hypsometer and by the same technician, but from two different positions and angles relative to the tree’s base (i.e., influence of topography), showed no statistical significant difference (P = 0.17) based on a paired t-test. A summary of the potential three sources of error is presented in Table 1.3.

In Barro Colorado Island, we compared measurements of 109 trees taken with the ultrasonic hypsometer with the known height (Fig. 1.4b). A paired t-test, failed to detect significant difference for trees <20 m tall (P = 0.14), while significant differences were found for trees ≥20 and <30 m, and trees ≥30 m, with Ps of 1.14×10^{-05} and 2.16×10^{-05}, respectively. The mean difference between measurements of known height and those taken with the ultrasonic hypsometer varied from ~2 to 4 m and ~13% among the three forest strata (Table 1.4). In general, it appears that measurements taken with the ultrasonic hypsometer tended to overestimate tree height with 79 measurements being greater than the known height (72%) and only 30 measurements being below (28%).

Scaling AGB estimates

Tree-level AGB estimates. The Chave et al. (2014) allometric equation was developed for trees up to a maximum diameter of 212 cm. Of the 1399 trees sampled in this study, all but nine met the maximum size threshold. Although we acknowledge that AGB estimates for trees that fall outside the established ranges for an allometric model may be inaccurate (Clark et al. 2001), it is likely that individual tree-level errors such as these average out in large plots such as the ones established in this study (Chave et al. 2004). The nine out-of-range trees were distributed throughout seven different plots.

Scaling from the tree to the plot. We found no significant difference (P = 0.89) in the mean “background” AGB values for subplots that have or lack large trees (i.e., ≥50 cm dbh). Similar to our results from *Tierras Colectivas*, no significant differences in “background” AGB were found between subplots with and without large trees for the validation carried out on subplots within the Barro Colorado Island plot (P = 0.09). Finally, the simulated comparison of mean known total “background” AGB with the mean total extrapolated values on Barro Colorado Island for 30 randomly selected plots, following a bootstrapping test (10,000 iterations), showed no significant difference either (P = 0.08). The results confirm that our design effectively captures plot-level AGB.

1.5 Discussion

Improving the effectiveness and efficiency of forest biomass monitoring

Our study was motivated, in part, by Baraloto et al. (2013) who ran a series of computer-based simulations on existing forest inventory data from six Neotropical sites. Using five different methods, they identified the most effective and efficient method for accurately estimating AGB and capturing floristic variation. In the case of AGB, they found that *modified Gentry plots of 0.5 hectare* outperformed all other methods in all sites with the exception of Barro Colorado Island in Panama (i.e., 0.5-ha square plots performed better). This method also required the least amount of effort, defined in person-days, compared to the other four methods tested.

The simulations, however, took place within permanent plot sites that range from 10 to 50 ha, and due to the nature of the study, no simulations were possible across large, heterogeneous forested landscapes. Our study, in contrast, was carried out across a landscape that covers approximately one-quarter of all of Panama's land-based area, and encompasses intact and intervened forested landscapes. It is also important to note that our study more than doubled the area sampled in mature forests through the INFC in Panama (i.e., 24 ha) (Melgarejo et al. 2015*b*). And in the case of Darién, our sampling intensity was almost four times greater.

From a methodological perspective, one of the noteworthy advantages of carrying out this study with indigenous organizations at the helm, and following strict protocols of FPIC, was being granted access to forests that many would qualify as inaccessible, due to remoteness, lack of approval from indigenous authorities, or security reasons. Even though the distances traveled during our study were far for those of us who were not from the territories, the forests we studied are in practice the "backyard" of the communities. We always reached the areas that the community advisory groups directed us toward and even set up nine plots in remote areas that had previously been sampled with airborne LiDAR (Asner et al. 2013). Asner et al. (2010) claimed that one of the key advantages of airborne LiDAR is its capacity to sample remote areas, but at least in the context of eastern Panama, working with indigenous peoples provides the same level of accessibility at lower costs.

We established and measured plots more rapidly than other studies. For example, in the pilot phase of the INFC, the estimated time to survey a 2-ha sampling unit was 4 d, or 2 d/ha (Melgarejo et al. 2015a), more than twice as much as our method. The INFC required 14 person-days to survey 1 ha (Melgarejo et al. 2015*b*), while we required 10.3, including a team of three technicians (i.e., two indigenous technicians supervised by a professional technician) that were charged with re-measuring trees to test for the various sources of error in dbh and height measurements (Table 1.5). Without this additional team, which would not be required in a fully operational forest inventory, we could measure a 1-ha plot in seven and half person-days, while the INFC would require 10.5 person-days (Table 1.5). In the case of the *modified Gentry plots of 0.5 hectare*, Baraloto et al. (2013) estimated that eight person-days are required to survey half a hectare, which is more than twice as much as the number person-days required with our method.

According to the financial report submitted by OJEWP to FCPF-World Bank (15 December 2014), of the US$50,000 grant they received, US$36,152 was used to carry out the forest inventory, including travel costs to and from the five territories and the ~38 meetings and trainings held as part of the FPIC process. The NEL contributed an additional US$11,250 in personnel and research costs, including the salaries of co-authors JM-V (project lead) and JM (professional technician). In addition, the National System of Frontiers, a body of Panama's police force, contributed approximately $1,600 in in-kind transportation support. As such, the forest inventory cost a total of US$49,002. This estimate excludes materials and equipment costs (~US$4,600) and the general oversight provided by the director of the NEL (co-author CP).

Although a full comparison of costs between our study and the INFC in Panama is currently not possible given the information that is publicly available, Melgarejo et al. (2015*a*) estimated that in the initial pilot phase of the INFC, the cost of inventorying a 2-ha sampling unit in a forested area is US$5,500, or $2,750/ha *excluding* travel costs. We presume, like in our study, that this amount also excludes the costs of the senior scientists from the Food and Agriculture Organization of the United Nations overseeing the project, as well as materials and equipment. If travel costs are excluded from our participatory forest inventory, our cost for sampling 1 ha was US$1,360 (Table 1.5).

According to the Panama National Programme Document of UN-REDD (UN-REDD 2009) , which outlines the country's REDD-readiness process, the *National Inventory and Monitoring System for Forests and Carbon* was allocated US$1,788,785, of which US$680,000 was used in the INFC (presentation delivered at Tryp Panama Albrook Mall Hotel, October 2015 by UN-REDD personnel). The breakdown for this amount is not readily available, but based on estimates of the cost of inventorying 1 ha of forest, as put forward by Melgarejo et al. (2015*a*), at least US$203,500 would have been invested in inventorying 74 ha of forests, which is the total area sampled through the INFC country-wide, *excluding* travel costs. With our methodology, the cost of sampling the same area (i.e., 74 ha), also *excluding* travel costs, would have been ~US$100,623 (Table 1.5). Even though the INFC and our study have different scopes, our results suggest that we sampled the equivalent of 41% of the surface area sampled through the INFC at half the cost.

As many developing countries approach the completion of their REDD-readiness processes, they are receiving additional financial and technical support from UN-REDD through country-specific “Targeted Support” under the “Support to National REDD+ Action: Global Programme Framework 2011–2015” (SNA). Globally, the SNA has granted ~US$7.1 million to 41 country requests for MRV and monitoring efforts, and ~US$2.4 million for 19 requests directed toward programs that aim to strengthen their engagement with indigenous peoples and local communities (UN-REDD 2016). We hope the results of our study, including procedural aspects, such as those outlined in Box 1, will inform future decisions and investments by these countries in national forest monitoring systems that seek to ensure the full and effective participation of indigenous peoples. Not only may costs be significantly reduced, but indigenous peoples, who serve as the custodians of extensive swaths of remaining tropical forests (WHRC and EDF 2015), will be afforded a legitimate role in REDD+, thus improving the prospects for the mechanism’s success.

Dispelling prejudices and reducing errors in community-generated data

Our study addresses and further debunks the belief that data gathered by local, “non-expert” technicians may be of lesser quality than data gathered by expert, professional technicians (Pratihast et al. 2013). It is, to the best of our knowledge, one of three efforts in monitoring AGB, including Butt et al. (2015) and Walker et al. (2014), to take place with the full and effective participation of indigenous peoples in the Neotropics. Our study also tackles calls for rigorous assessments of community-based biomass monitoring programs in the context of REDD+ initiatives and the inclusion of these in national forest monitoring systems (Skutsch et al. 2011, Pratihast et al. 2013, Balderas Torres 2014).

Within the context of REDD+, Danielsen et al. (2011) had previously demonstrated that community-based measures of AGB were comparable to those of professional foresters, based on a study carried out in simple-structured forests with relatively low tree diversity in Tanzania and India. Two out of the four sites sampled were highly degraded woodlands (Danielsen et al. 2013). A second study by Danielsen et al. (2013) in nine sites throughout China, Indonesia, Vietnam, and Laos, found similar results, but greater variation and significant differences in biomass estimates in at least three of the sites between local and professional measurements.

This study did not include tree height measurements. Brofeldt et al. (2014) built upon the study by Danielsen et al. (2013) and compared the accuracy of the community gathered data with that of professional technicians in a second iteration of sampling in the same nine sites. The second time around, significant differences were only found in one site, showing improved correspondence in measurements between both groups. A more recent study by Butt et al. (2015) took place in Guyana and engaged indigenous communities in assessing forest carbon stocks in eight different vegetation types. Of these, two were forests of larger stature (i.e., ≥20 m), similar to our study sites, encompassing an area of 3.31 ha. Our study sampled an area approximately an order of magnitude larger. Similar to Danielsen et al. (2013) and Brofeldt et al. (2014), the study by Butt et al. (2015) did not include tree height measurements; thus, they were unable to test the performance of the local community members in measuring this variable.

As such, our study and findings build upon and contribute to the aforementioned body of knowledge. Like Vergara-Asenjo et al. (2015) and others referenced throughout this paper, we found that participatory, community-based data collection can be equally as good as expert and technologically gathered data. Our study confirmed that well-supervised indigenous technicians, even when provided with brief, intensive training are equally proficient in carrying out forest inventories as seasoned professional technicians and, for the most part, produce data with no significant statistical differences. Significant errors found, for example, in tree height measurements during the complementary study carried out in Barro Colorado Island were not the product of subpar capacities from the indigenous technicians, but rather systemic challenges encountered in measuring trees in closed-canopy conditions (Hunter et al. 2013).

It is worth noting that in our study, the indigenous technicians were accompanied at all times by the project lead (co-author JM-V), who provided technical oversight of the research efforts, and a professional technician (co-author JM), who supervised the team conducting the re-measurements of tree height and DBH. In other participatory studies, such as Butt et al. (2015) and Luzar et al. (2011), both carried out in the Rupununi region of Guyana, non-indigenous personnel were usually not on site during data collection. Whether the constant presence of non-indigenous technical personnel and scientists has an influence on the quality of results is worthy of further examination. For example, in the study by Luzar et al. (2011), deliberate data fabrications of wildlife observations along linear transects were identified in eight of the 28 communities where the studies took place. In the context of REDD+, as pointed out by Danielsen et al. (2011) and Butt et al. (2015), there is the risk that communities will falsely report favorable changes in terms of forest cover and condition, or inflate individual tree measurements to bulk up per hectare forest carbon values, thus ensuring continued financial incentives. In all cases, regular data quality checks during studies, and third-party verification, is advocated.

In our study, the professional technician accompanied one of the teams at all times to ensure the correct use of the instruments and methods for taking both dbh and height measurements, while the other team of indigenous technicians took measurements independently and unsupervised. As discussed above, in general, there were no statistically significant differences between the measurements taking by both teams, suggesting that the presence of the professional technician and scientist did not result in improved performance, reduced biases, or data fabrication. However, unlike the aforementioned studies, our study had the advantage of replication, allowing each plot to be sampled twice, thus reducing the risk of fabrication as general data characteristics were checked daily (e.g., number of trees sampled by both teams). Potential bias would have also been detected during data analysis. Also, unlike animal observation studies, we measure sessile organisms (i.e., trees), and both teams sample each plot on the same day, thus eliminating the possibility of changing conditions (e.g., measuring different number of trees due to tree falls or timber extraction).

Our efforts to assess and reduce sources of error in tree dbh and height measurements were largely successful, which is particularly important in light of the need of reducing uncertainties in MRV in the context of REDD+ (VCS 2015). Unaccounted for uncertainties may ultimately compromise “the environmental integrity of carbon trading systems” (Pelletier et al. 2015). Our ability to include tree height was noteworthy; height data are often not collected in forest inventories due to the challenges of taking measurements in the field (Feldpausch et al. 2012). Although our study was limited to eastern Panama, we believe that our method is easily replicable and could be applied to diverse forest ecosystems in other tropical regions of the world with great potential.

Benefits from a fully participatory method for forest biomass monitoring

Our operational model, which aligns with calls for the legitimate involvement of indigenous people in REDD+ (Paragraph 72, Decision 1/ CP.16 [UNFCCC 2011]) resulted in a number of direct benefits to the indigenous technicians and communities where the study took place. As discussed above, our proposed method for forest inventorying not only cost less and was carried out quicker than the INFC, for example, but was also designed in the spirit of community and human resource development. It provided valuable income to those who are directly responsible for protecting the forest, and as emphasized by Luzar et al. (2011), demonstrated the value of programs, such as REDD+, in supplying communities with funds derived from the measurement and protection of forests. Of the funds executed by OJEWP, we estimate that ~79% (US$28,702) directly benefitted the technicians (i.e., through salaries), or the communities where the forest inventory took place, given that transportation services (boat and fuel), some of the food, and all lodging were procured locally.

At the local level, the study stimulated discussions within the communities about forests, their role in Emberá and Wounaan culture and livelihoods, and the implications of their loss. As documented in the video, "Our Green Gold: A New Perspective on Forests in the Collective Land Emberá, Wounaan" (Jaripio et al. 2015), our study served as a teaching moment, particularly for youth, about the spiritual connections between forests and people. The study also motivated a group of the technicians to better care for the region's forests and call, with support of some *Nokos*, for a blanket moratorium on logging activities until a thorough assessment was carried out in *Tierras Colectivas* (co-author M. Opua, *personal communication*).

Also at the local level, the indigenous technicians, most of who were youth, were praised by the *Caciques*, *Nokos,* and elders for their contributions to an initiative of great importance to *Tierras Colectivas*. Bestowed with the informal title of "carboneros" (Spanish play-on-words in reference to their work in monitoring forest *carbon*), this study seemed to instill in them a sense of accomplishment and pride, as we heard on many occasions in the communities. It also equipped them with skills that may come in handy in other forest inventorying efforts taking place throughout Panama, supplementing their income derived from other economic activities in which they are engaged.

This project also set the stage for OJEWP to take a prominent role in key regional and global events. Co-author, LO, adeptly presented the results of this study at the 2015 Global Joint FCPF/UN-REDD Programme Knowledge Exchange Day in San Jose, Costa Rica (8 November 2015) and at Indigenous Peoples' Pavilion at COP 21 of the UNFCCC in Paris, France (30 November–11 December 2015). Having a voice and this level of visibility in these forums is, perhaps for the first time, commensurate with the fundamental role that indigenous peoples play in protecting Panama's remaining forests (Vergara-Asenjo and Potvin 2014) and the role they could play in moving REDD+ forward in the country. Overall, we strived and succeeded in proposing a model that differs from one where intermediate organizations play a predominant role and local communities run the risk of becoming "cheap labor" vs. integral and fully engaged participants (Skutsch et al. 2014).

1.6 Conclusions

As in other parts of the world (Savaresi 2013), REDD+ remains a contentious issue with indigenous peoples in Panama where the REDD-readiness process created an environment of apprehension and fear (Potvin and Mateo-Vega 2013). Studies (Cuellar et al. 2013, Feiring and Abbott 2013) indeed revealed procedural and ethical missteps, particularly during the early stages of the REDD-readiness process in Panama, including a lack of or inappropriate participation of indigenous groups.

In this study, however, the indigenous technicians, traditional authorities, and project managers of *Tierras Colectivas* took full ownership of the work carried out and its results. They gained from having knowledge of the forest carbon contained in their forests, thus potentially allowing them to garner their fair share of benefits generated, if they opt to participate in a national REDD+ program. They now also have the capacity to carry out forest monitoring, within the context of MRV activities, on their own employing a method that is cost-effective and accurate. They are now poised to consider the pros and cons of REDD+, instead of reacting with fear.

Overall, without OJEWP and the *General Congress'* leadership, as well as the support of regional and local chiefs and community members, it is highly unlikely that this study would have been possible. The fully participatory nature of the study and the fact that results and data are co-owned by all parties involved proved to be the key toward opening the door to the extraordinary forests of Darién.

1.7 Acknowledgements

We are deeply grateful to the traditional authorities of Tierras Colectivas Emberá y Wounaan who authorized and supported this study, and to the administrators of OJEWP for overseeing the project. We greatly appreciate the contributions of the “carboneros” from the five territories, and the members of the communities for allowing us to share and learn from them: Isidro Berrugate, Rudecindo Bipuro, Abdiel Cabrera, David Cansarí, Leonel Cansarí, Suare Cansarí, Enrique Cuero, Luis Carlos Dogiramá, Generoso Grajales, Betildo Grajales, Polo Grajales, Javier Lana, Raúl Lino, Cloromiro Membache, Leovigildo Membache, Adriano Mermudez, Inocente Mosquera, Ricardo Mosquera, Alexis Ortega, Amarildo Sotillo, Juanito Valdespino. We thank the support provided by Milton Solano from the Smithsonian Tropical Research Institute (STRI; GIS); Daniel Lessieur from the Centre d’Etude de la Forêt (database architecture); Lady Mancilla from STRI (administration and logistics) and botanists Rodolfo Flores, Roberto Vergara, Ernesto Campos, and Juvenal Valerio. We are grateful to David Kaimowitz, Jason Cole, Johanne Pelletier and two anonymous reviewers for useful comments on earlier drafts of this paper. We also extend our special thanks to Helene Muller-Landau from STRI and her team for providing data on tree height and diameter from Barro Colorado Island. This study was possible due to financial support from the Forest Carbon Partnership Facility of the World Bank. We also thank McGill University, STRI and the Margaret A. Cargill Foundation for fellowships and support awarded to JM-V. The Barro Colorado Island forest dynamics research project was founded by S.P. Hubbell and R.B. Foster and is now managed by R. Condit, S. Lao, and R. Perez under the Center for Tropical Forest Science and the Smithsonian Tropical Research in Panama. Numerous organizations have provided funding, principally the U.S. National Science Foundation, and hundreds of field-workers have contributed.

1.8 References

Amado, A., G. Peterson St-Laurent, C. Potvin, and R. Llapur. 2014. Conflictos Territoriales: Modelo para su resolución en preparación para la protección de bosques. Pages 81-97 *in*

A. Pfund, editor. Experiencias Latinoamericanas en el Abordaje de Conflictos. Universidad para la Paz, San Jose, Costa Rica.

ANAM [Autoridad Nacional del Ambiente de Panamá]. 2008. Forest Carbon Partnership Facility. Readiness Plan Idea Note (R-Pin) Template. Forest Carbon Partnership Facility (FCPF), World Bank, Washington, D.C., USA and Panama City, Panama.

Asner, G. P., et al. 2013. High-fidelity national carbon mapping for resource management and REDD+. Carbon Balance and Management 8: 7. doi:10.1186/1750-0680-8-7.

Asner, G. P., et al. 2010. High-resolution forest carbon stocks and emissions in the Amazon. Proceedings of the National Academy of Sciences 107:16738-16742.

Balderas Torres, A. 2014. Potential for Integrating Community-Based Monitoring into REDD+. Forests 5:1815-1833.

Baraloto, C., Q. Molto, S. Rabaud, B. Hérault, R. Valencia, L. Blanc, P. V. A. Fine, and J. Thompson. 2013. Rapid Simultaneous Estimation of Aboveground Biomass and Tree Diversity Across Neotropical Forests: A Comparison of Field Inventory Methods. Biotropica 45:288-298.

Basset, Y., V. Novotny, S. E. Miller, G. D. Weiblen, O. Missa, and A. J. A. Stewart. 2004. Conservation and biological monitoring of tropical forests: the role of parataxonomists. Journal of Applied Ecology 41:163-174.

Boissière, M., G. Beaudoin, C. Hofstee, and S. Rafanoharana. 2014. Participating in REDD+ Measurement, Reporting, and Verification (PMRV): Opportunities for Local People? Forests 5:1855.

Brofeldt, S., et al. 2014. Community Monitoring of Carbon Stocks for REDD+: Does Accuracy and Cost Change over Time? Forests 5:1834.

Brown, S. 2002. Measuring carbon in forests: current status and future challenges. Environmental Pollution 116:363-372.

Butt, N., K. Epps, H. Overman, T. Iwamura, and J. M. V. Fragoso. 2015. Assessing carbon stocks using indigenous peoples' field measurements in Amazonian Guyana. Forest Ecology and Management 338:191-199.

Cansari, R. 2001. The Scientific Community and the Indigenous Emberá Community of Panama. Pages 26-40 *in* C. Potvin, M. Kraenzel, and G. Seutin, editors. Protecting Biological

Diversity. Roles and Responsibilities. McGill-Queen's University Press, Montreal, QC and Kingston, ON, Canada.

Chave, J., R. Condit, S. Aguilar, A. Hernandez, S. Lao, and R. Perez. 2004. Error propagation and scaling for tropical forest biomass estimates. Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences 359:409-420.

Chave, J., et al. 2014. Improved allometric models to estimate the aboveground biomass of tropical trees. Global Change Biology 20:3177-3190.

Chhatre, A., S. Lakhanpal, A. M. Larson, F. Nelson, H. Ojha, and J. Rao. 2012. Social safeguards and co-benefits in REDD+: a review of the adjacent possible. Current Opinion in Environmental Sustainability 4:654-660.

Clark, D. A., S. Brown, D. W. Kicklighter, J. Q. Chambers, J. R. Thomlinson, and J. Ni. 2001. Measuring Net Primary Production in Forests: Concepts and Field Methods. Ecological Applications 11:356-370.

Clark, D. B., and J. R. Kellner. 2012. Tropical forest biomass estimation and the fallacy of misplaced concreteness. Journal of Vegetation Science 23:1191-1196.

Colchester, M. 2010. Free, Prior and Informed Consent. Making FPIC work for forests and peoples. The Forest Dialogue, New Haven, CT, USA.

Condit, R. 1998. Tropical Forest Census Plots. Springer-Verlag and R. G. Landes Company, Berlin, Germany, and Georgetown, Texas, USA.

Constantino, P. d. A. L., H. S. A. Carlos, E. E. Ramalho, L. Rostant, C. E. Marinelli, D. Teles, S. F. Fonseca-Junior, R. B. Fernandes, and J. o. Valsecchi. 2012. Empowering Local People through Community-based Resource Monitoring: a Comparison of Brazil and Namibia. Ecology and Society 17:22.

Constantino, P. d. A. L., L. B. Fortini, F. R. S. Kaxinawa, A. M. Kaxinawa, E. S. Kaxinawa, A. P. Kaxinawa, L. S. Kaxinawa, J. M. Kaxinawa, and J. P. Kaxinawa. 2008. Indigenous collaborative research for wildlife management in Amazonia: The case of the Kaxinawá, Acre, Brazil. Biological Conservation 141:2718-2729.

CTFS [Center for Tropical Forest Science]. 2014. Center for Tropical Forest Science Wood Density Database. http://ctfs.si.edu/Public/CTFSRPackage/index.php/web/data_format/wooddensity_data.

Cuellar, N., S. Kandel, A. Davis, and F. Luna. 2013. Indigenous peoples and governance in REDD+ Readiness in Panama. Case study on COONAPIP, ANAM and the UN-REDD Program. PRISMA, San Salvador, El Salvador.

Cummings, A. R., J. M. Read, and J. M. V. Fragoso. 2015. Utilizing Amerindian Hunters' Descriptions to Guide the Production of a Vegetation Map. International Journal of Applied Geospatial Research 6:118-142.

Dam, P., and E. Trines. 2011. Can Carbon Compete with the Loggers in Papua New Guinea? Pages 158-168 *in* M. Skutsch, editor. Community Forest Monitoring for the Carbon Market: Opportunities under REDD. Earthscan, London, UK.

Danielsen, F., et al. 2011. At the heart of REDD+: a role for local people in monitoring forests? Conservation Letters 4:158-167.

Danielsen, F., et al. 2013. Community monitoring for REDD+: international promises and field realities. Ecology and Society 18 (3): 41. http://dx.doi.org/10.5751/ES-05464-180341.

Danielsen, F., et al. 2014. A Multicountry Assessment of Tropical Resource Monitoring by Local Communities. BioScience 64:236-251.

Feiring, B., and E. Abbott. 2013. Preliminary note on findings, conclusions and recommendations. Independent team for the investigation and evaluation of the UN-REDD Panama Programme, Panama, Panama City, Panama.

Feldpausch, T. R., et al. 2012. Tree height integrated into pantropical forest biomass estimates. Biogeosciences 9:3381-3403.

Fragoso, J. M. V., T. Levi, L. F. B. Oliveira, J. B. Luzar, H. Overman, J. M. Read, and K. M. Silvius. 2016. Line Transect Surveys Underdetect Terrestrial Mammals: Implications for the Sustainability of Subsistence Hunting. PLoS ONE 11:e0152659.

Gibbs, H. K., S. Brown, J. O. Niles, and J. A. Foley. 2007. Monitoring and estimating tropical forest carbon stocks: Making REDD a reality. Environmental Research Letters 2. doi:10.1088/1748-9326/2/4/045023.

GOFC-GOLD [Global Observation of Forest and Land Cover Dynamics]. 2015. A sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals associated with deforestation, gains and losses of carbon stocks in forests remaining forests, and forestation. GOFC-GOLD Report version COP21-1. GOFC-GOLD Land Project Cover Office, Wageningen Univesity, The Netherlands.

Goodman, R. C., O. L. Phillips, D. del Castillo Torres, L. Freitas, S. T. Cortese, A. Monteagudo, and T. R. Baker. 2013. Amazon palm biomass and allometry. Forest Ecology and Management 310:994-1004.

Hubbell, S. P., R. Condit, and R. B. Foster. 2010. Barro Colorado Forest Census Plot Data. http://ctfs.arnarb.harvard.edu/webatlas/datasets/bci.

Hubbell, S. P., R. B. Foster, S. T. O'Brien, K. E. Harms, R. Condit, B. Wechsler, S. J. Wright, and S. Loo de Lao. 1999. Light gap disturbances, recruitment limitation, and tree diversity in a neotropical forest. Science 283:554-557.

Hunter, M. O., M. Keller, D. Victoria, and D. C. Morton. 2013. Tree height and tropical forest biomass estimation. Biogeosciences 10:8385–8399.

IPCC [Intergovernmenteal Panel on Climate Change]. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories Prepared by the National Greenhouse Gas Inventories Programme, Published: IGES, Japan.

Janzen, D. H., W. Hallwachs, J. Jimenez, and R. Gamez. 1993. The role of parataxonomists, inventory managers and taxonomists in Costa Rica’s national biodiversity inventory. Pages 223–254 *in* W. V. Reid, S. A. Laird, C. A. Meyer, R. Gámez, A. Sittenfeld, D. H. Janzen, M. A. Gollin, and C. Juma, editors. Biodiversity Prospecting: Using Genetic Resources for Sustainable Development. World Resources Institute, Washington, D.C., USA.

Jaripio, I., B. Pacheco-Hijo, E. Bieberach, and T. Olea. 2015. Our Green Gold: A New Perspective on Forests in the Collective Land Emberá, Wounaan. McGill University, Montreal, QC, Canada and Panama City, Panama. https://www.youtube.com/watch?v=vRZxSRXbUhM&feature=youtu.be

Larjavaara, M., and H. C. Muller-Landau. 2013. Measuring tree height: a quantitative comparison of two common fieldmethods in amoist tropical forest. Methods in Ecology and Evolution 4:793–801.

Larrazábal, A., M. K. McCall, T. H. Mwampamba, and M. Skutsch. 2012. The role of community carbon monitoring for REDD+: a review of experiences. Current Opinion in Environmental Sustainability 4:707-716.

Le Quéré, C., et al. 2015. Global carbon budget 2014. Earth System Science Data 7:47-85.

Luzar, J. B., K. M. Silvius, H. Overman, S. T. Giery, J. M. Read, and J. M. V. Fragoso. 2011. Large-scale Environmental Monitoring by Indigenous Peoples. BioScience 61:771-781.

Mascaro, J., G. P. Asner, S. Davies, A. Dehgan, and S. Saatchi. 2014. These are the days of lasers in the jungle. Carbon Balance and Management 9: 7 http://wwwcbmjournal.com/content/9/1/7

McGill University. 2006. Protocol for Research in Panama's Indigenous Communities. McGill University - Neotropical Environment Option, Montreal, QC, Canada and Panama City, Panama.

Melgarejo, C., A. Calderón, and M. C. Ruiz-Jaén. 2015a. Inventario Nacional Forestal y de Carbono de Panamá. Diseño de la fase piloto 2013-2015 y propuesta para la fase final. UN-REDD and Ministerio de Ambiente de Panamá, Panama City, Panama.

Melgarejo, C., V. Corro, M. C. Ruiz-Jaén, A. Calderón, and M. Sánchez de Stapf. 2015b. Inventario Nacional Forestal y de Carbono de Panamá. Resultados de la fase piloto 2013-2015. UN-REDD and Ministerio de Ambiente de Panamá, Panama City, Panama.

Molto, Q., B. Hérault, J. J. Boreux, M. Daullet, A. Rousteau, and V. Rossi. 2014. Predicting tree heights for biomass estimates in tropical forests - a test from French Guiana. Biogeosciences 11:3121-3130.

Olsen, N., and J. Bishop. 2009. The Financial Costs of REDD: Evidence from Brazil and Indonesia. International Union for Conservation of Nature, Gland, Switzerland.

Pearson, T., S. Walker, and S. Brown. 2005. Sourcebook for Land Use, Land-Use Change and Forestry Projects., BioCarbon Fund of the World Bank and Winrock International, Washington, D.C., USA.

Pelletier, J., J. Busch, and C. Potvin. 2015. Addressing uncertainty upstream or downstream of accounting for emissions reductions from deforestation and forest degradation. Climatic Change 130:635-648.

Pistorius, T. 2012. From RED to REDD+: the evolution of a forest-based mitigation approach for developing countries. Current Opinion in Environmental Sustainability 4:638-645.

Potvin, C., and J. Mateo-Vega. 2013. Panama: Curb indigenous fears of REDD+. Nature 500:400.

Pratihast, A. K., M. Herold, V. De Sy, D. Murdiyarso, and M. Skutsch. 2013. Linking community-based and national REDD+ monitoring: a review of the potential. Carbon Management 4:91-104.

R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Richards, P. W. 1996. The tropical rain forest: an ecological study. Second edition. Cambridge University Press, Cambridge, Great Britain.

Saatchi, S. et al. 2011. Benchmark map of forest carbon stocks in tropical regions across three continents. Proceedings of the National Academy of Sciences 108:9899-9904.

Savaresi, A. 2013. REDD+ and Human Rights: Addressing Synergies between International Regimes. Ecology and Society 18 (3): 5. http://dx.doi.org/10.5751/ES-05549-180305.

Sheil, D., and A. Lawrence. 2004. Tropical biologists, local people and conservation: new opportunities for collaboration. Trends in Ecology & Evolution 19:634-638.

Skutsch, M., E. Turnhout, M. J. Vijge, M. Herold, T. Wits, J. W. den Besten, and A. Balderas Torres. 2014. Options for a National Framework for Benefit Distribution and Their Relation to Community-Based and National REDD+ Monitoring. Forests 7:1596-1617.

Skutsch, M., E. Zahabu, B. Karky, S. , and F. Danielsen. 2011. The costs and reliability of forest carbon monitoring by communities. Pages 73-81 *in* M. Skutsch, editor. Community Forest Monitoring for the Carbon Market: Opportunities under REDD. Earthscan, London, UK.

Slik, J. W. F., et al. 2013. Large trees drive forest aboveground biomass variation in moist lowland forests across the tropics. Global Ecology and Biogeography 22:1261-1271.

Stephenson, N. L., et al. 2014. Rate of tree carbon accumulation increases continuously with tree size. Nature 507:90-93.

UNFCCC [United Nations Framework Convention on Climate Change]. 2010. Report of the Conference of the Parties on its fifteenth session, held in Copenhagen from 7 to 19 December 2009. Addendum. Part Two: Action taken by the Conference of the Parties at its fifteenth session. FCCC/CP/2009/11/Add.1. United Nations Framework Convention on Climate Change, Copenhagen, Denmark.

UNFCCC [United Nations Framework Convention on Climate Change]. 2011. Report of the Conference of the Parties on its sixteenth session, held in Cancun from 29 November to 10 December 2010. Addendum part two: action taken by the Conference of the Parties at its sixteenth session. FCCC/CP/2010/7/Add.1., United Nations Framework Convention on Climate Change, Cancun, Mexico.

UNFCCC [United Nations Framework Convention on Climate Change]. 2015. Adoption of the Paris Agreement. Proposal by the President. FCCC/CP/2015/L.9/Rev.1. United Nations Framework Convention on Climate Change, Paris, France.

UN-REDD [United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries]. 2009. Panama National Programme Submission Form. October 2009. The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries, Panama City, Panama.

UN-REDD [United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries]. 2016. Targeted Support Performance Data. The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries. http://www.unredd.net/index.php?option=com_targetedsupport&view=targetedsupportoverview&Itemid=524

U.S. Forest Service. 2012. Forest Inventory and Analysis National Core Field Guide. Volume I: Field Data Collection Procedures for Phase 2 Plots. Version 6.0. U.S. Forest Service. U.S. Department of Agriculture, Washington, D.C., USA.

VCS. 2015. VMD0017. Estimation of uncertainty for REDD+ project activities (X-UNC). Version 2.1. Sectoral Scope 14. Verified Carbon Standard, Washington, D.C., USA.

Verchot, L.V., K. Anitha, E. Romijn, M. Herold, and K. Hergoualc'h. 2012. Emissions factors. Converting land use change to CO2 estimates. Pages 261–268 *in* A. Angelsen, M. Brockhaus, W. D. Sunderlin, and L.V. Verchot, editors. Analysing REDD+: Challenges and choices. CIFOR, Bogor, Indonesia.

Vergara-Asenjo, G., and C. Potvin. 2014. Forest protection and tenure status: The key role of indigenous peoples and protected areas in Panama. Global Environmental Change 28:205-215.

Vergara-Asenjo, G., D. Sharma, and C. Potvin. 2015. Engaging Stakeholders: Assessing Accuracy of Participatory Mapping of Land Cover in Panama. Conservation Letters 8:432-439.

Walker, W., et al. 2014. Forest carbon in Amazonia: the unrecognized contribution of indigenous territories and protected natural areas. Carbon Management 5:479-485.

WHRC [Woods Hole Research Center] and EDF [Environmental Defense Fund]. 2015. Tropical Forest Carbon in Indigenous Territories: A Global Analysis. A report prepared for UNFCCC COP 21. The Woods Hole Research Center and Environmental Defense Fund, Falmouth, MA and Washington, D.C., USA.

1.9 Supporting Information

Additional Supporting Information may be found online at:
http://onlinelibrary.wiley.com/doi/10.1002/ecs2.1635/full

1.10 Tables

Table 1.1. Meetings and trainings held with the general, regional and local chiefs, as well as technicians, advisors and community members prior to, during and following the completion of the study.

	Meetings & Trainings		
	Prior to study	During Study	Following study
Caciques	3	0	1
Regional Leaders/ Nokos/ Community	7	6	5
Technicians	1	5	N.A.
Advisors	N.A.	~10	N.A.
TOTAL	**11**	**~21**	**6**

Table 1.2. Mean difference and standard deviation of height measurements (meters and percentage) between the ultrasonic hypsometer and clinometer, and recently trained indigenous technicians and the seasoned professional technician.

		Hypsometer vs. clinometer			**Recently-trained vs. professional technician**		
Forest Strata	**Tree Height**	**No. Trees**	**Mean Diff. (m)**	**Mean Diff. (%)**	**No. Trees**	**Mean Diff. (m)**	**Mean Diff. (%)**
Emergent	≥40m	135	0.88 ± 0.78	2.0 ± 1.7	75	2.79 ± 3.58	6.0 ± 7.3
Canopy	≥30m - <40m	388	0.87 ± 0.78	2.6 ± 2.4	137	3.10 ± 3.14	9.0 ± 9.0
Mid & understory	<30m	1060	0.58 ± 0.51	3.5 ± 4.0	252	1.62 ± 2.39	7.2 ± 9.6

Table 1.3. Results from tests for significant differences in tree height measurements using different instruments, recently trained vs. seasoned professional technicians, and based on topography.

Forest Strata	**Tree Height**	**Instruments**	**Technicians**	**Topography**
Emergent	≥40m	p=0.42	p=0.064	p=0.17
Canopy	≥30m & <40m	p=0.04	p=1.124e-05	
Mid & understory	<30m	p=0.10	p=5.239e-12	

Table 1.4. Mean difference and standard deviation (meters and percentage) between known height measurements and those taken with an ultrasonic hypsometer.

Forest Strata	**Tree Height**	**No. Trees**	**Mean Difference (m)**	**Mean Difference (%)**
Canopy	≥30m	29	4.21 ± 2.83	12.9 ± 8.9
Mid-story	≥20m & <30m	52	3.38 ± 2.37	13.6 ± 9.4
Understory	<20m	28	2.12 ± 1.96	13.2 ± 11.9

Table 1.5. Number of team members, days, person days and costs (US$) required to sample one and 74 hectares of mature forest based on estimated costs of the current study.

Team size (Pilot phase)	11
Team size (Final phase)	8
Days to survey 1 ha (Pilot phase)	0.93
Person days to survey 1 ha (Pilot phase)	10.3
Days to survey 1 ha (Final phase)	0.93
Person days to survey 1 ha (Final phase)	7.5
Cost (US$)/ha including travel costs	~$1,633
Cost (US$)/ha excluding travel costs	~$1,360
Cost (US$)/74 ha including travel costs	~$120,872
Cost (US$)/74 ha excluding travel costs	~$100,623

1.11 Figures

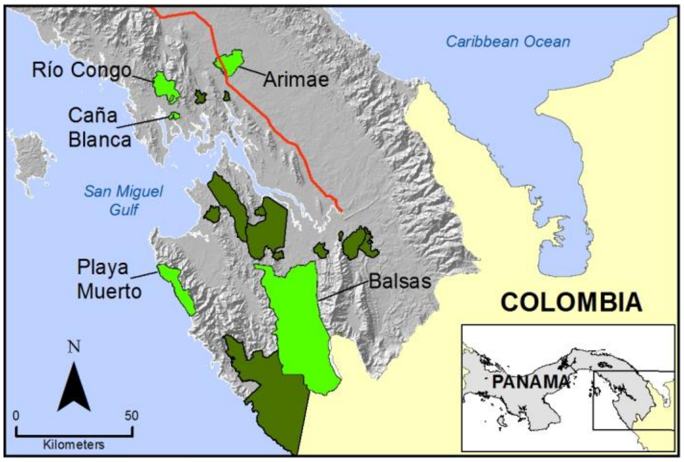

Figure 1.1. The region of Darién in eastern Panama. Light and dark green areas show the location of Tierras Colectivas. The red solid line is the Pan-American Highway.

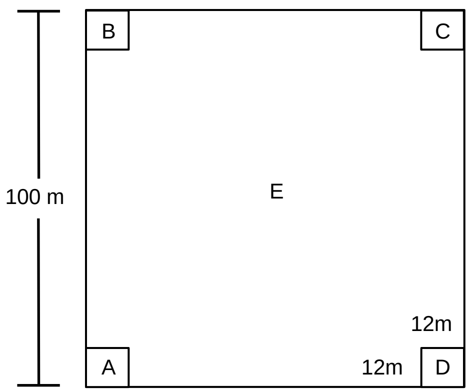

Figure 1.2. Plot design. Each plot (E) and subplot (A, B, C, D) has a unique identifying code.

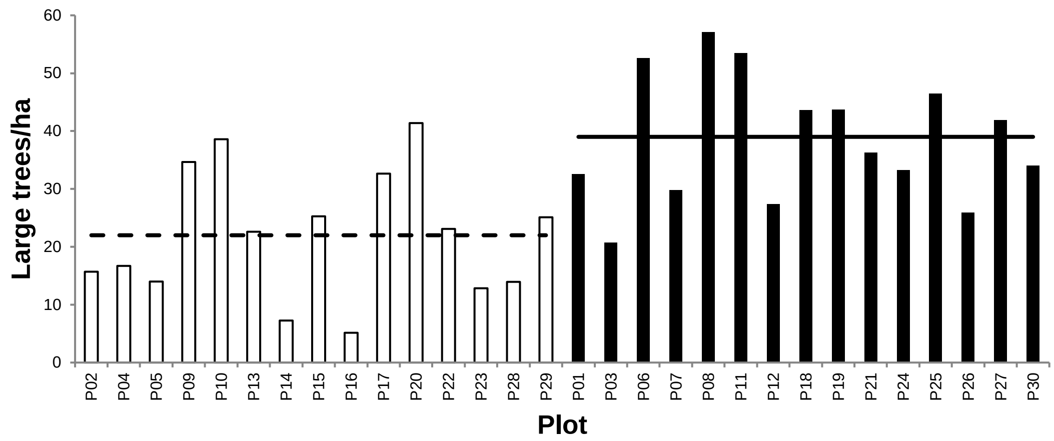

Figure 1.3. Total and mean number of large trees per hectare in the intervened (open bar; dashed line) and non-intervened (closed bar; solid line) plots (n=30), respectively

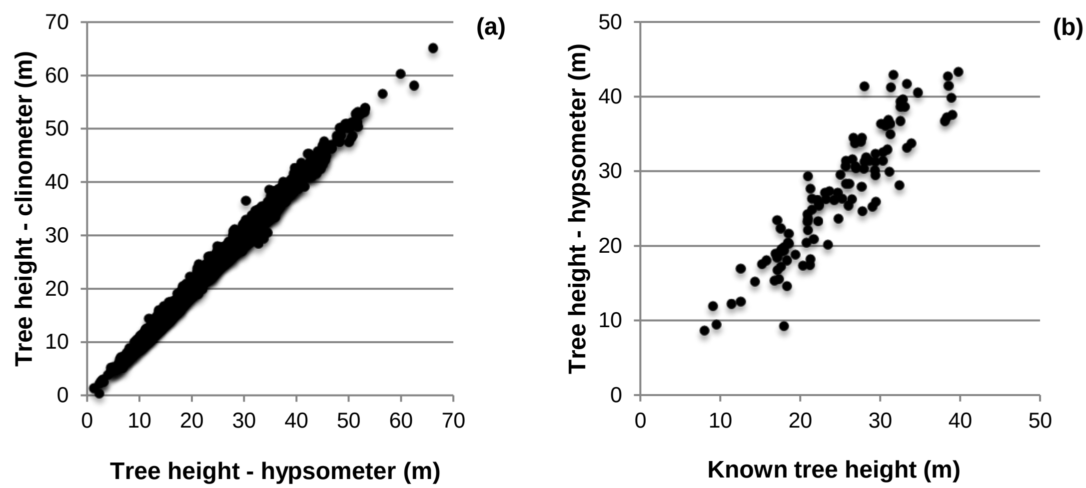

Figure 1.4. Scatter plots of (a) height measurements (meters) for individuals trees measured in Tierras Colectivas with a mechanical clinometer and ultrasonic hypsometer; and (b) a comparison of known tree height measurements with ultrasonic hypsometer estimates of 109 trees in Barro Colorado Island.

Box 1. Suggested blueprint for the full and effective participation of indigenous peoples in AGB monitoring through forest inventories (based on the experience in Tierras Colectivas and validated by the traditional authorities).

Box 1. Suggested blueprint for the full and effective participation of indigenous peoples in AGB monitoring through forest inventories (based on the experience in *Tierras Colectivas* and validated by the traditional authorities).

The following guidelines assume that:

- Indigenous authorities, at the highest decision-making level (e.g., General Congress), have been fully engaged in REDD+ discussions, understand the objectives of MRV, have been adequately briefed and comprehend the scope of the project proposed for their territories, and have approved it.
- Decision-making in the Indigenous territory takes place at multiple scales such as villages, regions, and groups of territories.
- Researchers have secured all other necessary permits (e.g., Ministry of Environment), have prepared consent forms and cleared ethics review processes.

Prior to study:

1. Establish a formal agreement with the General Congress and other relevant Indigenous authorities to conduct the study in the Indigenous territories.
2. Identify an indigenous organization that, with the approval of the indigenous authorities, will manage the project including receiving and administering the money.
3. Conduct culturally appropriate training for indigenous authorities at the highest level and members of involved indigenous NGOs on the objectives, process and methods for conducting forest inventories.
4. Rely on Indigenous authorities to identify a list of potential technicians, from which a core team will be selected, providing the authorities with the technical requirements.
5. Ask the Indigenous authorities to identify potential territories where the study can take place, complying with necessary selection criteria (e.g., forest types), and work with them to identify final locations.
6. Train the technicians selected by the authorities on climate change, deforestation, REDD+ and forest inventorying methods. These individuals will become a core team of technicians and will work with one professional technician throughout the study to ensure quality control.

During study:

7. Upon arrival in all communities, hold meetings to provide background training on climate change, deforestation, REDD+, and explain the objectives and process of conducting a forest inventory. These meetings should be co-facilitated by local leaders and involve as many members of the community as possible. Explicitly ask for a written authorization to enter the forest from the regional and/or local authorities and ensure that they understand the work that will be carried out.
8. Identify the sampling sites with community members selected by the authorities based on their knowledge of the territory and its access, as well as scientific criteria (e.g., forest types).
9. Invite local authorities and community members to a demonstration of the methods and equipment that will be employed in the forest. Incorporate a local crew of community members to the core team after training them on forest inventorying methods. The local authorities should identify these new local technicians.
10. Meet regularly (e.g., twice a week) with local authorities and when possible, community members, to provide updates on progress and address questions.
11. Prior to departing the territory, hold community-level meetings to present preliminary findings and interesting results (e.g., largest tree diameter and height measured).

After study:

12. Return to communities and hold a meeting to share the final results of the study providing, as a minimum, digital and printed copies of a full and summary report of the study. Additional materials may include AGB maps, pictures taken during the forest inventory, and explanatory posters depicting how the study was conducted.

Linking Statement 2

While Chapter 1 confirms that I developed a statistically robust, fast, and cost-effective forest biomass monitoring method that ensures the full and effective participation of Indigenous peoples, Chapter 2 presents the results of having applied the method in Panama's Darien region. Here, I test for sources of variation in AGB after revealing marked differences among the 30 1-ha plots sampled. The primary determinant of variation in AGB is found to be anthropogenic disturbance, and not ecological factors such as forest type. I also reveal that this variation in AGB, detected through my field-based inventory, is not discernible through remote sensing technologies, including LiDAR and course, freely-available satellite imagery. The implication is that field-based monitoring systems will remain key to elucidating AGB variation, particularly in areas where forest disturbance does not result in perceptible changes to forest structure or canopy, such as in areas under Indigenous stewardship. Finally, I reveal the critical importance of Darién's forest for climate change mitigation and biodiversity conservation, upon discovering that undisturbed forests in this region contain the highest known AGB per hectare in the Neotropics, and second highest tree species richness, when compared to well-studied forest plots across the region. Conserving and sustainably managing these forests with and for Indigenous peoples is discussed as a way forward.

Chapter 2: Tree aboveground biomass and species richness of the mature tropical forests of Darién, Panama, and their role in global climate change mitigation and biodiversity conservation

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2.1 Abstract

The remote forests of the Darién region in eastern Panama are among the last remnants of relatively undisturbed forest habitat in the Central American isthmus. Despite decades of efforts by the government, non-governmental organizations, and civil society, including Indigenous peoples, to protect the region's natural heritage, it remains under significant threat due to widespread illegal logging. Now, the Panamanian government is considering the mechanism, Reducing Emissions from Deforestation and Forest Degradation (REDD+), as another option to limit forest loss. Central to the proper functioning of REDD+ is the need to reduce uncertainties in estimates of aboveground biomass (AGB). These estimates are used to establish realistic reference levels against which additional contributions to reducing carbon dioxide emissions

from the loss and degradation of forests can be financially compensated. Also, highly desirable to REDD+ is the achievement of biodiversity co-benefits. REDD+ investments will likely be directed primarily to areas where the potential to simultaneously mitigate climate change and conserve biodiversity is highest. Here, we present the results of a field-based forest carbon inventorying method tested in Darién's mature forests with the participation of Emberá and Wounaan Indigenous peoples. We also explore whether variations in field-based estimates of AGB across mature forests, in both undisturbed and disturbed areas, are detectable through free and readily available remote sensing data sources. Furthermore, we examine and compare AGB and tree species richness in Darién with other well-studied forest sites across the tropics. Our findings reveal that Darién's forests play a crucial role globally and regionally in storing carbon and housing biodiversity, and support the imperative need to protect these forests in a culturally appropriate manner with the region's Indigenous peoples.

Keywords: community-based forest monitoring, deforestation, forest carbon, forest degradation, indigenous peoples, REDD+, tree diversity

2.2 Introduction

Darién (Figure 2.1), the juncture between Central and South America, is the only gap (~100 km) in the ~30,000 km-long Pan-American Highway, and home to ~1.33 million hectares (ha) (Global Forest Watch 2019*a*, *b*) of diverse tropical forest habitats (Herrera-MacBryde and ANCON 1997). The region is part of a global biodiversity hotspot (Myers et al. 2000) known for its remarkable ecological diversity, high species endemism (Herrera-MacBryde and ANCON 1997), and very high estimated, aboveground forest carbon stocks (Asner et al. 2013). The forests of Darién are also home to Indigenous peoples, namely the Guna, Emberá, and Wounaan, as well as Afro-Darienitas, descendants of escaped slaves. It is one of the last frontier forests in the world, that is, pristine forests under serious threat (Bryant et al. 1997, WWF 2015), and calls for its protection date back decades (Hanbury-Tenison and Burton 1973). The region, however, is undergoing a process of rapid transformation driven primarily by illegal logging (Arcia Jaramillo 2015).

Numerous conservation strategies have been deployed in Darién, including the establishment of a national park, forest reserve, biological corridor, hydrologic reserve, private reserve, UNESCO

World Heritage Site, Biosphere Reserve, and Ramsar Wetland of International Importance. Most recently, the Government of Panama identified REDD+ as an additional promising option to stem the loss of forests in Darién, and elsewhere in Panama (Melgarejo et al. 2015). Since 2007 (United Nations Framework Convention on Climate Change 2008), REDD+ has been at the forefront of international policy efforts to curb atmospheric carbon dioxide (CO_2) emissions from land use and land-use change. Given that deforestation and forest degradation account for ~9% of CO_2 emissions globally (Le Quéré et al. 2015), REDD+ could play a preponderant and cost-effective role (Stern 2007) in mitigating climate change.

The present paper is part of a participatory project that developed a culturally appropriate method to empower Emberá and Wounaan Indigenous peoples, the original custodians of Darién's forests, to estimate forest carbon stocks (Mateo-Vega et al. 2017). This project was requested by Indigenous authorities aware of a previous study by Asner et al. (2013), which pooled most of Darién's mature forests into a single, very high carbon density class of ≥130 Mg/ha (i.e., 277 Mg/ha of aboveground biomass—AGB) using airborne Light Detection and Ranging (LiDAR) technology. Results contrasted widely with those from Panama's field-based National Forest and Carbon Inventory (Melgarejo et al. 2015), which found that mature forests, such as those of Darién, only contained ~80 Mg/ha of carbon (i.e., 170 Mg/ha of AGB). Indigenous authorities were interested in quantifying forests carbon stocks using field-based measurements to validate the REDD+ potential of their forests, and engage in informed discussions with REDD+ proponents.

Accordingly, here we analyze sources of AGB variation in 30 plots of approximately 1 ha each, distributed across a large mature forest landscape. We hypothesize that (a) the relative density of large versus small trees, (b) forest types, and (c) disturbance resultant from traditional forest use could explain heterogeneity at the landscape level. As field inventories are expensive and time consuming, we also assess whether spatially coarse remote sensing-derived products capture differences in AGB between undisturbed and disturbed mature forest areas based on forest cover (Sexton et al. 2013) and tree height (Simard et al. 2011). To fully capture the conservation value of Darién's forests, we then compare our AGB estimates and tree species richness with other well-studied forests across the tropics.

2.3 Methods

Study site and data collection

Previous studies (Mascaro et al. 2011) have questioned the statistical power of single large plots in capturing landscape-level AGB. Therefore, as reported in Mateo-Vega et al. (2017), we chose to establish 30, square-shaped, nested plots of approximately 1 ha, with four internal 12 x 12-m subplots, in forests within five distant Indigenous territories that are part of *Tierras Colectivas Emberá y Wounaan of Darién* (Figures 2.1 and 2.2). The realized average plot size, given topography and human error, was 0.93 ha, and the total area sampled was ~28 ha (Mateo-Vega et al. 2017). The four subplots within each plot correctly measured 144 m^2.

We distributed our plots in clusters of 5–8 across ~3,500 km^2 (~5% of Panama's territory) (Figure 2.1), establishing 18 in Tropical Moist Forest, 8 in Pre Montane Wet Forest, and 4 in Tropical Wet Forest, following the Holdridge Life Zone classification system (Holdridge 1967) (Figure 2.2). Twenty-five plots were established in territories that are not accessible by road, and that require 6–20 h to reach via boat, dugout canoe and/or hiking, after a 7-h drive to Puerto Quimba, entry point to the easternmost part of Darién. The five remaining plots were located in a territory accessible by road, but require a 2–5-h hike to reach them, after a 6-h drive from Panama City. The sites and number of plots established per territory was determined in consultation with the Indigenous authorities. Fifteen plots were established in mature forests with evidence of disturbance (e.g., tree stumps, trails, and nearby agriculture) (Mateo-Vega et al. 2017) resultant from traditional land uses (e.g., selective logging, harvest of non-timber forest products), and the remainder in undisturbed areas (Figures 2.1 and 2.2). As a result of sampling design, we recognize subplots to be nested within plots, and plots to be nested under territories, as well as under forest types. In each territory, plots were established in intact and disturbed forests, and therefore these factors can be adequately considered crossed.

The diameter-at-breast-height (DBH) and height of all living large trees ≥50 cm DBH (including palms and excluding lianas) were measured in each 1-ha plot, while all small trees ≥10 cm to <50 cm DBH were measured in four internal subplots (Mateo-Vega et al. 2017). We measured the DBH and height of 1401 living trees, and identified these in the field or from voucher specimens at the species (144), genus (58), or family (64) level. All but 72 trees were identified at one of these levels. Because tree wood density is a key predictor of AGB (Chave et al. 2014), the wood density for each tree was determined using the Global Wood Density database (Chave et al. 2009, Zanne et al. 2009). For trees that professional botanists were unable to identify at any level, a regional wood density value for Central America was assigned (Chave et al. 2009, Zanne et al. 2009).

Tree biomass, canopy height, and species richness variation

As reported in Mateo-Vega et al. (2017), AGB for each tree was estimated using the Chave et al. (2014) pantropical allometric model. For palms, we used the Goodman et al. (2013) allometric model. We singled out three sources of variation in AGB hypothesizing that the relative density of large versus small trees could explain heterogeneity at the landscape level, and that large trees density could result from differences across forest types, natural forest dynamics, or human intervention.

Despite representing a small percentage of trees in a forest, large trees account for a sizeable proportion of total AGB and may be key predictors of stand-level biomass (Slik et al. 2013). To elucidate sources of large tree AGB variation, and recognizing incomplete nesting of factors (Figure 2.2), we ran separate one-way analysis of variance (ANOVA) tests to compare the plot-level mean AGB of large trees among the five territories, three forest types, and three forest types while controlling for undisturbed and disturbed areas. Due to imbalanced sampling, we ran bootstrapping tests (10,000 iterations) to select the minimum number of plots for each category. We also compared plot-level mean AGB of large trees between undisturbed and disturbed plots using a Welsh two-sample *t*-test. We used AGB values scaled to 1 ha based on plot measurements for all tests.

To elucidate AGB variation for small trees within and among territories, we ran a two-level nested ANOVA on subplot mean AGB. The model employed subplots nested within plots in each territory (first level), and then subplots in plots nested among the five territories (second level). Due to imbalanced sampling, we ran a bootstrapping test (10,000 times) to randomly select five plots per territory and three subplots per plot (i.e., minimum number of plots and subplots sampled per territory and plot, respectively) for each iteration, thus restoring equal sample size.

We also examined AGB variation at the landscape level by scaling mean small-tree AGB in each plot to a 1-ha area, then summing these values with large tree AGB to obtain total AGB per ha. An ANOVA was then carried out to test for significant differences in plot-level AGB among the five territories using a bootstrapping test (10,000 iterations) to randomly select five plots per territory. We examined differences between plot-level AGB in undisturbed and disturbed forest plots using a Welsh two-sample *t*-test. We further used the coefficient of variation (CV) of all plots, and among or within the five territories, three forest types, and two forest states, to quantify variation. All statistical analyses were conducted in R Version 3.3.1 (R Core Team 2016).

Canopy structure characteristics are key for estimating AGB with field-based (Chave et al. 2005) and remote-sensing methods (Asner et al. 2013). To test for significant differences between undisturbed and disturbed forest plots, we compared our mean large-tree height field measurements using a Welsh two-sample *t*-test. To corroborate if our upper canopy height measurements are consistent with remotely-sensed data, we compared them with the Global Forest Canopy Height 2005 dataset (Simard et al. 2011). Due to cloud cover in the satellite images, we excluded one undisturbed and three disturbed forest plots from our analysis. Furthermore, we tested for significant differences in height measurements between undisturbed and disturbed forest plots based on the satellite images using a Wilcoxon/Kruskal–Wallis test. We also examined differences in tree cover, an indicator of forest degradation, for undisturbed and disturbed forest plots based on the freely available Landsat vegetation continuous field (VCF) satellite imagery layers of Sexton et al. (2013) for 2010 and 2015. We excluded eight and six plots for both time periods, respectively, due to cloud cover. These layers estimate the percentage of horizontal ground covered by woody vegetation greater than 5 m in height, at a 30 m spatial resolution (Appendix B). We tested for significant differences in percentage tree cover for undisturbed and disturbed forest plots using a Wilcoxon/Kruskal–Wallis test.

Finally, to examine tree species variation across the five territories, we measured beta diversity (Sorensen), including species turnover (species replacement at one site by others) and nestedness (absence and non-replacement of species from one site to another) (Baselga and Orme 2012). Each territory, and plots contained therein, was considered a single site. We examined various beta diversity components for (a) all living trees, (b) large and small trees, (c) trees in undisturbed and disturbed forest plots, (d) trees in different forest types (excluding Tropical Wet Forest, found only in one territory), and (e) combinations of large and small trees with undisturbed and disturbed sites, and forest types (excluding all Tropical Wet Forest and Pre Montane Wet Forest plots in disturbed forest areas, found in only one territory). Bootstrapping tests of 1,000 iterations were carried out to randomly select the number of territories, and plots per territory, necessary to run the comparisons across all categories and permutations. We used the *betapart* function in R by Baselga and Orme (2012), namely the multi-sites dissimilarities computation, to carry out the analyses.

Establishing the importance of Darién's AGB and tree diversity in relation to other tropical forests

To compare Darién to other well-studied forests throughout the Neotropics, tropical Asia and Africa, we used AGB estimates of our plots with the same allometric models and wood density values (Chave et al. 2005, Chave et al. 2009, Zanne et al. 2009), as synthesized in Réjou-Méchain et al. (2014). The comparison only considers undisturbed sites, with the exception of the Luquillo Forest Dynamics Plot (Puerto Rico) (Thompson et al. 2004).

Comparing tree species richness from our plots with other sites is challenging given differences in plot size and configuration (i.e., single large plot versus numerous 1-ha plots across a landscape). Nonetheless, we compared our plots with Barro Colorado Island (BCI) in central Panama, a reference point for tree diversity in Panama and the Neotropics, more generally. For this, we ran a bootstrapped analysis (1,000 iterations) on the 2010 Census 7 BCI data (Condit 1998, Hubbell et al. 1999, Hubbell et al. 2010). The 50-ha plot was divided into 50, 1-ha plots with their respective subplots as described in Mateo-Vega et al. (2017). For each iteration, 30 plots were randomly selected, and the mean number of species estimated for large trees at the plot level, and small trees at the subplot level.

2.4 Results

AGB and tree species variation

We found no significant difference in mean per-ha AGB of large trees among territories ($F_{4, 20}$ = 1.99, p value = 0.23) or among the three forest types sampled ($F_{2, 12}$ = 0.91, p value = 0.60).

Likewise, large tree AGB per ha among the three forest types in undisturbed forest plots, exhibited no significant difference ($F_{2, 6}$ = 2.51, *p* value = 0.21). The same analysis for disturbed forest plots, only comparing Pre Montane Wet Forest and Tropical Moist Forest (i.e., there was only one Tropical Wet Forest plot in disturbed forests), did not reveal significant differences either ($F_{1, 1}$ = 5.44, *p* value = 0.45). However, large tree AGB ranged from 121 to 349 Mg/ha in undisturbed forest plots, and from 12 to 200 Mg/ha in disturbed forests, and the difference between the two forest states was significant (t = -5.751, *p* value = 3.603e-06).

We also examined variation in small-tree AGB using a nested ANOVA within and among territories. Mean subplot small-tree AGB among the five territories ranged from 0.96 to 1.87 Mg/ha. The results of the ANOVA indicate no significant variation for subplots nested within plots in individual territories ($F_{20, 50}$ = 0.79, *p* value = 0.70), nor among the five territories ($F_{4, 20}$ = 3.3, *p* value = 0.07). The absence of variation confirmed that our scaling-up approach, applying small-tree biomass to the entire plot, was adequate.

For all 30 plots, mean large tree AGB accounts for 63.3% of total AGB, and is found in 30 (*SD* 14) trees/ha on average (Figure 2.3). Small-tree AGB accounts for 36.7% and is found on average in 374 (*SD* 112) trees/ha. In undisturbed forest plots, the proportion of mean AGB for large trees increases to 68.5% (mean of 39 [*SD*1 1] trees/ha) and lowers to 31.5% (mean of 369 [*SD* 128] trees/ha) for small trees. In disturbed forest plots, mean AGB of large trees decreases to 55.3% (mean of 22 [*SD* 11] trees/ha), thus increasing small-tree AGB to 44.7% (mean of 337 [*SD* 97] trees/ha).

Total AGB among all 30 plots ranged from 87 to 460 Mg/ha with a mean of 283 [*SD* 89] Mg/ha (Figure 2.4). This is equivalent to 133 Mg of carbon/ha, similar to the value assessed by Asner et al. (2013)—i.e., 130 Mg carbon/ha—for the forests of Darién using airborne LiDAR (2% difference). Mean AGB among the five territories ranged between 206 and 366 Mg carbon/ha, and we found no significant difference among these ($F_{1, 2}$ = 5.3, *p* value = 0.05).

In undisturbed forest areas, mean plot-level AGB was 54% greater than in disturbed forest areas. We found significant differences between plot-level AGB for undisturbed and disturbed forest areas (t = -4.984, *p* value = 2.931e-05) across the five territories. Total mean AGB for plots in Tropical Moist Forests in undisturbed areas was highest (379 [*SD* 51] Mg/ha), and also exhibited the largest difference (71%) with plots in disturbed forest areas. In the case of Pre Montane Wet and Tropical Wet Forest plots, the differences in mean AGB between undisturbed and disturbed areas was also large, that is, 47% and 32%, respectively.

The CV allowed us to quantify the amount of variation in AGB across the landscape. We found that ecological determinants of forest carbon stocks (e.g., forest types) cause less variation in forest AGB than anthropogenic activity, since the CV among forest states (i.e., undisturbed and disturbed) amounted to 30%, whereas only 7% amongst forest types (Table 2.1).

To test for significant differences in canopy height and tree cover between undisturbed and disturbed forest plots, we used field measurements and freely available satellite data. We focused on these two categories for the satellite imagery analysis to corroborate our field measurements, which yielded significant differences. The mean canopy height of large trees in disturbed forests based on field measurement was 30.3 m (*SD* 8) and 31.8 m (*SD* 8) for undisturbed forests. The results were statistically significant (t = -2.459, p value = 0.014). The analysis of upper canopy tree height with the satellite-based Global Forest Canopy Height dataset (Simard et al. 2011), revealed that undisturbed forest plots had a mean height of 33.2 m (*SD* 6), while disturbed forest plots had a mean height of 29.6 m (*SD* 5). The difference was not statistically significant. When comparing percentage total tree cover between disturbed and undisturbed forest plots using the satellite-based VCF forest cover layers of Sexton et al. (2013), no significant differences were found (Z = 0.11577, p value = 0.908).

The analysis of tree diversity revealed that disturbed forest plots have essentially the same tree species richness as undisturbed plots, 205 versus 206. Mean species richness per plot was 22 (*SD* 4) for the latter, 25 (*SD* 5) for the former, and not significantly different (t = -1.852, p value = 0.075). For large trees, however, undisturbed plots had 123 species, while disturbed plots only 94. With a mean species richness of 14 (*SD* 4) for undisturbed plots, and 11 (*SD* 3) for disturbed plots, the difference is significant (t = -2.745, p value = 0.010). In the case of small trees, across all five sites, disturbed plots house 144 species versus 128 in undisturbed plots, but the mean subplot species richness is 14 (*SD* 3) and 13 (*SD* 4), respectively, and not significantly different (t = 0.607, p value = 0.54).

The analysis of beta diversity revealed a high level of spatial dissimilarity across the five sites in Darién. Mean species turnover (Simpson dissimilarity) across all categories and permutations was 0.90 (min 0.78, max 0.98; *SD* 0.04), while nestedness was 0.01 (min 0.001; max 0.042; *SD* 0.006), thus species turnover is the primary driver of variation. Total beta diversity (Sorensen) was also very high with a mean of 0.91 (min 0.82; max 0.98; *SD* 0.032).

The relative importance of Darién's AGB and tree diversity

We compared our plot-level AGB values with other well-studied plots across the tropics (Figure 2.5) located in intact forests, except for Luquillo (Poncy et al. 1998, Anderson-Teixeira et al. 2015). Based on data synthesized from Réjou-Méchain et al. (2014), mean AGB per ha is highest in Africa (466 Mg), followed by Asia (394 Mg) and lastly, the Neotropics (303 Mg). Our undisturbed forest plots (*n* = 15), however, had the highest mean AGB values in the Neotropics (436 Mg/ha), surpassing mean AGB values for all forest plots in Asia, and almost matching mean AGB values for plots in Africa.

We also compared tree species richness in our plots in Darién with other plots across the Neotropics, (Table 2.2) (Condit 1998, Hubbell et al. 1999, Thompson et al. 2004, Valencia et al. 2004, Vallejo et al. 2004, Hubbell et al. 2010). Noteworthy is the difference with the 50-ha BCI plot, which has 88 tree species ≥10 cm DBH fewer than our plots in Darién, despite having 22 additional ha (79% area increment). Our bootstrapped analysis revealed that BCI has 73–85 tree species (95% confidence intervals) ≥50 cm DBH per 30 randomly selected 1-ha plots, compared to169 species in our plots. In the case of subplots, BCI has 112–130 tree species (95% confidence intervals) ≥10 cm to <50 cm DBH, versus 219 in our subplots. It is important to note, however, that BCI is a single 50-ha plot located only a 1560-ha island, while our 30 plots were distributed across a large landscape, thus likely capturing a greater proportion of species richness.

2.5 Discussion

Capturing AGB variation at the landscape level

Although the remote forests that we sampled had not undergone a significant and visible change in land use, such as to agriculture or cattle ranching, closer scrutiny revealed that not all these mature forests were intact. As mentioned above, half the plots had been subject to traditional indigenous extractive activities. We found that the key determinant of AGB variation is the level of disturbance. Neither differences across forest types, nor spatial variation, either random or due to biophysical factors, had as much effect on AGB as the selective extraction of large trees. Our results also highlight that this variation in ABG did not affect the forest canopy height, and that it was not captured by our satellite-based analyses of vegetation cover, nor an analysis using LiDAR data (Asner et al. 2013).

Previous studies have highlighted that differences between disturbed and intact mature forests are not easily detected through remote sensing techniques unless the type, duration, frequency, intensity, and extent of disturbance results in significant changes to the forest canopy structure (Bustamante et al. 2016). Forest degradation indeed, unlike deforestation, occurs along a continuum (Putz and Redford 2010), and its detection has proven challenging in the establishment of baselines for REDD+. Despite this, remote detection of degradation has been achieved in previous studies relying on time-series data from sites where changes in forest structure and cover are discernable, such as heavily logged and burned forests (Souza Jr et al. 2003), areas experiencing shifting cultivation (Pelletier et al. 2012), or where the presence of surface debris, bare soils, and other human infrastructure (e.g., logging roads, skid tracks, adjacent agriculture) is detectable or used to infer degradation (Margono et al. 2012).

This is not the case in the landscape that we studied where selective logging by Indigenous peoples does not lead to discernible damage to the forest or its surroundings. Therefore, disturbed forests may maintain the structure and characteristics of mature forests, even if AGB volumes differ vastly. The use of satellite time-series data, versus single-time frames has been proposed to identify more subtle changes (Pelletier et al. 2012), but our analyses of canopy height with two different time periods (i.e., 2005 and 2010) did not reveal significant differences. More extended time series might capture gap dynamics, or we may need to rely on proxies. For example, Bucki et al. (2012), in the context of forest monitoring for REDD+, proposed stratifying forested lands between intact and nonintact using distance from the forest edge as a proxy. In this case, the authors suggested a distance of 500 m. The distance proxy was based on results from previous studies that examined the penetration of impacts from various forms of forest disturbance.

In support of the use of proxies, we tested for and found significant differences between undisturbed and disturbed plots in terms of their distance to a nearest community (t = -2.0757, p value = 0.047). Undisturbed plots were on average at 4.6 km from the nearest community, while at 3.1 km for disturbed forest plots. This is consistent with previous studies in eastern Panama that examined the relationship between the harvest of useful plants and distance to a community (Dalle and Potvin 2004). Thus, for remote but inhabited mature forests, one could conceivably define a "buffer zone" of disturbed forests around settlements, and consider that the remaining forest matrix has higher carbon stocks than areas surrounding communities.

Climate change mitigation and biodiversity conservation in Darién

At the global scale, carbon-rich and high-biodiversity areas overlap (Venter et al. 2009, Strassburg et al. 2010), but the trend is not universal (Murray et al. 2015). Our study revealed that even when disturbed forest plots have up to 54% less carbon than undisturbed plots, they maintain the same tree species richness. As such, policy instruments with a focus on carbon or biodiversity, may not be able to fully capitalize on "filling two needs with one deed". Instead, policy development will have to explicitly factor both biodiversity conservation and carbon sequestration, since an umbrella effect in which one can be a surrogate for the other may not always exist. It is important to note, however, that even though disturbed forest areas may not hold the same volume of forest carbon stocks, studies (Bongers et al. 2015, Chazdon et al. 2016) have revealed their disproportionately high capacity to sequester CO_2. Thus, a lack of overlap between carbon and species rich areas does not necessarily preclude these disturbed forest areas from being targeted by policy instruments such as REDD+.

Darién was identified as a priority area during Panama's REDD-Readiness process (ANAM 2008). But how REDD+ may be operationalized in this region remains an open question. Our results position Darién's forests among the most carbon-rich in the tropics, and most tree species rich in the Neotropics. These findings underscore the global importance of this region for climate change mitigation and conservation. However, Darién is undergoing a process of rapid transformation, colonization, and deforestation (Arcia Jaramillo 2015). The region is considered among the most threatened frontier forests in the Americas (Bryant et al. 1997, WWF 2015) due to century-old plans to open the "Darién Gap" (Miller 2014), and more recently, the Panamanian and Colombian governments' plans to develop an electrical interconnection project that could pass through Darién (Proyecto-Mesoamérica 2015). Any linear infrastructure, whether roads or power lines, could lead to further colonization and exploitation (Laurance et al. 2009).

In regions inhabited by Indigenous peoples or local groups, clear and secure land tenure has been posited as a key requirement for REDD+ (Larson et al. 2013). In the case of Darién, most forested areas are located on lands under Indigenous stewardship (Vergara-Asenjo and Potvin 2014), many that overlap fully or partially with protected areas under different management categories. This complex matrix of overlapping land tenure and management regimes, coupled with a long history of land invasions by migrant colonist farmers (Herlihy 2003), creates a challenging socio-political context for REDD+, but one that the proponents of the mechanism must address if they intend to deliver on expected REDD+ outcomes and co-benefits.

The importance and value of intact and near intact forests, those that have been mostly spared from anthropogenic impacts, has been underscored in previous studies (Potapov et al. 2017). These forests, including Darién, make significant contributions, in comparison to degraded forests, to conserving biodiversity, sequestering and storing carbon, and providing a variety of other key ecosystem services. In addition to these global environmental values, intact forest areas may also hold fundamental cultural and social values, particularly for Indigenous peoples (Watson et al. 2018). Darién's three indigenous cultures, namely the Emberá, Wounaan and Guna, are intimately tied to these forests (Heckadon-Moreno et al. 1984). This study provides supporting evidence for the imperative need to direct greater attention to the intact forests of Darién, given the disproportionately important role they play in mitigating climate change and housing biodiversity. Darién's undisturbed forests have the highest carbon stocks among nine mature forest sites across the Neotropics, and the second highest tree species richness among five mature forest sites in the same region.

2.6 Acknowledgements

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2.7 Conflict of Interest

The authors declare no potential conflict of interests.

2.8 Author Contributions

J.M.-V. and C.P. designed the study. J.M.-V. carried out the fieldwork, conducted the analyses and wrote the manuscript. J.P.M.-A. contributed with data preparation and satellite imagery analyses. All authors reviewed and edited the final manuscript.

2.9 Data Accessibility

Data available upon request from the corresponding author.

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2.11 References

ANAM. 2008. Forest Carbon Partnership Facility. Readiness Plan Idea Note (R-Pin) Template. Forest Carbon Partnership Facility (FCPF), World Bank.

Anderson-Teixeira K. J., et al. 2015. CTFS-ForestGEO: a worldwide network monitoring forests in an era of global change. Global Change Biology **21**:528-549.

Arcia Jaramillo O. 2015. Bosques de Darién, en peligro por tala ilegal. La Prensa, Panama City, Panama.

Asner G. P., et al. 2013. High-fidelity national carbon mapping for resource management and REDD+. Carbon Balance and Management **8**.

Baselga A.Orme C. D. L. 2012. betapart: an R package for the study of beta diversity. Methods in Ecology and Evolution **3**:808-812.

Bongers F., Chazdon R., Poorter L.Peña-Claros M. 2015. The potential of secondary forests. Science **348**:642-643.

Bryant D., Nielsen D.Tangley L. 1997. The Last Frontier Forests: Ecosystems and Economies on the Edge. What is the Status of the World's Remaining Large, Naturel Forest Ecosystems? . World Resources Institute, Washington, D.C. .

Bucki M., Cuypers D., Mayaux P., Achard F., Estreguil C.Grassi G. 2012. Assessing REDD+ performance of countries with low monitoring capacities: the matrix approach. Environmental Research Letters **7**:014031.

Bustamante M. M. C., et al. 2016. Toward an integrated monitoring framework to assess the effects of tropical forest degradation and recovery on carbon stocks and biodiversity. Global Change Biology **22**:92-109.

Chave J., et al. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia **145**:87-99.

Chave J., Coomes D., Jansen S., Lewis S. L., Swenson N. G.Zanne A. E. 2009. Towards a worldwide wood economics spectrum. Ecology Letters **12**:351-366.

Chave J., et al. 2014. Improved allometric models to estimate the aboveground biomass of tropical trees. Global Change Biology **20**:3177-3190.

Chazdon R. L., et al. 2016. Carbon sequestration potential of second-growth forest regeneration in the Latin American tropics. Science Advances **2**.

Condit R. 1998. Tropical Forest Census Plots. Springer-Verlag and R. G. Landes Company, Berlin, Germany, and Georgetown, Texas.

Dalle S.Potvin C. 2004. Conservation of useful plants: An evaluation of local priorities from two indigenous communities in Eastern Panama. Economic Botany **58**:38-57.

Global Forest Watch. 2019a. Tree cover in Darién, Panama. Accessed on March 11, 2019 from http://www.globalforestwatch.org.

Global Forest Watch. 2019b. Tree cover in Emberá, Panama. Accessed on March 11, 2019 from http://www.globalforestwatch.org.

Goodman R. C., Phillips O. L., del Castillo Torres D., Freitas L., Cortese S. T., Monteagudo A.Baker T. R. 2013. Amazon palm biomass and allometry. Forest Ecology and Management **310**:994-1004.

Hanbury-Tenison A. R.Burton P. J. K. 1973. Should the Darién Gap Be Closed? The Geographical Journal **139**:43-52.

Heckadon-Moreno S., Herrera F.Pastor Nuñez A. 1984. Breve estudio de los grupos humanos del Darién. Pages 81-104. in Heckadon-Moreno S.McKay A., editors. Colonización y Destrucción de Bosques en Panamá. Asociación Panameña de Antropología, Panama.

Herlihy P. H. 2003. Participatory Research Mapping of Indigenous Lands in Darién, Panama. Human Organization **62**:315-331.

Herrera-MacBryde O.ANCON. 1997. Darién Province and Darién National Park, Panama. Pages 226-232 in Davis S., Heywood V. H., Herrera-MacBryde O., Villa-Lobos J.Hamilton A. C., editors. Centres of Plant Diversity: A Guide and Strategy for their Conservation. . World Wildlife Fund For Nature (WWF) and IUCN-The World Conservation Union., Washington, D.C.

Holdridge L. R. 1967. Life Zone Ecology. Rev. ed. . Tropical Science Center, San Jose, Costa Rica.

Hubbell S. P., Condit R.Foster R. B. 2010. Barro Colorado Forest Census Plot Data. http://ctfs.arnarb.harvard.edu/webatlas/datasets/bci.

Hubbell S. P., Foster R. B., O'Brien S. T., Harms K. E., Condit R., Wechsler B., Wright S. J.Loo de Lao S. 1999. Light gap disturbances, recruitment limitation, and tree diversity in a neotropical forest. Science **283**:554-557.

Larson A. M., et al. 2013. Land tenure and REDD+: The good, the bad and the ugly. Global Environmental Change **23**:678-689.

Laurance W. F., Goosem M.Laurance S. G. W. 2009. Impacts of roads and linear clearings on tropical forests. Trends in Ecology & Evolution **24**:659-669.

Le Quéré C., et al. 2015. Global carbon budget 2014. Earth System Science Data **7**:47-85.

Margono B. A., Turubanova S., Zhuravleva I., Potapov P., Tyukavina A., Baccini A., Goetz S.Hansen M. C. 2012. Mapping and monitoring deforestation and forest degradation in Sumatra (Indonesia) using Landsat time series data sets from 1990 to 2010. Environmental Research Letters **7**:034010.

Mascaro J., Asner G. P., Muller-Landau H. C., van Breugel M., Hall J.Dahlin K. 2011. Controls over aboveground forest carbon density on Barro Colorado Island, Panama. Biogeosciences **8**:1615-1629.

Mateo-Vega J., et al. 2017. Full and effective participation of indigenous peoples in forest monitoring for reducing emissions from deforestation and forest degradation (REDD+): trial in Panama's Darién. Ecosphere **8**:e01635-n/a.

Melgarejo C., Corro V., Ruiz-Jaén M. C., Calderón A.Sánchez de Stapf M. 2015. Inventario Nacional Forestal y de Carbono de Panamá. Resultados de la fase piloto 2013-2015. UN-REDD and Ministerio de Ambiente de Panamá, Panama.

Miller S. W. 2014. Minding the Gap: Pan-Americanism's Highway, American Environmentalism, and Remembering the Failure to Close the Darién Gap. Environmental History **19**:189-216.

Murray J. P., Grenyer R., Wunder S., Raes N.Jones J. P. G. 2015. Spatial patterns of carbon, biodiversity, deforestation threat, and REDD+ projects in Indonesia. Conservation Biology **29**:1434–1445

Myers N., Mittermeier R. A., Mittermeier C. G., da Fonseca G. A. B.Kent J. 2000. Biodiversity hotspots for conservation priorities. Nature **403**:853-858.

Pelletier J., Codjia C.Potvin C. 2012. Traditional shifting agriculture: tracking forest carbon stock and biodiversity through time in western Panama. Global Change Biology **18**:3581-3595.

Poncy O., Riéra B., Larpin D., Belbenoit P., Jullien M., Hoff M.Charles-Dominique P. 1998. The Permanent Field Research Station 'Les Nouragues' in the Tropical Rainforest of French Guiana: Current Projects and Preliminary Results on Tree Diversity, Structure, and Dynamics. Pages 385-410 in Dallmeier F.Comiskey J. A., editors. Forest biodiversity in North, Central and South America, and the Caribbean: research and monitoring. UNESCO & Parthenon Pub. Group, Paris and New York.

Potapov P., et al. 2017. The last frontiers of wilderness: Tracking loss of intact forest landscapes from 2000 to 2013. Science Advances **3**.

Proyecto-Mesoamérica. 2015. Interconexión Eléctrica Panamá-Colombia. Proyecto Integración y Desarrollo Mesoamérica.

Putz F. E.Redford K. H. 2010. The Importance of Defining 'Forest': Tropical Forest Degradation, Deforestation, Long-term Phase Shifts, and Further Transitions. Biotropica **42**:10-20.

R Core Team. 2016. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Réjou-Méchain M., et al. 2014. Local spatial structure of forest biomass and its consequences for remote sensing of carbon stocks. Biogeosciences **11**:6827-6840.

Sexton J. O., et al. 2013. Global, 30-m resolution continuous fields of tree cover: Landsat-based rescaling of MODIS Vegetation Continuous Fields with lidar-based estimates of error. International Journal of Digital Earth **130321031236007. doi:10.1080/17538947.2013.786146**.

Simard M., Pinto N., Fisher J. B.Baccini A. 2011. Mapping forest canopy height globally with spaceborne lidar. Journal of Geophysical Research: Biogeosciences **116**:n/a-n/a.

Slik J. W. F., et al. 2013. Large trees drive forest aboveground biomass variation in moist lowland forests across the tropics. Global Ecology and Biogeography **22**:1261-1271.

Souza Jr C., Firestone L., Silva L. M.Roberts D. 2003. Mapping forest degradation in the Eastern Amazon from SPOT 4 through spectral mixture models. Remote Sensing of Environment **87**:494-506.

Stern N. H. 2007. The Economics of Climate Change: the Stern Review. Cambridge University Press, Cambridge, UK; New York.

Strassburg B. B. N., et al. 2010. Global congruence of carbon storage and biodiversity in terrestrial ecosystems. Conservation Letters **3**:98-105.

Thompson J., Brokaw N., Zimmerman J. K., Waide R. B., Everham III E. M.Schaefer D. A. 2004. Luquillo Forest Dynamics Plot, Puerto Rico, United States. Pages 540-550 in Losos E. C.Leigh Jr. E. G., editors. Tropical Forest Diversity and Dynamism. Findings from a Large-Scale Plot Network. The University fo Chicago Press, Chicago.

United Nations Framework Convention on Climate Change. 2008. Report of the Conference of the Parties on its thirteenth session, held in Bali from 3 to 15 December 2007. Addendum Part Two: Action taken by the Conference of the Parties at its thirteenth session. United Nations Framework Convention on Climate Change. .

Valencia R., et al. 2004. Yasuní Forest Dynamics Plot, Ecuador. Pages 609-620 in Losos E. C.Leigh Jr. E. G., editors. Tropical Forest Diversity and Dynamism. Findings from a Large-Scale Plot Network. The University fo Chicago Press, Chicago.

Vallejo M. I., Samper C., Mendoza H.Otero J. T. 2004. La Planada Forest Dynamics Plot, Colombia. Pages 517-526 in Losos E. C.Leigh Jr. E. G., editors. Tropical Forest Diversity and Dynamism. Findings from a Large-Scale Plot Network. The University fo Chicago Press, Chicago.

Venter O., Laurance W. F., Iwamura T., Wilson K. A., Fuller R. A.Possingham H. P. 2009. Harnessing Carbon Payments to Protect Biodiversity. Science **326**:1368.

Vergara-Asenjo G.Potvin C. 2014. Forest protection and tenure status: The key role of indigenous peoples and protected areas in Panama. Global Environmental Change **28**:205-215.

Watson J. E. M., et al. 2018. The exceptional value of intact forest ecosystems. Nature Ecology & Evolution **2**:599-610.

WWF. 2015. WWF Living Forests Report: Chapter 5. Saving Forests at Risk. World Wildlife Fund for Nature, Gland, Switzerland.

Zanne A. E., et al. 2009. Data from: Towards a worldwide wood economics spectrum. Dryad Digital Repository.

2.12 Tables

Table 2.1. Mean AGB (Mg /ha) with +1 standard deviation and coefficient of variation (CV, in %) for plots in all territories (Arimae, Balsas, Caña Blanca, Playa Muerto and Rio Congo), and among territories, forest types (Tropical Moist, Tropical Wet, and Pre Montane Wet), and forest states (undisturbed and disturbed).

Plots	Mean AGB (Mg /ha)	CV
All Territories	283 (SD 89)	31 %
Among Territories	280 (SD 58)	21 %
Among Forest Types	291 (SD 19)	7%
Among Forest States	283 (SD 85)	30 %

Table 2.2. Number of tree species (≥10 cm DBH) in selected forest plots in the Neotropics ordered by plot area size.

Site	State[a]	Total Plot Area (ha)	No. of Species (≥10 cm DBH)
Luquillo (Puerto Rico)	D	16	86
La Planada (Colombia)	UD	25	179
Darién (Panama)[b]	UD and D	28	311
Yasuni (Ecuador)	UD	50	820
Barro Colorado Island (Panama)	UD	50	223

[a] D=disturbed forest area; UD=undisturbed forest area

[b] Results of our current study

2.13 Figures

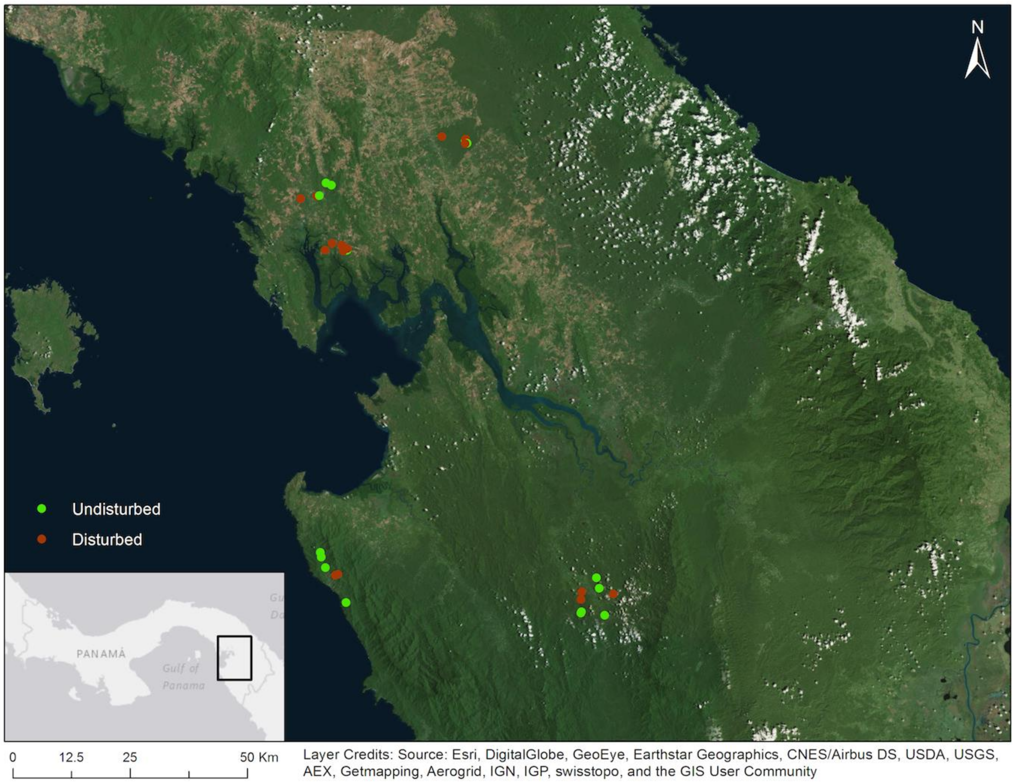

Figure 2.1. Location of undisturbed (green) and disturbed (red) mature forest plots in Darién.

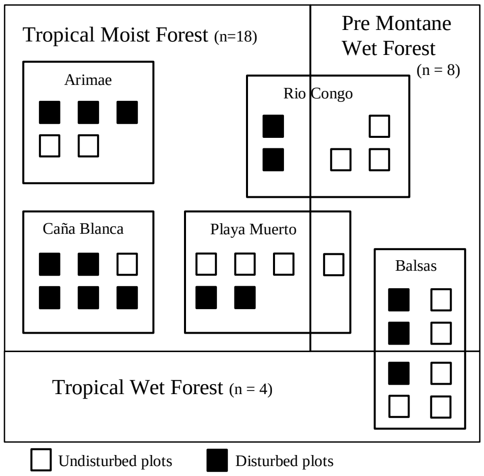

Figure 2.2. Sampling scheme according to forest types, territories and forest state.

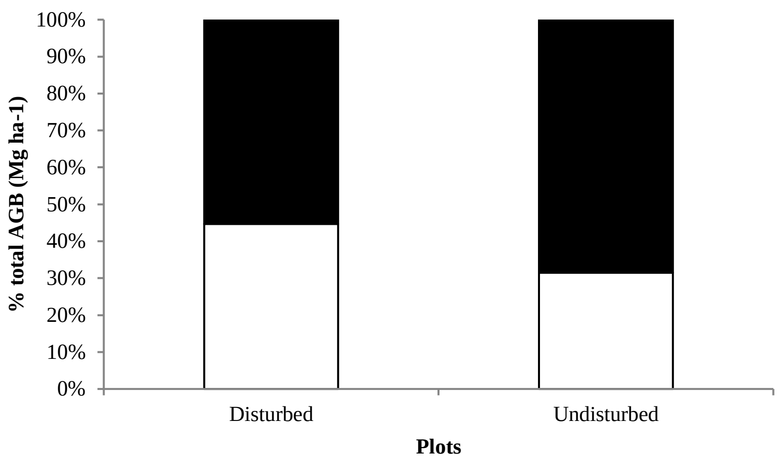

Figure 2.3. Percentage of small (open bar) and large tree (closed bar) AGB for plots in disturbed and undisturbed forest areas.

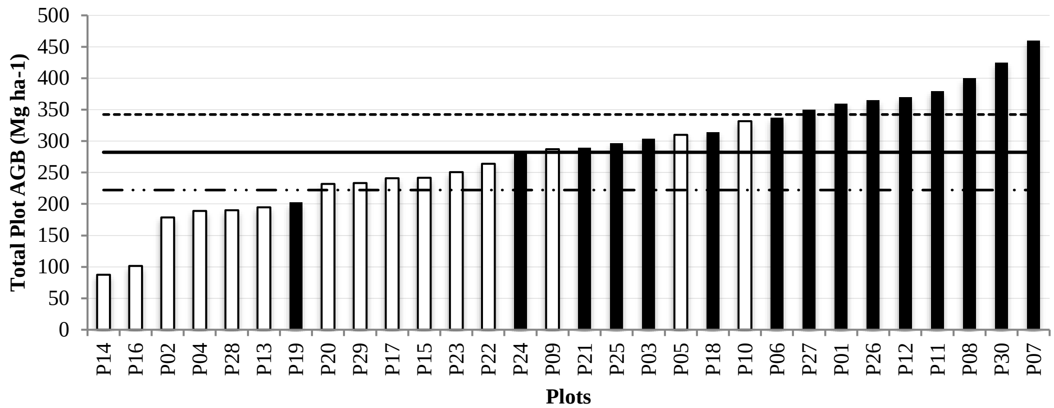

Figure 2.4. Total plot-level AGB (Mg /ha) in undisturbed (solid bar) and disturbed (open bar) forests, and mean total AGB (Mg /ha) for all plots (solid line), undisturbed plots (upper dashed line) and disturbed plots (lower dashed line).

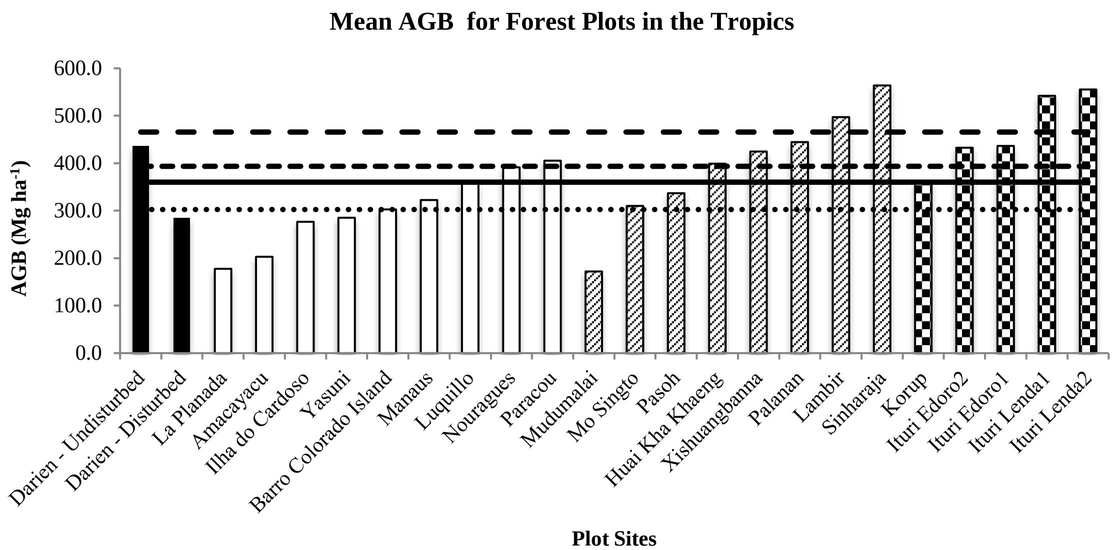

Figure 2.5. Mean plot and regional AGB (Mg /ha) in Darién (solid bars and line), and in undisturbed plots in the Neotropics (excepting Luquillo; open bar; lower dashed line), Asia (hashed bar; middle dashed line), and Africa (checkered bar; upper dashed line).

Linking Statement 3

In the General Introduction, the devolution of forests and their management to communities, including Indigenous peoples, is presented as a second key policy innovation in the context of land tenure reforms taking place around the world, along with the REDD+, a key NbS. Both, in principle, have the potential to arrest forest loss and degradation, and improve the livelihoods of forest dependent communities. In Chapter 3, I shift from the pristine landscapes of eastern Darién to the abutting complex socio-ecological system (SES) of the Upper Bayano Watershed, where remaining swaths of forest are under threat due to long-standing conflicts between Emberá and Guna Indigenous peoples, and colonist farmers. In this chapter, I provide an introduction to Watershed, including its peoples, forests, and land-use dynamics in three Indigenous territories, namely Ipetí, Piriatí, and the Comarca Kuna de Madungandi. I also provide an introduction to REDD+ and the evolution of discussions regarding the mechanism in Panama, revealing the positioning of the three groups in regards to this mechanism. The interactions and tensions between them and the governmental authorities promoting REDD+ is considered, and serves as the basis for the participatory scenario-based planning exercises discussed in Chapter 4. It is important to note that this chapter was also devised as a pedagogical tool and has already been used by the authors, and others, as a teaching case study in numerous graduate-level courses at McGill University, Yale University, and the University of Pennsylvania, among others.

Chapter 3: Deforestation, territorial conflicts, and pluralism in the forests of eastern Panama: a place for Reducing Emissions from Deforestation and Forest Degradation (REDD+)?

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3.1 Abstract

Deforestation is a primary contributor to global climate change. When the forest is felled, and the vegetation is burnt or decomposes, carbon dioxide, a greenhouse gas, is released into the atmosphere. An approach designed to stem climate change is *Reducing Emissions from Deforestation and Forest Degradation* (REDD+), a global financial mechanism that requires intricate governance requirements to be met – a significant challenge in developing areas. In Panama, the government is responsible for designing and implementing a national REDD+ strategy with support from multilateral organizations. This case study is built through the experience of a public hearing on the potential implementation of REDD+ in the highly contested Upper Bayano Watershed in eastern Panama. The Upper Bayano Watershed is comprised of vast and diverse forest ecosystems. It forms part of the Choco-Darién ecoregion, a global biodiversity hotspot, and is home to two Indigenous groups (Kuna and Emberá) and populations of migrant farmers (*colonos*), all with different histories, traditions, and worldviews concerning forests and land management, often resulting in territorial conflicts. A major social-ecological issue facing the region is deforestation, which is driving biodiversity loss and landscape change, and threatening traditional livelihoods and cultures. The public hearing stimulates difficult discussions about access to land, tenure security, biodiversity conservation,

poverty reduction, identity, power, trade-offs and social justice. The case is designed to confront participants with the challenges of implementing ambitious, international, and often-prescriptive natural resource policies at local levels.

3.2 Key Message

Users of this case will (1) develop an understanding of the complex interactions between socio-economic, cultural, and political components of coupled natural and human forest ecosystems in eastern Panama, (2) learn to articulate different stakeholder perspectives on tropical forests and climate change policy issues using the case of REDD+ in Panama, and (3) gain insight into some of the challenges and opportunities facing coordinated policy responses to tropical deforestation.

3.3 Introduction

Forests and climate change

Forests play a fundamental role in the global carbon cycle, serving as both sinks and sources of carbon dioxide (CO_2) [1], a greenhouse gas that is the primary contributor to global climate change [2]. When forests are felled or degraded, carbon is released back to the atmosphere in the form of CO_2 if the vegetation is left to decompose or is burnt. Between 1990 and 2015, the global rate of deforestation decreased, but remained alarmingly high with a net loss of 129 million hectares (ha), mostly in the tropics [3]. During the same period, Panama lost 423,000 ha of forest [4]. In the Upper Bayano Watershed, an analysis by Vergara-Asenjo et al. [5], based on maps by Hansen et al. [6], revealed that 17,901 ha were lost between 2001–2012, representing an annual rate of deforestation of 0.42%, while the national rate was 0.35%. Globally, deforestation and forest degradation account for ~9% of anthropogenic CO_2 emissions [7].

Introduction to Reducing Emissions from Deforestation and Forest Degradation (REDD+)

Recognizing that deforestation and forest degradation are important contributors to climate change, a proposal was put forward by the governments of Papua New Guinea and Costa Rica in 2005 [8], to include actions aimed at “reducing emissions from deforestation” (RED) as part of the United Nations Framework Convention on Climate Change. Also referred to as “avoided deforestation”, this proposed RED mechanism was deemed one of the most cost-effective strategies to fight climate change [9] . The concepts of RED and avoided deforestation have now morphed into REDD+ [10, 11]. REDD+ is a policy instrument by which developed countries may partially offset their CO_2 emissions, and thus mitigate global climate change, by financing developing countries to reduce deforestation and degradation, and enhance forest carbon stocks through forest conservation, sustainable forest management, and afforestation and reforestation [11, 12]. REDD+ may also achieve various co-benefits including biodiversity conservation, rural development, poverty alleviation, and improved forest governance [13-15].

REDD+ opportunities and challenges

No other international mechanism on forests or climate change has generated as much interest, debate and controversy as REDD+ [16]. It has spawned a deluge of research and publications in both academic and policy circles, been the theme of myriad conferences and meetings, and drawn the mass attention of media [17, 18]. Interest in REDD+ stems from the multiple benefits it may generate, including mitigating the impacts of climate change, and protecting and restoring large swaths of forests and the ecosystem services they provide [19]. If well designed, REDD+ could also generate valuable revenue and employment for local communities, thus improving their livelihoods [20]. In addition, the mechanism could lead to more secure land tenure rights, as the clarification of tenure by governments is necessary to provide assurances to investors that forests are under the stewardship of those receiving payments [21]. Furthermore, REDD+ could result in improved forest governance [22] by stimulating reforms in support of the mechanism.

However, several challenges with REDD+ have been articulated [23-26]. Concerns over the infringement of human rights of forest-dependent and dwelling people have percolated REDD+ discussions [27]. There are fears that REDD+ might stimulate land grabbing and invasions by elite groups (*e.g.* governments and large landholders) wanting to capitalize on carbon offset payments [21]. Uncertainties regarding land and carbon tenure, and thus the potential for the inequitable distribution of benefits,[5] as well as the exclusion of minority perspectives in decision making, have also been key sources of tension between REDD+ proponents and potential beneficiaries [14, 28-32]. The capacity of developing countries to enact changes in forest governance is also highly debated, particularly in “fragile” states fraught with corruption, widespread poverty, poor enforcement capacity, gross social discrimination, and economic inequalities [33-36]. However, in balance, there appears to be enough institutional backing and impetus behind REDD+ for it to move forward [37].

REDD+ in Panama with Indigenous peoples

Panama was among the first countries to begin to prepare for REDD+ in 2008 by developing and strengthening the social, technical and institutional capacities necessary for the mechanism. At the time, 54% of remaining mature forests in Panama were located in Indigenous territories [38], so the participation of Indigenous peoples was deemed essential to the success of REDD+. Progress, however, was hampered by complaints against the Government of Panama and the United Nations Collaborative Programme on REDD+ (UN-REDD), by the National Coordinating Body of Indigenous Peoples of Panama (COONAPIP), for not guaranteeing the respect of Indigenous peoples' human rights, or ensuring their full and effective participation in REDD+ [39-41].

In early 2013, COONAPIP withdrew from the REDD+ process, but later that year, made amends with UN-REDD and the Government of Panama. Eventual fractures within COONAPIP resulted in some Indigenous groups expressing an interest in REDD+, others rejecting it, and some failing to define a position, a situation that remains. The only known experience with REDD+ in Indigenous territories in Panama, a forest conservation and restoration project in an Emberá community in eastern Panama, suggests that state support would be a necessary condition for the success of REDD+ initiatives given promising community-level adoption [42].

3.4 Case Examination

The Upper Bayano Watershed socioecological system (SES)

The 3,695-km^2 Upper Bayano Watershed (Figure 3.1), located 90 km east of Panama City along the Pan-American Highway, is part of a complex socio-ecological system (SES) [43] and biodiversity hotspot [44] that houses forests that extend contiguously ~250 km eastward into the province of Darién. This SES hosts one of the last remaining stands of pristine, tropical forests in Mesoamerica [45, 46], which is under threat by competing development interests [47, 48]. Widespread illegal deforestation (Figure 3.2) has raised concerns over the future of this region's natural and cultural heritage [48-50].

The Upper Bayano Watershed has been the stage of long-standing territorial conflicts between Kuna and Emberá Indigenous peoples, and farmers, known as *colonos* (i.e., individuals colonizing the agricultural frontier), who migrated from central and western Panama in search of land for subsistence farming and cattle ranching [51-53]. These conflicts, catalyzed by the forced displacement of local populations during the construction of the Bayano Hydroelectric Complex in the 1970s, have yet to be fully addressed [53, 54], despite a 2014 ruling by the Inter-American Court of Human Rights that requires the government of Panama to resolve the problem of insecure land tenure [55]. Differing worldviews about land management, land invasions by *colonos*, and poor enforcement of land tenure, have been sources of disputes between these groups and drivers of landscape-level changes, primarily along the Pan-American Highway [5, 46, 56-58]. Conflicts between Kunas and Emberás center on overlapping land delimitation. In general, these two Indigenous nations live alongside with little interaction. They collaborate occasionally; most recently through the case brought forward to the Inter-American Court of Human Rights demanding indemnification for loss of ancestral lands due the construction of the Bayano Hydroelectric Complex [55].

This case study explores how different stakeholders, who share a common landscape and value forests in fundamentally different ways, view the potential for REDD+ to contribute to sustainable development. It is structured around Ostrom's [43] framework for analyzing SES, with a focus on stakeholders (i.e., resource users) and how they may exercise their agency to either accept or reject REDD+.

3.5 Stakeholders in Bayano

Emberás

The Emberás migrated to eastern Panama from Colombia starting in the 19th century [51]. Their presence in the Bayano region is reported in the 1940s in isolated home sites along the Bayano River and its tributaries [51, 59]. Recognizing the value of collective action in dealing with the government, the Emberás settled in villages in the 1950s and 1960s [51, 59]. With the construction of the Bayano Hydroelectric Complex, they were re-settled in three territories, Ipeti, Piriati and Majé (Figure 3.1). With the passing of law No. 72 in 2008 [60], which established the norms for adjudicating collective lands to Indigenous communities outside of *comarcas* (i.e., legally declared Indigenous territories), the Emberás politically organized themselves as the *Tierras Colectivas Emberá de Alto Bayano* (Figure 3.1). After almost 40 years, Piriati and Ipeti received their land titles in 2014 and 2015, respectively. Majé, which has the highest percentage of remaining forests, but is also the most threatened due to illegal logging and land invasions, has not received its title as of 2017 [5].

Historical logging, land invasions by *colonos*, and agriculture carried out by the Emberás, have resulted in the loss of important tracts of forest [61, 62]. Since REDD+ is performance-based [37] (payments are made against proof that rates of forest carbon stocks losses have been curbed) the onus would fall on the Emberás to protect what remains of their forest. The Emberás have a strong connection to the forest, but due to deforestation are no longer able to benefit as much from traditional uses. Community members are facing difficulties with finding medicinal plants, wild meat, and places to enjoy nature. It has become harder for the Emberás to access natural construction materials, which along with the challenges of maintaining traditional homes, has led to a widespread shift from traditional Emberá architecture (Figure 3.3) to building methods employed by *colonos*. Traditional huts, built on stilts with forest materials, have given way to ground-level cinder block homes with metal zinc roofs.

The Emberás in the Bayano have experience with carbon sink projects, including a native tree species reforestation and forest conservation project in the community of Ipeti established to offset a Panama-based research institution's carbon dioxide emissions [42]. Despite this, the Emberás have not formally accepted to participate in the national REDD+ strategy.

Kunas

The Kunas in the Bayano region are remnant Indigenous populations from a migration toward Panama's Caribbean coast in the 18th century from the province of Darién [51], abutting Colombia. They were adjudicated legal title in 1996 [63] to 2,318.8 km^2 (Figure 3.1), also the result of the forced displacement of their communities during the construction of the Bayano Hydroelectric Complex and subsequent flooding of their ancestral lands [53]. The *Comarca* has 14 villages, and all have been built according to traditional norms, using materials from the forest (Figure 3.4).

The Kunas maintain the largest tracts of forest, particularly north of Lake Bayano (Figure 3.1). The region of the *Comarca* near the Pan-American Highway continues to be subject to invasions by *colonos*. Agreements have been reached with some *colonos* so that they can remain on *Comarca* lands, but waves of migrants have continued to arrive, resulting in occasionally violent confrontations between both groups. Some invasions have also begun to occur in the more inaccessible lakeside region.

Like the Emberás, the *Comarca Kuna de Madungandi* has opted to not participate in the REDD+ mechanism [64]. Among their arguments is the incongruent view between REDD+ proponents, for whom the forest is, in essence, an absorber and repository of carbon, and the Kunas who view trees as their brothers [65]. Despite these cultural norms, some villages have established forestry concessions with logging companies [5]. The leaders of the *Comarca* have also begun to revisit the issue of REDD+ following meetings with representatives from the Government of Panama, while still not committing to participate in the mechanism.

Colonos

Colonos began to arrive in the Bayano in the 1950s, with colonization steadily increasing with the construction of the hydroelectric dam and the Pan-American Highway [53]. These farmers migrated in search of land, and implemented their traditional agricultural practices of subsistence farming, followed by pasture establishment for low-density cattle-ranching [52]. They mostly manage small farming units (Figure 3.5). Few *colonos* have formal land title. Instead, many have possession rights, i.e., tenure of land without a government-issued title [66, 67]. Possession rights are reversible and thus, may impede the *colonos* from accessing REDD+ benefits.

Some *colonos* that invaded Indigenous lands in the 1970s and 80s have signed agreements with the Kunas to work their lands, but their tenure status is precarious. New waves of *colonos* continue to arrive in the region, often invading Indigenous lands. These do not have any arrangements with the Indigenous authorities and evictions are continuous, and tend to be violent. Unlike the Emberás and Kunas, they are not accustomed to working collaboratively and, generally, lack organizational structures that represent their interests [56, 66]. A previous study [66] explored opportunities and challenges for implementing REDD+ with *colonos* , and found that unless REDD+ reconciles farmers' cultural uses of lands and avoids disparities in the sharing of benefits, it would likely not succeed. This same study, however, revealed that *colonos* value forests and may conserve these ecosystems if conferred formal land title by the government [66].

Government of Panama

The Ministry of Environment is leading national REDD+ efforts in Panama, in close collaboration with UN-REDD. Internationally, Panama has positioned itself as a leader on the mechanism. For example, it presided over the Coalition of Rainforest Nations, an inter-governmental organization that addresses issues of tropical forest sustainability, and led the creation of the International Center for the Implementation of REDD+ [68]. Through it, Panama is pursuing an ambitious reforestation initiative, called the Alliance for one Million Hectares (hereafter Alliance), working with government agencies and local NGOs to restore degraded lands over the next 20 years.

Locally, however, the government-led REDD+ process has encountered difficulties, particularly in their engagement with Indigenous peoples. It has taken the Ministry of Environment more than three years since problems with COONAPIP emerged, to initiate the consideration of safeguards to reduce the deleterious impacts and maximize the benefits of REDD+ on stakeholders [69]. The Ministry of Environment is now holding discussions individually with Indigenous authorities, and in the case of the Upper Bayano Watershed, these have centered on restoring degraded and invaded lands as part of the Alliance. With a history of land grabbing [58], unclear, insecure and poorly-enforced tenure regimes [5, 48], and a system of social and environmental safeguards whose implementation is yet to be operationalized, questions remain about the government's capacity to ensure that REDD+ meets its full intent.

3.6 Case Study Questions

For this case study, participants should be divided in four groups that represent the Emberás, Kunas, *colonos* and government officials (for more details, see Teaching Notes). Each group will articulate their position on REDD+ while role-playing in the context of a public hearing. Like in real life, those representing the Kunas, Emberás and *colonos* will either opt in or out of REDD+, conditioning their participation or justifying their non-engagement. The government's role is to encourage the participation of the other three groups, as without them – particularly Indigenous peoples – REDD+ is likely to have limited impact in Panama's efforts to mitigate climate change.

The course instructor should serve as chairperson of the hearing, representing an independent consultant leading a study on the prospects and viability of REDD+ in Panama. The chairperson is encouraged to initiate by providing (Appendix C1) an overview of REDD+, the process underway in Panama, stakeholders, and REDD+ relevant issues taking place in the Bayano, namely that:

1. REDD+ is considered one of the most cost-effective mechanisms to mitigate climate change globally [9]. If well designed, REDD+ could also contribute to conserving biodiversity and ecosystem services, and improving the livelihoods of the rural poor [19, 20].

2. Internationally, Panama has been a leader in REDD+. Nationally, engagement with Indigenous peoples has alternated between periods of collaboration and tension [40] . The government continues to make efforts to improve their rapport with Indigenous peoples.

3. Indigenous peoples are the primary stewards of remaining forests in Panama [38], and therefore could expect to benefit more from REDD+ than other stakeholders. In Bayano, the Kunas have the largest forest estate, and hold title to this land. The Emberá territory of Majé has the second largest forest estate, but the Emberás have not been conferred formal title to this land. Majé overlaps with a hydrologic reserve, which is subject to government management, and is undergoing a rapid process of deforestation.

4. Land invasions by *colonos* are the primary driver of deforestation in the Bayano [5]. *Colonos*, continue to arrive in the Bayano due to the exhaustion of affordable land elsewhere in Panama [66].

5. Avoiding the loss of ~5,000 ha of forests to land invasions could potentially generate ~US$330,000/year in the Bayano through REDD+ revenue, enough to deploy key strategies to protect and restore forests, and provide income to local communities [5].

6. To date, the Kunas, Emberás and *colonos* have not agreed to take part in REDD+. However, the government continues to meet with them regarding plans to reforest one million hectares of land over 20 years, which has sparked the interest of all groups.

Each group should prepare to present and defend their position based on internal consensus. If divergent views between the four groups are put forward, they should develop recommendations on how to potentially reconcile these contrasting perspectives on REDD+. The following questions should serve to incite discussions:

1. What conditions would have to be met for REDD+ to be adopted in the Bayano by the different groups, and what actions would be required for these conditions to be met?

2. What management tools/approaches may stimulate adoption of REDD+ by the different groups?

3. What role does each group play in protecting and/or felling and degrading forest areas that could be slated for REDD+?

4. What are the broader political economic conditions that affect/influence decisions around the use of natural resources?

5. In the context of Panama and the Bayano, what elements may generate power asymmetries and influence REDD+ adoption or rejection?

6. How could local stakeholders resist or support REDD+ programs? Who would be their allies locally, nationally and internationally?

7. What opportunities and challenges do deforestation and climate change mitigation-related policy initiatives face in Panama? How might community and policy responses be more effective?

3.7 Author Contributions

Conceptualization, investigation, methodology, project administration, visualization, and writing (original draft, review, and editing): JM-V. Conceptualization, method- ology, project administration, and writing (review and editing): AKS and GMH. Conceptualization, funding acquisition, investigation, methodology, project adminis- tration, supervision, and writing (review and editing): CP.

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3.10 Competing Interests

The authors declare no competing interests.

3.11 Supplementary Materials

Appendix C1: Teaching Notes
Appendix C2: Classroom management

Appendix C3: Proposed grading rubric

Appendix C4: Background to the case study

3.12 References

1. Brinck K, Fischer R, Groeneveld J, Lehmann S, Dantas De Paula M, Pütz S, et al. High resolution analysis of tropical forest fragmentation and its impact on the global carbon cycle. Nature Communications. 2017;8:14855.
2. IPCC. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland: IPCC; 2007.
3. FAO. Global Forest Resources Assessment 2015. How are the world's forests changing? Second edition. Rome: Food and Agriculture Organization of the United Nations; 2016.
4. FAO. Global Forest Resources Assessment 2015. Desk Reference. Rome, Italy: Food and Agriculture Organization of the United Nations; 2015.
5. Vergara-Asenjo G, Mateo-Vega J, Alvarado A & Potvin C. A participatory approach to elucidate the consequences of land invasions on REDD+ initiatives: A case study with Indigenous communities in Panama. PLOS ONE. 2017;12(12):e0189463.
6. Hansen MC, Potapov PV, Moore R, Hancher M, Turubanova SA, Tyukavina A, et al. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science. 2013;342(6160):850-3.
7. Le Quéré C, Moriarty R, Andrew RM, Peters GP, Ciais P, Friedlingstein P, et al. Global carbon budget 2014. Earth System Science Data. 2015;7(1):47-85.
8. UNFCCC. Item 6 of the provisional agenda. Reducing emissions from deforestation in developing countries: approaches to stimulate action. Montreal, Quebec, Canada.: United Nations Framework Convention on Climate Change; 2005.
9. Stern NH. The Economics of Climate Change: the Stern Review. Cambridge, UK; New York: Cambridge University Press; 2007.
10. UNFCCC. Report of the Conference of the Parties on its fifteenth session, held in Copenhagen from 7 to 19 December 2009. Addendum. Part Two: Action taken by the Conference of the Parties at its fifteenth session. FCCC/CP/2009/11/Add.1. United Nations Framework Convention on Climate Change.; 2010.

11. UNFCCC. Report of the Conference of the Parties on its sixteenth session, held in Cancun from 29 November to 10 December 2010. Addendum part two: action taken by the Conference of the Parties at its sixteenth session. FCCC/CP/2010/7/Add.1.: United Nations Framework Convention on Climate Change.; 2011.
12. Olander LP, Galik CS & Kissinger GA. Operationalizing REDD+: scope of reduced emissions from deforestation and forest degradation. Curr Opin Environ Sustain. 2012;4(6):661-9.
13. Potts MD, Kelley LC & M. Doll HM. Maximizing biodiversity co-benefits under REDD+: a decoupled approach. Environmental Research Letters. 2013;8(2):024019.
14. Chhatre A, Lakhanpal S, Larson AM, Nelson F, Ojha H & Rao J. Social safeguards and co-benefits in REDD+: a review of the adjacent possible. Curr Opin Environ Sustain. 2012;4(6):654-60.
15. Pokorny B, Scholz I & de Jong W. REDD+ for the poor or the poor for REDD+? About the limitations of environmental policies in the Amazon and the potential of achieving environmental goals through pro-poor policies. Ecology and Society. 2013;18(2).
16. Angelsen A, Brockhaus M, Duchelle AE, Larson A, Martius C, Sunderlin WD, et al. Learning from REDD+: a response to Fletcher et al. Conservation Biology. 2017;31(3):718-20.
17. Redford KH, Padoch C & Sunderland T. Fads, Funding, and Forgetting in Three Decades of Conservation. Conservation Biology. 2013;27(3):437-8.
18. Lund JF, Sungusia E, Mabele MB & Scheba A. Promising Change, Delivering Continuity: REDD+ as Conservation Fad. World Development. 2017;89:124-39.
19. Turnhout E, Gupta A, Weatherley-Singh J, Vijge MJ, de Koning J, Visseren-Hamakers IJ, et al. Envisioning REDD+ in a post-Paris era: between evolving expectations and current practice. Wiley Interdisciplinary Reviews: Climate Change. 2017;8(1):e425-n/a.
20. Caplow S, Jagger P, Lawlor K & Sills E. Evaluating land use and livelihood impacts of early forest carbon projects: Lessons for learning about REDD+. Environmental Science & Policy. 2011;14(2):152-67.
21. Larson AM, Brockhaus M, Sunderlin WD, Duchelle A, Babon A, Dokken T, et al. Land tenure and REDD+: The good, the bad and the ugly. Global Environmental Change. 2013;23(3):678-89.

22. Mulyani M & Jepson P. REDD+ and Forest Governance in Indonesia: A Multistakeholder Study of Perceived Challenges and Opportunities. The Journal of Environment & Development. 2013;22(3):261-83.
23. Angelsen A. Moving ahead with REDD: Issues, options and implications. Angelsen A, editor. Bogor, Indonesia.: CIFOR; 2008. 156 p.
24. Visseren-Hamakers IJ, Gupta A, Herold M, Peña-Claros M & Vijge MJ. Will REDD+ work? The need for interdisciplinary research to address key challenges. Curr Opin Environ Sustain. 2012;4(6):590-6.
25. Phelps J, Guerrero MC, Dalabajan DA, Young B & Webb EL. What makes a 'REDD' country? Global Environmental Change. 2010;20(2):322-32.
26. Fletcher R, Dressler W, Büscher B & Anderson ZR. Questioning REDD+ and the future of market-based conservation. Conservation Biology. 2016;30(3):673-5.
27. Wallbott L. Indigenous Peoples in UN REDD+ Negotiations: Importing Power and Lobbying for Rights through Discursive Interplay Management. Ecology and Society. 2014;19(1).
28. Hiraldo R & Tanner T. Forest Voices: Competing Narratives over REDD+. IDS Bulletin. 2011;42(3):42-51.
29. Lyster R. REDD+, transparency, participation and resource rights: the role of law. Environmental Science & Policy. 2011;14(2):118-26.
30. Sikor T, Stahl J, Enters T, Ribot JC, Singh N, Sunderlin WD, et al. REDD-plus, forest people's rights and nested climate governance. Global Environmental Change. 2010;20(3):423-5.
31. Griffiths T. Seeing 'REDD?' Forests, climate change mitigation and the rights of indigenous peoples and local communities. Updated Version. . Forest Peoples Programme.; 2009.
32. Luttrell C, Loft L, Fernanda Gebara M, Kweka D, Brockhaus M, Angelsen A, et al. Who Should Benefit from REDD+? Rationales and Realities. Ecology and Society. 2013;18(4).
33. Karsenty A & Ongolo S. Can "fragile states" decide to reduce their deforestation? The inappropriate use of the theory of incentives with respect to the REDD mechanism. Forest Policy and Economics. 2012;18:38-45.

34. Hansen CP, Lund JF & Treue T. Neither Fast, Nor Easy: The Prospect of Reduced Emissions from Deforestation and Degradation (REDD) in Ghana. International Forestry Review. 2009;11(4):439-55.
35. Unruh JD. Tree-Based Carbon Storage in Developing Countries: Neglect of the Social Science. Society & Natural Resources. 2011;24(2):185-92.
36. Peskett L & Yanda P. The REDD+ outlook: how different interests shape the future. United Kingdom. : Overseas Development Institute; 2009.
37. Brockhaus M, Korhonen-Kurki K, Sehring J, Di Gregorio M, Assembe-Mvondo S, Babon A, et al. REDD+, transformational change and the promise of performance-based payments: a qualitative comparative analysis. Climate Policy. 2017;17(6):708-30.
38. Vergara-Asenjo G & Potvin C. Forest protection and tenure status: The key role of indigenous peoples and protected areas in Panama. Global Environmental Change. 2014;28(0):205-15.
39. Cuellar N, Kandel S, Davis A & Luna F. Indigenous peoples and governance in REDD+ Readiness in Panama. Case study on COONAPIP, ANAM and the UN-REDD Program. San Salvador, El Salvador: PRISMA; 2013.
40. Feiring B & Abbott E. Preliminary note on findings, conclusions and recommendations. Panama: Independent team for the investigation and evaluation of the UN--REDD Panama Programme; 2013.
41. Tuckman J. Panama's indigenous people see Redd over UN forest conservation scheme. The Guardian. 2013.
42. Holmes I, Potvin C & Coomes O. Early REDD+ Implementation: The Journey of an Indigenous Community in Eastern Panama. Forests. 2017;8(3):67.
43. Ostrom E. A General Framework for Analyzing Sustainability of Social-Ecological Systems. Science. 2009;325(5939):419-22.
44. Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB & Kent J. Biodiversity hotspots for conservation priorities. Nature. 2000;403:853-8.
45. Bryant D, Nielsen D & Tangley L. The Last Frontier Forests: Ecosystems and Economies on the Edge. What is the Status of the World's Remaining Large, Naturel Forest Ecosystems? . Washington, D.C. : World Resources Institute; 1997.

46. Sloan S. Reforestation amidst deforestation: Simultaneity and succession. Global Environmental Change. 2008;18(3):425-41.
47. Suman D. Globalization and the Pan-American Highway: Concerns for the Panama-Colombia Border Region of Darién-Chocó and its Peoples. University of Miami Inter-American Law Review. 2007;38(3):539-614.
48. Foro_y_Observatorio_de_Sostenibilidad. Recomendaciones del Consejo Consultivo en Resolución de Conflictos en REDD+, para solucionar conflictos territoriales en Panamá. Dirigidas al Consejo Nacional de Tierras, a través del Ministerio de Gobierno, y a la Autoridad Nacional del Ambiente. Panama City, Republic of Panama: INDICASAT, USMA, STRI, McGill University, UNITWIN/UNESCO; 2015.
49. Arcia Jaramillo O. Bosques de Darién, en peligro por tala ilegal. La Prensa. 2015.
50. Miller SW. Minding the Gap: Pan-Americanism's Highway, American Environmentalism, and Remembering the Failure to Close the Darién Gap. Environmental History. 2014;19(2):189-216.
51. Torres de Araúz R. Phase I - Final Report. Human Ecology Studies, Panama. Columbus, Ohio: Battelle Memorial Institute, Columbus Laboratories.; 1967.
52. Heckadon-Moreno S. La colonización campesina de bosques tropicales en Panamá. In: Heckadon-Moreno S, McKay A, editors. Colonización y Destrucción de Bosques en Panama. Panama: Asociacion Panameña de Antropologia; 1984. p. 17-44. .
53. Wali A. Kilowatts and crisis: hydroelectric power and social dislocation in eastern Panama. Boulder, CO, USA: Westview Press; 1989.
54. OAS-IACHR. Inter-American Commission on Human Rights. 2013. [August 25, 2013]. Available from: .
55. IACHR. Caso Pueblos Indígenas Kuna de Madungandí y Emberá de Bayano y sus Miembros Vs. Panamá. Sentencia de 14 de octubre de 2014. (Excepciones Preliminares, Fondo, Reparaciones y Costas). Resumen oficial emitido por la Corte Interamericana. . San José, Costa Rica: Inter-American Court of Human Rights.; 2014.
56. Wali A. The transformation of a frontier: state and regional relationships in Panama, 1972-1990. Human Organization 1993;52(2):115-29.
57. Simmons CS. Forest management practices in the Bayano region of Panama: Cultural variations. World Development. 1997;25(6):989-1000.

58. Velásquez Runk J. Indigenous Land and Environmental Conflicts in Panama: Neoliberal Multiculturalism, Changing Legislation, and Human Rights. Journal of Latin American Geography. 2012;11(2):21-47.
59. Pastor Nuñez A. Los Emberá-Waunana y su Incorporación a la Sociedad Marginal Urbana de Panamá. In: Pastor Nuñez A, editor. Antropología Panameña - Pueblos y Culturas. Panamá, República de Panamá: Editorial Universitaria.; 1998. p. 141-50.
60. República de Panamá. Ley 72. "Que establece el procedimiento especial para la adjudicación de la propiedad colectiva de tierras de los pueblos indígenas que no están dentro de las comarcas", (2008).
61. Sharma D, Vergara-Asenjo G, Cunampio M, Cunampio RB, Cunampio MB & Potvin C. Genesis of an indigenous social-ecological landscape in eastern Panama. Ecology and Society. 2015;20(4).
62. Sharma D, Holmes I, Vergara-Asenjo G, Miller WN, Cunampio M, B. Cunampio R, et al. A comparison of influences on the landscape of two social-ecological systems. Land Use Policy. 2016;57:499-513.
63. República de Panamá. Ley 24. "Por la cuál se crea la Comarca Kuna de Madungandi", (1996).
64. Potvin C & Mateo-Vega J. Panama: Curb indigenous fears of REDD+. Nature. 2013;500(7463):400-.
65. Castillo G. Investing in Locally Controlled Forestry. Introduction and Working Paper. Panama, Republic of Panama: The Forest Dialogue; 2009.
66. Peterson St-Laurent G, Gélinas N & Potvin C. REDD+ and the agriculture frontier: Understanding colonists’ utilization of the land. Land Use Policy. 2012.
67. Spalding AK. Exploring the evolution of land tenure and land use change in Panama: Linking land policy with development outcomes. Land Use Policy. 2017;61:543-52.
68. MiAmbiente. Inauguran Centro Internacional de Reducción de Emisiones por Deforestación y Degradación de los Bosque en Panamá (ICIREDD) Panama City, Republic of Panama: MiAmbiente; 2016 [Available from: .
69. MiAmbiente. Marco conceptual, basado en las mejores prácticas internacionales, para el diseño del Enfoque Nacional de Salvaguardas y el Sistema de Información de

Salvaguardas adaptados al contexto de Panamá. Panama City, Republic of Panama: MiAmbiente; 2016.

3.13 Figures

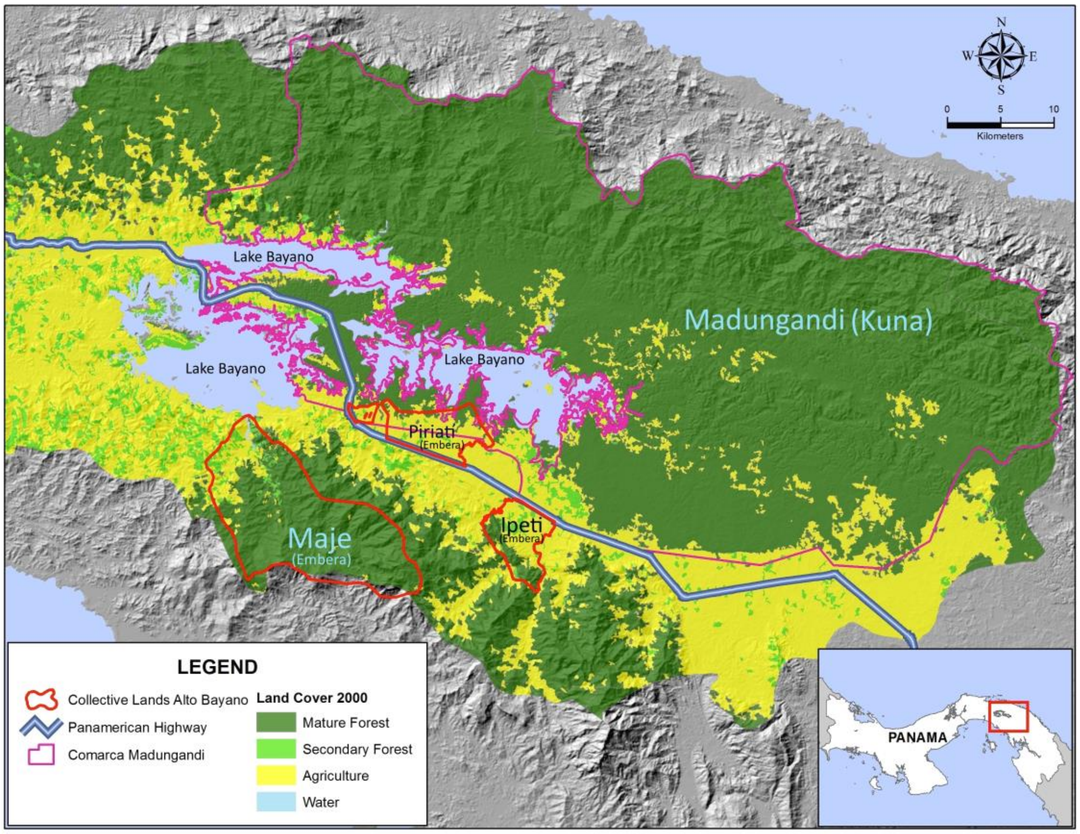

Figure 3.1. The Upper Bayano Watershed of eastern Panama

Figure 3.2. Deforestation in eastern Panama. (Photo credit: Javier Mateo-Vega)

Figure 3.3. Traditional Emberá village in eastern Panama. (Photo credit: Javier Mateo-Vega)

Figure 3.4. Kuna village nestled in the forests of the Upper Bayano Watershed. (Photo credit: Javier Mateo-Vega)

Figure 3.5. Colonos live in dispersed houses throughout the Upper Bayano Watershed. (Photo credit: Javier Mateo-Vega)

Linking Statement 4

When deploying NbS, such as REDD+, in the context of devolved forest management to local communities, including Indigenous peoples, it is key to elucidate the potential future trajectories of land-use and their implications on the forest estate. However, limited attention has been given to understanding how communities envision managing their forests over time, based on their aspirations and needs, once awarded land title or user rights. In Chapter 4, I present the results of a participatory scenario-based planning exercise carried out to reveal Indigenous visions for the future of their forests under business-as-usual and their desired scenarios. The results are markedly divergent, with the former scenario revealing a sustained process of forest attrition, and the latter scenario prognosticating the expansion of the forest estate. To avoid continued forest loss (business-as-usual scenario), both the Emberás and Gunas outline a series of pathways (i.e., strategies) to achieve their desired vision for the future of their territories and forests. Implications of these visions in the context of REDD+ are discussed.

Chapter 4: Participatory visioning and pathways for forest conservation and restoration in Indigenous lands: elucidating potential future states

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4.1 Abstract

Estimates suggest that, globally, ~20% of tropical forest carbon and up to 80% of biodiversity is housed in Indigenous territories, both recognized and under claim. As such, Indigenous peoples have the potential to play a preponderant role in Nature-based Solutions to climate change and biodiversity loss. Elucidating potential land-use trajectories in these territories is key to informing reference emissions levels against which carbon gains or losses may be estimated and compensated. To date, however, the future extent and condition of forests in lands under Indigenous stewardship has been primarily projected using computer-based models, thus, ignoring the aspirations and needs of those who inhabit these areas. Facilitated and culturally appropriate participatory scenario-building is a complementary method that has the power to foment social learning and catalyze alternative land-use pathways. Using the Upper Bayano Watershed in eastern Panama, and working with Emberá and Guna Indigenous peoples, we use *visioning* and *pathways development* to reveal potential futures for the region's Indigenous forest estate under business-as-usual and desired scenarios. Our study reveals a marked disconnect between their desired vision and the current state and potential land-use trajectories of their territories. We consider the results in the context of two policy innovations, namely the devolution of forest to communities as part of land tenure reforms, and the Nature-based

Solution, Reducing Emissions from Deforestation and Forest Degradation (REDD+). Key conditions required for Indigenous peoples to realize their desired vision for their forests, and fully reap the rewards of these policy instruments, are still missing in Panama, a problem that is shared with many other forest-rich countries in the developing world.

Keywords: participatory scenario-based planning, visioning, pathways development, Indigenous peoples, Nature-based Solutions, REDD+

4.2 Introduction

Indigenous peoples are stewards, owners or have legally-designated rights to approximately a quarter of the world's global forest estate (Garnett et al., 2018; Ginsburg and Keene, 2018), more than a third of intact forest landscapes (Watson et al., 2018), and almost a fifth of forest carbon stocks based on a sample of 64 countries that account for ~70% of the world's forest cover (Frechette et al., 2018). Estimates also suggest that lands under Indigenous stewardship overlap with areas that might host up to 80% of the world's biodiversity (Sobrevila, 2008). Until now, however, scant attention has been paid to elucidating potential land-use trajectories in Indigenous territories, which is essential for implementing Nature-based Solutions for climate change, biodiversity loss and human well-being (Griscom et al., 2017; Seddon et al., 2020), including Reducing Emissions from Deforestation and Forest Degradation (REDD+) (Parsamehr et al., 2020). The few studies that have examined how the forest estate under Indigenous tenure might change over time, both in extent and condition (Walker et al., 2014; Vergara-Asenjo et al., 2017; Alejo et al., 2021), have done so through computer-based modeling exercises, overlooking the aspirations, needs, intentions, and plans for land-use and forest management by the Indigenous groups inhabiting these landscapes. These studies, although valuable in providing insights to potential future forest outcomes in Indigenous territories, have not fully embraced Indigenous peoples' rights to self-determination—i.e., to plan, chart and shape their own destiny—thus missing a key piece of information regarding the future of these forests.

Participatory scenario-based planning allows for the consideration of different potential futures—i.e., scenarios—and the development of robust and alternative policies and solutions to those prospective scenarios, thus allowing groups to cope with and manage uncertainty and change (Bennett et al., 2003). The Millenium Ecosystem Assessment, for example, helped to hone a systematic methodology for elucidating plausible futures for ecosystems undergoing change, the implications of these changes on the delivery of ecosystem services globally, and their consequences on human well-being (Carpenter et al., 2006). Drawing from this body of work, Evans et al. (2006) proposed four different participatory scenario-based methods for communities to consider their future, and how to allocate, use and manage their natural resources: (1) *alternative scenarios*, which are two or more stories about plausible futures derived from an understanding of the driving forces leading to changes in a socio-ecological system; (2) *projections*, which calculate a single potential future based on analyses of current trends; (3) *visioning*, which considers a single possible future for a community or territory based on stakeholders' aspirations and hopes; and (4) *pathways*, which allows participants to devise strategies and actions to connect the current state of their communities with their vision for the future. This study considers the latter two.

Through *visioning*, a community works collectively to reflect upon and conceive of an ideal, yet achievable, future, drawing from the expectations of its inhabitants (Evans et al., 2006). The common *vision* may be depicted in the form of maps of the territory derived from land-use plans, sketches of the community and its people, written as a narrative story, or even acted out as a skit (Evans et al., 2010). One key mechanism for carrying out a *visioning* exercise is through participatory land-use planning, i.e., the process of defining where and how land will be used in a defined area and over a determined period of time (Chigbu et al., 2017). In the context of forested landscapes in the tropics, this approach to planning has been embraced since the early 1990s when a trend of forest devolution and government decentralization began (Evans et al., 2010). These participatory approaches, which counter (or complement) state-led planning exercises, are highly collaborative processes that integrate different types of knowledge (e.g., traditional ecological knowledge from Indigenous Peoples with "Western" scientific knowledge) and prepare and empower stakeholders to consider alternative futures to the path that they are currently on (Evans et al., 2010; Oteros-Rozas et al., 2015). They were born from a recognition that communities have the right to protect their interests, livelihoods, and define their future (Evans et al., 2006), especially when they are the most directly affected by decisions regarding the use and management of their natural resources. It has been demonstrated that community-level participation in planning results in greater buy-in and sustainability of actions taken, reduces conflict, increases community resilience, and maximizes benefits sharing (Evans et al., 2006; Ostrom, 2009; Oteros-Rozas et al., 2015; Patrick et al., 2017).

However, participatory planning efforts have also been criticized as covert mechanisms for modern day colonialism, often resulting in the imposition of top-down decision making by more powerful and politically savvy actors that sideline the interests of communities (Hibbard et al., 2008; Porter, 2010; Patrick et al., 2017). This is particularly problematic in contexts of marginalized groups, such as Indigenous peoples, where poverty and illiteracy rates are high, language barriers may exist, and communities might lack negotiation and collective decision-making skills and norms (Evans et al., 2010). Mapping, for example, a fundamental element of land-use planning, has been used for centuries as a tool by powerful elites to establish empires and convert large expanses of the world into real estate, often at the costs of Indigenous peoples and local communities (Chapin et al., 2005; Bryan, 2011). Land-use planning itself, has historically been devoid of key collaborative governance principles including engagement by all relevant stakeholders, transparency, equity, and accountability, often resulting in elite capture and control of land and natural resources, and tokenism (Evans et al., 2010; Chigbu et al., 2017).

As a result, within community-engaged or participatory planning, scholars and practitioners alike have proposed *Indigenous planning* as an alternative approach that follows Indigenous worldviews, avoids translating Indigenous culture and values through western planning logic, and recognizes Indigenous peoples as holders of the essence of knowledge in these processes (Jojola, 2013). Although Indigenous planning follows, in essence, the same steps as conventional land-use planning, according to Patrick et al. (2017), "Indigenous planning comes from a different place, wherein a collective vision is centered on land stewardship, where the benefits of plan making are distributed evenly across space and where the planning horizon is multigenerational." As advanced by Elder Albert Marshall of the Mi'kmaw Nation (Bartlett *et al.*, 2012), Indigenous planning, as a discipline, follows the concept of *Two-Eyed Seeing*. Through *Two-Eyed Seeing*, one eye is used to draw from and interpret the world through Indigenous knowledge and ways of knowing, while the other does the same, but through mainstream "Western" sciences, and both eyes are used to reconcile the two bodies of knowledge (Peltier, 2018). It is important to note that Indigenous planning is not new; it has taken place for centuries, but is now being "reclaimed" (Jojola, 2013), primarily as a form of resistance or co-existence with planning systems espoused by non-Indigenous peoples (Prusak et al., 2016).

Once a community has settled on a common *vision* for the future of their territory, they can devise specific *pathways*—i.e., strategies and actions—to achieve their desired outcomes (Evans et al., 2010). As part of this process, participants conduct a diagnosis of existing problems with regards to the use and management of their territory. Based on the results, participants can formulate solutions to the problem and define the *pathway* from the present to their desired future, created during the *visioning* exercise (Evans et al., 2006).

Here we examine how culturally appropriate, participatory scenario-based planning can (1) elucidate the potential future extent and condition of forests, and (2) reveal alternative land-use trajectories, based on local expectations and aspirations using a case-study conducted in Eastern Panama. We illustrate the power of participatory scenario-based planning through a study commissioned and led by Emberá and Guna Indigenous peoples, in three territories under significant deforestation pressure in the Upper Bayano Watershed (Figure 4.1). In this context, we specifically sought to answer the following questions:

1. What is the vision of the Emberá and Gunas for their forests in their three territories over a 40-year horizon;

2. What potential implications do these visions of land-use trajectories have on the extent of their forests;

3. What actions do they intend to pursue to fulfill their vision, and what internal and external enabling conditions must be met?

The study was conducted drawing from good practices in participatory mapping (Corbett, 2009) and Indigenous land-use planning (Prusak et al., 2016) that are transferable to broader scenario-based planning efforts, namely that: (1) the traditional authorities would be responsible for convening the community members to the various planned workshops that would take place as part of the *visioning* and *pathways* development exercises, and all efforts would be made to ensure broad participation, including of elders, women and youth; (2) the communities would be in control of decision-making during the exercises, while the researchers would serve as facilitators of process; (3) the workshops would respect Indigenous life and not interfere with key activities, such as traditional congresses, celebrations, and agricultural sowing and harvesting periods; and (4) all information generated would be co-owned by the Indigenous communities and the researchers. This latter group would be allowed to remove key outputs from the territories, such as the participatory maps produced, to analyze and publish the results, but these would be returned to the communities, along with any additional new outputs derived from the analyses.

4.3 Methods

Study site: Indigenous territories in the Upper Bayano Watershed

This study took place in three Indigenous territories within the Upper Bayano Watershed (Figure 4.1), located ~90 km eastward from Panama City, namely the Comarca Kuna de Madungandi (~231,880 ha; 4,575 people) (INEC, 2013) and two of three Emberá territories that make up the Collective Lands Emberá of Alto Bayano: Piriatí (3,944 ha; 497 people) (ANATI, 2014) and Ipetí (3,285 ha; ~550 people) (ANATI, 2015; Sharma et al., 2016; Holmes et al., 2017). Although the Emberá territories of Ipetí and Piriatí have similar settlement history, location and size, they have undergone marked divergent land-use trajectories since establishment, resulting in two distinct socio-ecological systems (Sharma et al., 2016). For this reason, they were treated independently from one another in this study. The Upper Bayano Watershed encompasses an area of ~4,844 km^2 and is still largely forested (Guillemette et al., 2017). The area has elevations that range from ~50 to 900 m, an annual average rainfall between1600 and 2400 mm, and a rainy season that lasts between May and December (Wali, 1989). The Upper Bayano Watershed is shared principally by Guna and Emberá Indigenous peoples, and migrant farmers, known as *colonos*, all who depend on the area's lands and forests for subsistence (Wali, 1989).

This participatory scenario-based planning study took place under the auspices of a project, *Juntos para Proteger Nuestra Cuenca* ("Together to Protect our Watershed", in English) aimed at conserving forests under threat from deforestation, and restoring degraded forests in the Upper Bayano Watershed, by lessening long-standing tensions between local Indigenous peoples and *colonos* (Guillemette et al., 2017). *Juntos para Proteger Nuestra Cuenca* was developed and executed in collaboration with the traditional Indigenous authorities of the Comarca Kuna de

Madungandi and the Emberá Collective Lands of Alto Bayano, together with two Indigenous NGOs, i.e., Organización Kuna de Madugandi (ORKUM) and Dobbo Yala Foundation, and two farmer associations, i.e., Asociación de Productores de Agropecuarios de Platanilla (APAP) and Asociación Unión de Campesinos de la Provincia de Panamá (AUCPP)). Focal points from each of these groups were selected by competent authorities, whether from the Indigenous congresses or the organizations, to accompany the implementation of the project with the researchers co-leading this effort.

Participatory scenario-based planning

We used two scenario-based planning methods (Evans et al., 2010)—i.e., participatory *visioning* and *pathways*—to ensure the systematic and culturally-appropriate consideration of Indigenous peoples expectations for the management of their natural resources, in full compliance with their right to self-determination. These methods help communities prepare for the future by encouraging them to consider alternative outcomes, leverage opportunities, and mitigate threats to their territories, including forests and other natural resources. In participatory scenario-based planning, stakeholders, often with the support of researchers, take a leadership role in examining plausible futures, different to their current state, through a highly collaborative process, and then design actions to pursue their desired future (Oteros-Rozas et al., 2015). All steps employed in the *visioning* and *pathways* development exercises (Figure 4.2) were co-designed with the Indigenous focal points.

We held a series of four preparatory meetings in March and April 2016 (two with the Emberás and two with the Gunas) (Figure 4.2) with the focal points, traditional authorities and their advisors, and Indigenous technicians. The purpose of these meetings was to define the scope of the study and establish a series of procedural rules (Appendix D1). Noteworthy, as part of the *visioning* exercises, the group opted to devise a normative scenario of the future of their territories and forests (Oteros-Rozas et al., 2015), depicting their ideal *vision*, and to complement this, for comparative purposes, with an explorative scenario, depicting the evolution of their estate under business-as-usual. Naturally, *pathways* to achieve the vision were to only be devised for the ideal scenario, and not the business-as-usual scenario. These preparatory meetings were key in terms of complying with the principles of free, prior and informed consent (FPIC), which ensures that Indigenous peoples or traditional communities are afforded the opportunity to give or withhold consent to an initiative that may have any bearing on their lands, resources and livelihoods in full understanding of its implications (Colchester, 2010).

The *visioning* exercises were carried out through a process of Indigenous land-use planning, in May and June 2016 (for details, see Appendix D2), during which the following steps were carried out:

1. Identification by participants of highly-valued landscape features and locations in the Upper Bayano Watershed and the reasons behind these;

2. Historical reconstruction of land use, definition of current land use (i.e., in 2015), and *visioning* of desired future land use across the territories;

3. Participatory visualization in the form of maps of the *visions* of future land use; and

4. Preparation of a narrative story or list of key aspirational elements of the *visions* of future land use.

The workshops lasted between 1.5 and 2 days and were attended by a total of 90 people: 41 in Ipetí (19 women; 22 men), 32 in Piriatí (12 women; 20 men) and 17 in the Comarca Kuna de Madungandi (2 women; 15 men). In all three cases, a core group of 21 people in Ipetí, 11 in Piriatí, and 15 in the Comarca, were consistently present throughout the workshops, while others attended intermittently. To the best of our knowledge, and in line with best practices (Evans et al., 2006; Oteros-Rozas et al., 2015), all perspectives from the communities were considered.

In two subsequent focus-group workshops held in June 2016, one with representatives from both Emberá communities, and the other with the Gunas, we facilitated the process of defining *pathways* for these communities to move from their current status of land use to their desired *vision* for 2055 defined in the *visioning* exercises. To support this process, we conducted *problem tree* analyses to (1) examine and consider the central problems affecting their territories with a focus on their forest estate; (2) explore the origins of these problems through an analysis of drivers of change; and (3) determine their effects and consequences, represented metaphorically by the trunk, roots and branches and leaves of a tree, respectively (Anyaegbunam et al., 2004). During the workshops, we placed a poster-sized image of a tree on a wall. Participants were then asked to write their ideas on sticky notes, and place these in the corresponding section of the tree, i.e., the roots, trunk, branches, and leaves. We then facilitated a discussion around the poster to reach a consensus on both the ideas presented, and their placement on the tree. Based on the *problem tree* analyses, both groups outlined a series of strategic objectives and activities—i.e., *pathways*—that they would like to pursue to address the central problems identified in the analyses and achieve their desired land-use futures. For both groups, the traditional authorities and their advisors carried out the development of *pathways*, with 7 and 8 participants respectively.

The primary outputs of the study were comprised of both quantitative and qualitative data. Quantitative data included the matrices used to reconstruct perceived historical land use (1975–2014), and compare land use category allocations between the ideal *visions* of land use for the Emberá and Guna territories, and the business-as-usual scenarios, from 2015 to 2055. Additional quantitative data included the original hand-drawn participatory ideal, and business-as-usual scenario maps, which were scanned and digitized with a GIS (ArcMap/ArcGIS). In the case of the latter two, which were prepared for the year 2055, the total amount and percentage allocation for each land use category was derived from the maps with the GIS. These were then compared to contrast how land use in the three territories could evolve with, or in the absence of, concrete actions to pursue the desired futures identified by the Emberás and Gunas. We also compared, both in total amount and percentage, the different land-use category allocations between the matrices and *visioning* maps for the year 2055 of the three territories. This was done to provide land-use category allocations in ranges, versus single set values. Primary qualitative data, which included the *problem tree* analyses, *pathways* (i.e., strategies and actions), and narrative stories and lists of key elements describing the future of the territories, were all transcribed into Word documents. It is important to note that a composite map of the three territories was also produced, thus depicting the three territories' collective *vision* of future land use, and the business-as-usual scenario.

Socialization of results

To initiate the socialization of results, we first held a workshop in July 2016 in Akua Yala with 14 Emberá and Guna traditional authorities, including the first and second Chiefs, their advisors, and teams of technicians. During this workshop, each group presented to each other the results of the work that had been produced, including the *visioning* maps, matrices, *problem trees* and *pathways*. This space was used to share and discuss their experiences and results. As described in Appendix D, and in compliance with ethics protocols (Appendix D3), all outputs of the study were then made readily available in print and digital format to all communities, reaching the ~5,600 Indigenous inhabitants across the three territories.

4.4 Results

Visioning future land-use in the Upper Bayano Watershed

The identification of highly-valued locations and landscape elements was used to prepare the participants to consider their ideal scenario for the future of their territories in a subsequent stage of the workshop. A total of 109 responses were provided by the 90 participants, namely 23 locations and 86 landscape elements. The study revealed two key findings for the Emberás and Gunas collectively in terms of their favored locations. First, of the 23 locations mentioned (Table 4.1; Table D4.1A, Appendix D4), 16 (70%) are near, or are themselves, bodies of water, including rivers and Lake Bayano. It is also worth noting that all communities and rivers referenced in the 16 responses are surrounded by forests, even in Piriatí, whose last remnants of forest are located near the bodies of water mentioned by the participants. Another 5 (22%) responses referred directly to forest areas, while the remaining two responses (8%) referenced entire territories, either the Comarca Kuna de Madungandi or Ipetí. The second noteworthy finding is that, with the exception of the two mentions to general territories, all preferred locations that are remote (21, 91%), i.e., only accessible by foot or boat, or a combination of these, and far removed from the Pan-American Highway. Not one community, river or forest area referenced in the discussions was near the highway, which has been mostly deforested on both margins, replaced by mixed cropping systems, cattle ranching, mechanized rice fields, teak plantations, short and tall fallows, and small dispersed communities.

Of the 86 responses registered regarding highly-valued landscape elements (Table 4.1; Table D4.1B, Appendix D4), animals (i.e., wildlife), forests and water were the most referenced, with

30 (35%) 27 (31%) and 20 (23%) mentions, respectively. The remaining nine responses were distributed between restoration (i.e., reforestation with native tree species) and production systems (2; ~2%), and boulders, caves, and fresh air (7; ~8%). In the case of animals, participants made 13 mentions of mammal, bird and fish species that are hunted or fished traditionally by the Emberás and Gunas, including the guacuco fish (*Chaetostoma sp*.), white-lipped peccary (*Tayassu pecari*), white-tailed deer (*Odocoileus virginianus*), lowland paca (*Cuniculus paca*), agouti (*Dasyprocta punctate*), great tinamou (*Tinamus major*), and crested guan and/or currasow birds (*Penelope purpurascens* and/or *Crax rubra*). These species have historically represented important sources of protein for both groups, and are commonly found in forest areas and clean rivers. No domesticated animal species were referenced in any of the three workshops. In the case of forests, participants made general and specific mentions (20 in total) to particular tree species and medicinal plants.

There were three discernable differences in responses among the Emberás and Gunas with regards to favored landscape elements. In Piriatí, likely due to the very limited remaining forest, animals were only referenced once and in general terms (i.e., no particular species was identified). As reported by the participants, wildlife of interest to the Emberás is rarely spotted in this territory and hunting is no longer common. The two mentions of restoration and production systems (i.e., agroforestry) were only made by participants from Ipetí who, unlike Piriatí at the time of this study, have a history of working these two types of activities from previous and ongoing reforestation initiatives. The seven references to boulders, caves and fresh air were only made by the Gunas. Boulders are found along remote rivers that flow from the heavily forested Cordillera of San Blas in the northern part of the Upper Bayano Watershed, toward Lake Bayano. These rivers, as discussed by the participants, have crystalline waters, are surrounded by old-growth, undisturbed forests, including *kalus* (i.e., sacred forests), and the hunting along the boulders and rivers is exceptionally good. The caves, on the other hand, are part of the karst topography on the southern part of the watershed (Kueny and Day, 2002), formally outside of the Comarca Kuna de Madungandi. These caves have been carved out by the Seco River and are frequented by the Gunas, other local residents, and tourists. The two mentions of fresh air were in relation to the remote forests and boulders in the northern part of the Comara Kuna de Madungandi.

There were also noteworthy age-dependent and gendered differences in responses among the Emberá. Among those who provided responses, 5 (28%) were youth (3 women and 2 men, with ages oscillating between 13 and 26 years old), following the definition employed by Sharma et al. (2015), and based on consultations with the Emberá traditional authorities. The youth appeared to struggle in identifying their favorite locations. Four indicated that they had never visited areas beyond their communities or nearby towns along the Pan-American Highway within the Upper Bayano Watershed. Only one had experienced walking and hunting in pristine forests, and swimming and fishing in a crystalline river in the Comarca Kuna de Madungandi. None of the three young women had experienced these kind of pristine settings, and all expressed disappointment with this fact. Overall, the Emberá youth identified their own communities as their favorite places in the watershed in the absence of other references. Elders, on the other hand, identified areas that still have forest cover and/or clean rivers and streams as their favorite locations. In two cases, this included areas that are now part of the Comarca Kuna de Mandungandi (i.e., Capandi River and community of Ikandi), as Emberás used to live dispersed across this landscape along with the Gunas prior to the construction of the hydroelectric project (Wali, 1989). The reasons listed by the elders for valuing these areas included access to bushmeat, fish and fruit, plants to prepare traditional medicines, and construction materials to build traditional homes (Table D4.1B, Appendix D4). They also mentioned that these areas are less hot (i.e., there is a cool breeze) and beautiful.

In the case of the Gunas, elder men provided all responses (i.e., ≥26 years old), thus no age-dependent or gendered perspectives were discernable. However, it is important to note that 10 of the 14 communities in the Comarca are located in remote areas (i.e., only accessible by boat or foot) with direct and close access to old-growth forest and clean rivers, where residents can reap all the material and immaterial benefits these areas provide. When the Guna elders were asked about access by youth to the pristine natural environments, the general agreement was that across all ages, experience in pristine environments for all members of the Comarca is commonplace. They did acknowledge, as is also revealed in the literature (Sherzer, 1987; Tice, 1995), that women tend to be more closely bound to life within and in near proximity to the community, including helping in the fields, while men are the ones that wander farther into the wilderness to hunt and gather.

The historical reconstruction of land use (1975–2015) for the Emberá and Guna Indigenous territories (Figure 4.3; Appendix D5) was carried out to serve as reference for both groups to develop their vision of desired futures of land use for the period of 2016-2055. Here, we report both on perceived changes in "forest cover" and "tree cover". Primary, secondary, and sacred forests comprise the former category, with sacred forests also being primary forests, but with a special cultural designation conferred by the Gunas. Tree cover accounts for the three aforementioned forest types, but also includes native tree species reforestation, agroforestry systems and tall fallows, following the definition employed by Global Forest Watch (2019).

The Emberás' perception was that, at the time of their arrival in their newly assigned territories of Ipetí and Piriatí in 1975, natural forests covered ~80% of the land (Figure 4.3; Appendix D5). Their assessment suggests that an additional 5% of Ipetí's territory had tree cover, including cacao and coffee mixed with other trees (i.e., agroforestry), while the remainder of lands in both Emberá territories had – for the most part in equal proportions—recently cleared forest areas, mixed cropping systems, short fallows, and in the case of Piriatí, some pastures for livestock. In the case of the Comarca Kuna de Madungandi, the perception of the participants was that 95% of the land had natural forest cover, including sacred forests, while the remaining 5% was comprised of mixed crops and short fallows. These land use classifications are consistent with what is described in the literature for the time period (Wali, 1989).

During the following forty years, up to 2015, participants from all three territories perceived a marked decline in forest cover, with Madungandi dropping to 75% of their territory (i.e., 65% primary and sacred; 10% secondary), Ipetí to 35%, and Piriatí to 5% (Figure 4.3; Appendix D5). In the case of Madungandi, participants recalled that the forest was mostly replaced with mixed crops, short fallows, and the establishment of pastures for livestock production. Original agricultural lands and short fallows, according to their collective memory, reverted to secondary forest and tall fallows, thus the Comarca still seemingly maintained tree cover in approximately 85% of the territory by 2015. In Ipetí, their recollection is that the amount of recently cleared land, short fallows, mixed crops, pastures, and mechanized rice, covered more than a third of their territory, while the remainder had agroforestry, tall fallows, and native tree species reforestation, bringing the total area with tree cover to 60% for the same time period. Piriatí, which according to participants' perception experienced the most drastic decline in forest cover, seemingly had 80% of the territory transformed into permanent pastures, lands that alternated between pasture and mechanized rice, mixed cropping systems, short fallows, and monocultures of plantain. By 2015, participants suggested that Piriatí had 20% of tree cover, comprised of 5% of forest cover, and the remainder of tall fallows and some reforestation with native tree species.

The business-as-usual scenarios for future land use developed by the Emberás and Gunas, covering the period of 2016–2055, revealed the participants' belief that the historical pattern of forest and tree cover attrition would continue unabated. This is reflected both through the results of the matrices (Figure 4.3; Appendix D5) and mapping exercises (Figure 4.4; Appendices D6 and D7) reported here. In contrast, their visions of desired futures, covering the same period, revealed their aspiration to increase forest and tree cover, to diversify their land uses, and make these more consonant with traditional practices compared to the baseline date of 2015 in the three territories (Figure 4.3 and 4.4; Appendices D5, D6 and D7).

Under the business-as-usual scenario, community members of Piriatí envisioned losing the totality of their remaining forests by 2025 (in a single decade) and not recovering any of it over the following three decades. By 2055, they estimated that only ~5% of the territory would have tree cover (i.e., reforested lands with native tree species), while the rest would become much more homogenized with mechanized rice and pastures dominating the socio-ecological system, resembling more closely land use by *colonos* in the region. On the contrary, their desired vision of future land use portrays a very different outcome by 2055, with 70–75% percent of the territory under forest and tree cover with a diverse mix of forests, agroforestry and silvopastoral systems, and reforested lands. They envisioned the remainder of the land having mixed cropping systems instead of monocultures of mechanized rice and plantain, or pastures (Figures 4.3 and 4.4; Appendices D5, D6 and D7).

In the case of Ipetí, community members similarly envisioned that under the business-as-usual scenario, forest cover would decline to 10–15% of territory by 2055, and other forms of tree cover would also decrease, accounting for to 20–27% of the territory. The results suggest that in the remainder of the territory, the community would continue to actively colonize the forest frontier by clearing land, and transforming fallows to expand agricultural production, primarily with mixed cropping systems, mechanized rice, and pastures. Alternately, the community's desired vision of future land use reveals their aspiration to recover large swaths of forest, up to 52% of the territory, with an additional 31–34% of the territory under some form of tree cover. The remaining 15–17% would be used for mixed cropping systems and mechanized rice (Figures 4.3 and 4.4; Appendices D5, D6 and D7).

In the territory of Madungandi, the participants envisioned that under a business-as-usual scenario, by 2055, forest cover would account for 48–55% of the territory, while an additional 5–10% would be under other forms of tree cover, namely reforestation with native tree species. The rest of the territory, according to their projections, would be used primarily for agriculture including mechanized rice, pastures, and mixed cropping systems. In contrast, their desired vision of future land use revealed their wish to have up to 70% of the territory under forest cover, with an additional 7-15% with other forms of tree cover. Under this scenario, they envisioned that 15-37% of the remainder of the territory would be used for agriculture, all of it under their control, with none rented out to *colonos* (Figures 4.3 and 4.4; Appendices D5, D6 and D7).

The *visioning* exercises were completed with each group drafting a narrative description of their territory for the year 2055, based on their ideal vision. These were produced in a participatory manner, and in the case of the Emberás, a single statement was produced for both Ipetí and Piriatí. Verbatim translations from Spanish to English can be consulted in Appendix D8. The narrative descriptions for both the Gunas and Emberás cover social, cultural, economic, political, organizational, and environmental elements, all which are intimately tied to the condition of their territory. Both groups reveal in their descriptions of their territories for 2055, their desire to uphold, strengthen and recuperate—the latter, particularly relevant in the case of the Emberás—their cultural identity, including traditions and ways of living such as language, dress, diet, rituals, architecture, arts (including song, chants and dance), internal laws, organizational structures, and land use. However, it is clear that they also envision their territories having strong bi-cultural elements, key to ensuring their participation in Panamanian society, such as education, medical care, and infrastructure. It is important to highlight that in the case of the Gunas, during this part of the workshop, the two women who had helped with the visualization (i.e., preparation of the maps) of the business-as-usual and desired visions of land use, were very active in the discussion, and key ideas related to women's participation in social, cultural, and political life were captured. In both the cases of the Gunas and Emberás, the final reading out of the narrative descriptions to the groups, once agreed upon, resulted in applauses, and cheering by the participants.

Pathways development

The process for developing the *pathways*—i.e., strategies and actions—for each territory to achieve their desired vision of land use for the year 2055 consisted of two steps, namely (1) a participatory diagnosis of problems affecting their territory, carried out using a *problem tree* analysis, and (2) the definition of the strategies themselves.

The *problem tree* analyses were carried out to facilitate the identification of the core problems affecting the territories from a land-use perspective, as well as the origins and causes of these undesired situations, and their effects and consequences, represented by the trunk, roots and branches and leaves of a tree, respectively (Anyaegbunam et al., 2004). Both the Gunas and Emberás, in their own workshops, agreed that deforestation and the adoption of non-traditional forms of agricultural production are the core problems affecting their territories (Table 4.2). The Emberás went on to identify eight root causes (i.e., drivers of change), while the Gunas identified seven for these core problems, related primarily to the westernization of land use due to an erosion of traditional knowledge and collective action, as well as lack of governmental support, including with addressing the pervasive problem of land invasions (Table 4.2). The effects of the loss of forests and adoption of western forms of agriculture identified by both the Gunas and Emberás were similar, and can be grouped into three categories, namely (1) loss of traditions and key cultural elements, including medicine, language, and world views; (2) loss of natural resources key to their sustenance, including wildlife, forest-based construction materials, and water; and (3) environmental and health impacts, including droughts, floods, reduced water quality, land degradation and illnesses. In addition, the Emberás noted how the core problems also result in the loss of their credibility as protectors of nature, while the Gunas highlighted increase fighting with *colonos* due to access to land.

The *pathways* devised by the Gunas and Emberás to achieve their desired outcomes for future land use in their territories shared many similarities. Using the core problems identified in the *problem tree* analysis—i.e., forest loss and non-traditional agriculture—they outlined two strategic objectives, one related to the protection and restoration of forests, and the other to reverting to traditional and sustainable forms of production (Appendix D9). Although it is advisable that *pathways* define specific steps, assign responsibilities and timelines, and outline deliverables (Evans et al., 2006), the Guna and Emberá traditional authorities determined that they would do this on their own account working with their technical advisors. As such, this study only reveals the strategies they identified for achieving their ideal vision of future land use.

For the strategic objectives related to conserving and protecting the forest, both groups determined that implementing REDD+ in a manner that is culturally appropriate could advance their vision for future land use, along with creating and deploying Indigenous park ranger forces, evicting colonist farmers, reforesting with native tree species (including creating nurseries), creating agro-eco-ethno tourism programs, strengthening traditional knowledge and world views about the importance of forests, and designing and enforcing better laws and policies for forest protection and restoration within the territories. In the case of the Emberás, they went further and identified the need for continued land-use planning to guide protection and restoration efforts, signage at the limits of the territories to dissuade land invasions, training the newer generations on the traditional medicines found in the forest, and acquiring additional lands abutting the territories, which they could protect or restore.

With regards to the objective of re-adopting traditional and sustainable forms of production (e.g., agroforestry), both the Gunas and Emberás, coincided on the need for capacity development and awareness raising among the communities about these methods. The Emberás suggested creating a “model farm” for teaching purposes. Both groups also agreed on the need for creating enabling conditions for these forms of agricultural production, including access to finance and markets (including the transportation of products), and establishing functional institutional structures, such as cooperatives, to guide and regulate production. The Gunas highlighted the critical importance of rescuing and strengthening their traditional forms of production.

4.5 Discussion

Insights from participatory scenario-based planning in a context of decentralization and forest devolution

The devolution of land and forests to communities as part of government decentralization policies in the developing world has become increasingly prevalent (Evans et al., 2010; Yiwen et al., 2020). It is considered one of the most important reforms to have taken place in the forestry sector during the last two decades (Dang et al., 2018). These reforms are supported by emerging evidence that forest devolution to Indigenous peoples and local communities results in decreased forest loss and degradation (Seymour et al., 2014; Min-Venditti et al., 2017; Watson et al., 2018), thus contributing to mitigate the impacts of climate change, and avert the loss of biodiversity and other ecosystems services.

However, evidence linking devolved land tenure to improved forest condition is not universal (Yin, 2016; Min-Venditti et al., 2017). Chief among the reasons for subpar outcomes, in some cases, for forests and people under these tenure regimes can be attributed to the lack of investment in strengthening the capacity of forest-dependent communities to self-govern, including planning and managing their lands, defining user rights and obligations, and establishing mechanisms to enforce property rights with neighbors, or engage with external stakeholders who hold economic interests in their natural resources (Agrawal et al., 2008; Evans et al., 2010). Panama has not been exempt from the many challenges that truncate successful land and forest devolution to Indigenous peoples. In general, investments in institutional capacity building for Indigenous peoples in Panama to plan and manage their territories have been the exception rather than the norm, despite their importance in tenure reform (Evans et al., 2010). Most support has been delivered sporadically by non-State actors such as NGOs, research organizations, and groups of scholars, and has taken place primarily prior to the adjudication of lands (Velásquez Runk, 2012). This support has mostly come in the form of participatory mapping efforts, which have been employed to petition the Panamanian government for land titles (Chapin and Threlkeld, 2001; Herlihy, 2003; Rainforest Foundation US, 2020) or gain a better understanding of Indigenous land management strategies and options to conserve remnant forests without compromising traditional uses on lands that have already been formally titled (Smith et al., 2017) . Overall, these participatory mapping exercises have primarily focused on elucidating the state of the territory in a particular moment in time, and not to plan for long-term future land use.

To the best of our knowledge, we facilitated the first comprehensive participatory scenario-based planning exercise with and for Indigenous peoples in Panama. In addition to producing key evidence about possible futures for forests in Indigenous territories in the Upper Bayano Watershed over a 40-year timespan, the study yielded valuable insights of relevance to land tenure reform processes and land-use planning efforts involving Indigenous territories in Panama and beyond. Noteworthy, was what we have termed the "awakening" of the communities. Prior to this study, Indigenous peoples in the region had not been afforded the opportunity to collectively and systematically consider the future of their territories. In the case of the Emberás, who received formal title to their collective lands of Piriatí and Ipetí in 2014 and 2015, respectively (ANATI, 2014, 2015), this awakening was best reflected in the words of Chief Rodolfo Cunampio who publicly stated during a workshop, "*We have been so busy fighting for the title of our territory, that we forgot to think about what to do with our land once it is ours. This has opened our eyes*" (personal communication, June 9, 2016). Although both communities have experienced differential forest loss driven by factors such as history of timber extraction pre-settlement (Potvin et al., 2006), proximity to markets and roads, topography, land tenure, quality of remaining forests, and political pressure (Sharma et al., 2016), participants from Ipetí and Piriatí alike lamented the marked declines in forest cover since the time the communities were established 40 years prior. During the workshops, participants were disquieted, some even seemed shocked and surprised, by the results of the historical reconstruction of land use, and the business-as-usual scenarios and maps, which depict a clear and sustained process of forest attrition. Discussions that ensued from this "awakening" revolved primarily around two fundamental issues, namely whether they had the credibility to still claim, as Indigenous peoples, to be the protectors of the forest in light marked forest loss, and what would be the condition of the territory that they would bequeath to future generations.

In the case of the Gunas, the traditional authorities highlighted that the constant threat of land invasions by *colonos* had monopolized their attention over the last two decades and hindered them from thinking about the future of their territory, despite having secured title for the Comarca 20 years prior to Ipetí and Piriatí (República de Panamá, 1996). All participants in the workshop concurred with this assessment. The participatory scenario-based planning exercises afforded the communities insights to futures that might have otherwise gone unnoticed or unconsidered (Tuck, 2009), and appeared to awaken their desire to course-correct as demonstrated in the results of this study. We contend that this process of awakening catalyzed by the participatory scenario-based planning exercises will be key for the Indigenous communities of the Upper Bayano Watershed to exercise their right to self-govern, including fighting for tenure security, and defining and protecting their vision for future land use.

The prospects for REDD+ in the Upper Bayano Watershed of Panama and beyond

Both the Emberás and Gunas identified culturally-appropriate REDD+ as a key strategy for fulfilling their ideal vision for the future of their territories. Both groups have indicated their desire for a marked increase in land uses that preserve and restore tree cover over the 40-year period of 2016–2055, all of which are consonant with REDD+'s objectives (UNFCCC, 2011). However, the Emberás and Gunas disposition to take part in the mechanism must be tempered with the reality of the evolution of REDD+ in recent years, both as stand-along projects and as part of jurisdictional approaches.

Even though 50 countries have developed national REDD+ strategies, and more than 350 individual REDD+ projects have been implemented globally (Duchelle et al., 2018*a*), REDD+ has generally failed to deliver on its promise as a Nature-based Solution (Angelsen et al., 2018). REDD+ results-based payments have seldom materialized, funding has remained well below projected levels, carbon markets have exhibited subpar performance compared to expectations, and carbon and land use outcomes have yielded marginal positive results to date (Duchelle et al., 2018*b*). The project-level approach to REDD+ has also been criticized for not setting the conditions for scalability, often taking place in isolation from domestic policy, national and sub-national governmental authorities, and broader rural development agendas (Nepstad et al., 2013*b*). This is not to say that REDD+ has not facilitated progress on several policy and technical fronts. The mechanism has proven effective in placing forests much more prominently on international and national agendas, helping countries to better understand drivers of deforestation, establishing forest-monitoring systems, and improving stakeholder engagement in national forest policy discussions (DiGiano et al., 2016; Duchelle et al., 2018a). However, enthusiasm for the mechanism has waned and the prospects for its continued implementation as stand-alone projects remains in question (DiGiano et al., 2016).

Panama embarked on its REDD-readiness process in 2008 (ANAM, 2009; Kapos et al., 2015; FCPF, 2018), and completed it in late 2019 with a project-based focus (UNDP, 2019). As a result of this preparatory phase, the country now has a National REDD + Strategy, a National Forest

Monitoring System, a Forest Emission Reference Levels baseline, and an Environmental and Social Safeguards Information System. According to an announcement of the completion of the readiness phase (UNDP, 2019), the country is now positioned to move forward with the development of local projects, and access funding from multilateral and bilateral sources to ensure payments against results of emission reductions. However, project-level REDD+ efforts in the country will have to overcome many of the aforementioned challenges.

A voluntary REDD+ project was developed in the Emberá territory of Ipetí between 2008–2012 (Holmes et al., 2017). The aim of the project, inspired by the Clean Development Mechanism (CDM), was to sequester carbon, protect biodiversity and improve the livelihoods of community members (Potvin et al., 2007) through reforestation and avoided deforestation. As noted by Holmes et al. (2017), the Ipetí REDD+ project fell significantly short in terms of delivering projected carbon sequestration and carbon stock enhancement goals. Among the key challenges identified by the authors, was the lack of a strong multi-stakeholder approach, not only to ensure that the community had access to bridging support from third parties, but also to create spaces for dialogue, conflict resolution, and the consideration of land-use options with the array of actors that have competing interests for the resources across the territory. The greatest challenge, however, identified by Holmes et al. (2017) was the lack of interest and backing from the State. In this particular case, the State showed little interest in the scope of both the CDM and REDD+ initiative, or in identifying potential carbon buyers, and failed to act to stymie the tide of invading *colonos* that compromised the avoided deforestation component; so much that those lands were invaded and entirely cleared by *colonos*.

The general shortcomings noted above and those specific to the case of the Ipetí REDD+ project are not anomalous. As such, alternative models to rural development that advocate for "jurisdictional approaches" (JA) to sustainability and REDD+ have emerged over the past decade (Boyd et al., 2018; Stickler et al., 2018). JAs, like REDD+, are not "cheap, fast or easy" (Angelsen et al., 2018), but hold greater potential for emissions reductions than individual project-level REDD+ initiatives, given that — in principle — they incorporate more communities and land uses (DiGiano et al., 2016), can better protect the social and environmental integrity of reductions, involve governmental authorities at a scale that can control land use, and align with global climate policy and negotiations, and public and private sector shifts toward sustainable practices (Seymour, 2020). Furthermore, JAs also consider supply chain initiatives that aim to embed sustainable practices in agricultural and forestry value chains (Nepstad et al., 2013*a*).

However, JAs are more than often designed and deployed at the sub-national level (Stickler et al., 2018), and second-tier governments often do not possess the types and levels of authority required to fully deliver on forest-related or low-emissions development objectives (Busch and Amarjargal, 2020). Furthermore, governmental authorities, in general, are subject to political turnover (Boyd et al., 2018), introducing continuity risks, and have low technical, implementation and finance capacity (Stickler et al., 2018). In the case of Panama, if JA approaches to REDD+ were to be pursued, they would also face significant challenges. For example, as reported in the news (Bustamante, 2017), when the law for the decentralization of public administration (República de Panamá, 2015) went into effect, a study on the management capacity of all 77 municipal governments in Panama was conducted by the Secretariat of Municipal Affairs. The results revealed major deficiencies in elements relevant to the implementation of JAs to REDD+ and rural development, including a lack of district-level strategic plans, and outdated or non-existent procedures and manuals for general operational matters. However, the study also revealed a number of strengths relevant to a JA to REDD+, including procedures for the development of community-level projects, guidelines for investment in public works and municipal services, which could serve to reduce pressures on natural ecosystems from infrastructure projects (e.g., secondary and tertiary roads), and mechanisms to strengthen public participation and transparency in the development of community-level initiatives.

Panama has advanced in establishing the mechanisms for delivering on project-based REDD+ initiatives (UNDP, 2019), and the Emberás and Gunas in the Upper Bayano Watershed could benefit from performance-based investors operating at this scale. Both Indigenous groups have identified, as part of their primary strategies for achieving their vision of future land use, the three natural climate solutions that holds the greatest potential for curbing carbon emissions globally, namely reforestation, avoided forest conversion and natural forest management (Griscom et al., 2017). However, given the subpar evolution of REDD+ thus far (Angelsen et al., 2018), and the marked shift around the world toward JAs for REDD+ and sustainability (Stickler et al., 2018), the question remains if the country will be competitive and attractive, under a project-based model, to investors seeking deeper and more ambitious cuts in greenhouse gas emissions across a range of land-use sectors, including agricultural and forestry value chains. And even if the country were to adopt JA to REDD+, significant deficiencies in municipal capacities and budget, and political turnover, could prove equally as challenging.

4.6 Conclusions

Global efforts to devolve forests to Indigenous peoples and local communities, as part of decentralization efforts, are ongoing. However, in the absence of spaces for these groups to exercise their right to self-determination, accompanied with culturally appropriate capacity development mechanisms, the prospects of forest reforms yielding positive outcomes for people and nature are unlikely to fully materialize. Participatory approaches, including scenario-based planning, are well-recognized tools for the design of policies and strategies that can help Indigenous peoples and local communities take control of their future, and play—and benefit from—a more active role in achieving global sustainability goals (Evans et al., 2010). However, evidence suggests that multiple obstacles still exist for communities to move from statutory rights, to the implementation of their desired visions of future land use, and eventual access to benefits (Larson, 2011). Among these is the inability to deliver on the results and strategies—i.e., *pathways*—that emerge from planning exercises (Oteros-Rozas et al., 2015). In the context of the Upper Bayano Watershed in Panama, the Emberá and Gunas opted to devise concrete action plans, built from the *pathways* they devised, to move forward with their ideal vision for the future of their territories. And although, we have witnessed the use of the materials that resulted from this study in various scenarios, there is little evidence to suggest that actions plans are in place, and that these are moving at the pace and scale required to achieve their visions of future land use. As noted by Yiwen et al. (2020) in the context of forest reform in China, without institutional strengthening and consideration of broader socio-economic contexts, efforts of this nature are left to operate in a vacuum of capacity. As the world emerges from a crippling pandemic, the need for more sustainable, resilient, and inclusive models to development has never been greater. We contend that the participation of Indigenous peoples and their visions for the future, exercised through their rights to self-determination, will be essential to achieve progress, propped by international support.

4.7 References

Agrawal, A., Chhatre, A., Hardin, R., 2008. Changing Governance of the World's Forests. Science 320, 1460-1462.

Alejo, C., Meyer, C., Walker, W.S., Gorelik, S.R., Josse, C., Aragon-Osejo, J.L., Rios, S., Augusto, C., Llanos, A., Coomes, O.T., Potvin, C., 2021. Are indigenous territories effective natural climate solutions? A neotropical analysis using matching methods and geographic discontinuity designs. PLOS ONE 16, e0245110.

ANAM, 2009. Forest Carbon Partnership Facility (FCPF) Readiness Plan (R-Plan) Template. Albrook, Edificio 804, Panama, p. 78.

ANATI, 2014. Piriatí. Resolución ADMG-164-2014 de 30 de abril de 2014. In: Tierras, A.N.d.A.d. (Ed.), Panama City, Republic of Panama.

ANATI, 2015. Ipetí. Resolución ADMG-012-2015 de 19 de enero de 2015. In: Tierras, A.N.d.A.d. (Ed.), Panama City, Republic of Panama.

Angelsen, A., Martius, C., De Sy, V., Duchelle, A., Larson, A.M., Thuy, P.T. (Eds.), 2018. Transforming REDD+: Lessons and new directions. Center for International Forestry Research, Bogor, Indonesia.

Anyaegbunam, C., Mefalopulos, P., Moetsabi, T., 2004. Participatory Rural Communication Appraisal Starting with the People: A Handbook. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

Bartlett, C., Marshall, M., Marshall, A., 2012. Two-Eyed Seeing and other lessons learned within a co-learning journey of bringing together indigenous and mainstream knowledges and ways of knowing. Journal of Environmental Studies and Sciences 2, 331-340.

Bennett, E., Carpenter, S., Peterson, G., Cumming, G., Zurek, M., Pingali, P., 2003. Why global scenarios need ecology. Frontiers in Ecology and the Environment 1, 322-329.

Boyd, W., Stickler, C., Duchelle, A., Seymore, F., Nepstad, D., Bahar, N.H.A., Rodriguez-Ward, D., 2018. Jurisdictional Approaches to REDD+ and Low Emissions Development: Progress and Prospects." Working Paper. World Resources Institute, Washington, DC, USA.

Bryan, J., 2011. Walking the line: Participatory mapping, indigenous rights, and neoliberalism. Geoforum 42, 40-50.

Busch, J., Amarjargal, O., 2020. Authority of Second-Tier Governments to Reduce Deforestation in 30 Tropical Countries. Frontiers in Forests and Global Change 3.

Bustamante, A., 2017. Diagnóstico del Proceso de Descentralización: Deficiencias en los municipios. La Prensa, Panama City, Panama.

Carpenter, S.R., Bennett, E.M., Peterson, G.D., 2006. Scenarios for Ecosystem Services: An Overview. Ecology and Society 11.

Chapin, M., Lamb, Z., Threlkeld, B., 2005. Mapping Indigenous Lands. Annual Review of Anthropology 34, 619-638.

Chapin, M., Threlkeld, B., 2001. Indigenous Landscapes: A Study in Ethnocartography. Center for the Support of Native Lands, Washington, D.C., USA.

Chigbu, U.E., Schopf, A., de Vries, W.T., Masum, F., Mabikke, S., Antonio, D., Espinoza, J., 2017. Combining land-use planning and tenure security: a tenure responsive land-use planning approach for developing countries. Journal of Environmental Planning and Management 60, 1622-1639.

Colchester, M., 2010. Free, Prior and Informed Consent. Making FPIC work for forests and peoples. The Forest Dialogue, New Haven, CT, US.

Corbett, J., 2009. Good Practices in Participatory Mapping. A review for the International Fund for Agricultural Development. International Fund for Agricultural Development (IFAD). Rome, Italy.

Dang, T.K.P., Visseren-Hamakers, I.J., Arts, B., 2018. Forest devolution in Vietnam: From rhetoric to performance. Land Use Policy 77, 760-774.

DiGiano, M., Stickler, C., Nepstad, D., Ardila, J., Becerra, M., Benavides, M., Bernadinus, S., Bezerra, T., Castro, E., Cendales, M., Chan, C., Davis, A., Kandel, S., Mendoza, E., Montero, J., Osorio, M., Setiawan, J., 2016. Increasing REDD+ Benefits to Indigenous Peoples and Traditional Communities through a Jurisdictional Approach. Earth Innovation Institute, San Francisco, CA, USA.

Duchelle, A., Seymour, F., Brockhaus, M., Angelsen, A., Larson, A.M., Moeliono, M., Wong, G.Y., Pham, T.T., Martius, C., 2018a. REDD+: Lessons from National and Subnational Implementation. World Resources Institute, Washington, D.C., USA.

Duchelle, A.E., Simonet, G., Sunderlin, W.D., Wunder, S., 2018b. What is REDD+ achieving on the ground? Curr. Opin. Environ. Sustain. 32, 134-140.

Evans, K., Jong, W.d., Cronkleton, P., Nghi, T.H., 2010. Participatory Methods for Planning the Future in Forest Communities. Society & Natural Resources 23, 604-619.

Evans, K., Velarde, S.J., Prieto, R., Rao, S.N., Sertzen, S., Dávila, K., Cronkleton, P., de Jong, W., 2006. Fieldguide to the future: Four ways for communities to think ahead. In: (eds.), B.E.a.Z.M. (Ed.). Center for International Forestry Research (CIFOR), ASB, World Agroforestry Centre Nairobi, p. 87.

FCPF, 2018. Panama. Forest Carbon Partnership Facility, Washington, DC, USA.

Frechette, A., Ginsburg, C., Walker, W., 2018. A Global Baseline of Carbon Storage in Collective Lands. Indigenous and local community contributions to climate change mitigation. Rights and Resources Initiative, Washington, D.C.

Garnett, S.T., Burgess, N.D., Fa, J.E., Fernández-Llamazares, Á., Molnár, Z., Robinson, C.J., Watson, J.E.M., Zander, K.K., Austin, B., Brondizio, E.S., Collier, N.F., Duncan, T., Ellis, E., Geyle, H., Jackson, M.V., Jonas, H., Malmer, P., McGowan, B., Sivongxay, A., Leiper, I., 2018. A spatial overview of the global importance of Indigenous lands for conservation. Nature Sustainability 1, 369-374.

Ginsburg, C., Keene, S., 2018. At a Crossroads: Consequential Trends in Recogntion of Community- Based Forest Tenure, From 2002-2017. Rights and Resources Initiative, Washington, D.C.

Global_Forest_Watch, 2019. Tree cover in Emberá, Panama. Accessed on March 11, 2019 from http://www.globalforestwatch.org.

Griscom, B.W., Adams, J., Ellis, P.W., Houghton, R.A., Lomax, G., Miteva, D.A., Schlesinger, W.H., Shoch, D., Siikamäki, J.V., Smith, P., Woodbury, P., Zganjar, C., Blackman, A., Campari, J., Conant, R.T., Delgado, C., Elias, P., Gopalakrishna, T., Hamsik, M.R., Herrero, M., Kiesecker, J., Landis, E., Laestadius, L., Leavitt, S.M., Minnemeyer, S., Polasky, S., Potapov, P., Putz, F.E., Sanderman, J., Silvius, M., Wollenberg, E., Fargione, J., 2017. Natural climate solutions. Proceedings of the National Academy of Sciences 114, 11645-11650.

Guillemette, M., Potvin, C., Martinez, L., Pacheco, B., Caño, D., Pérez, I., 2017. Building a common description of land cover in a tropical watershed plagued with intercultural conflicts: The value of participatory 3D modelling. FACETS 2, 195-211.

Herlihy, P.H., 2003. Participatory Research Mapping of Indigenous Lands in Darién, Panama. Human Organization 62, 315-331.

Hibbard, M., Lane, M.B., Rasmussen, K., 2008. The Split Personality of Planning Indigenous Peoples and Planning for Land and Resource Management. Journal of Planning Literature 23, 131-156.

Holmes, I., Potvin, C., Coomes, O., 2017. Early REDD+ Implementation: The Journey of an Indigenous Community in Eastern Panama. Forests 8, 67.

INEC, 2013. Estimación y proyección de la población total de la República, por provincia, comarca indígena, distrito y corregimiento, según sexo y edad: al 1 de julio de 2010-20. Contraloría General de la República de Panamá, Panama City, Panama.

Jojola, T., 2013. Indigenous planning: Towards a seven generations model. In: Walker, R., Natcher, D., Jojola, T. (Eds.), Reclaiming Indigenous planning. McGill Queens University Press, Montréal, QC, pp. 457-472.

Kapos, V., Walcott, J., Thorley, J., Mariscal, E., Labbate, G., Ravilious, C., Miles, L., Narloch, N., Trumper, K., Bertzky, M., 2015. Planificación de REDD+ en Panamá: asegurando beneficios sociales y ambientales. UNEP-World Conservation Monitoring Centre, Cambridge, UK.

Kueny, J.A., Day, M.J., 2002. Designation of protected karstlands in Central America: A regional assessment. Journal of Cave and Karst Studies 64, 165-174.

Larson, A.M., 2011. Forest tenure reform in the age of climate change: Lessons for REDD+. Global Environmental Change 21, 540-549.

McGill_University, 2006. Protocol for Research in Panama's Indigenous Communities. McGill University - Neotropical Environment Option, Montreal, QC and Panama City, Panama.

Min-Venditti, A.A., Moore, G.W., Fleischman, F., 2017. What policies improve forest cover? A systematic review of research from Mesoamerica. Global Environmental Change 47, 21-27.

Nepstad, D., Irawan, S., Bezerra, T., Boyd, W., Stickler, C., Shimada, J., Carvalho, O., MacIntyre, K., Dohong, A., Alencar, A., Azevedo, A., Tepper, D., Lowery, S., 2013a. More food, more forests, fewer emissions, better livelihoods: linking REDD+, sustainable supply chains and domestic policy in Brazil, Indonesia and Colombia. Carbon Management 4, 639-658.

Nepstad, D.C., Boyd, W., Stickler, C.M., Bezerra, T., Azevedo, A.A., 2013b. Responding to climate change and the global land crisis: REDD+, market transformation and low-emissions rural development. Philosophical Transactions of the Royal Society B: Biological Sciences 368.

Ostrom, E., 2009. A General Framework for Analyzing Sustainability of Social-Ecological Systems. Science 325, 419-422.

Oteros-Rozas, E., Martín-López, B., Daw, T.M., Bohensky, E.L., Butler, J.R.A., Hill, R., Martin-Ortega, J., Quinlan, A., Ravera, F., Ruiz-Mallén, I., Thyresson, M., Mistry, J., Palomo, I., Peterson, G.D., Plieninger, T., Waylen, K.A., Beach, D.M., Bohnet, I.C., Hamann, M., Hanspach, J., Hubacek, K., Lavorel, S., Vilardy, S.P., 2015. Participatory scenario planning in place-based social-ecological research: insights and experiences from 23 case studies. Ecology and Society 20.

Parsamehr, K., Gholamalifard, M., Kooch, Y., 2020. Comparing three transition potential modeling for identifying suitable sites for REDD+ projects. Spatial Information Research 28, 159-171.

Patrick, R.J., Machial, L., Quinney, K., Quinney, L., 2017. Lessons Learned Through Community-Engaged Planning. The International Indigenous Policy Journal 8.

Peltier, C., 2018. An Application of Two-Eyed Seeing: Indigenous Research Methods With Participatory Action Research. International Journal of Qualitative Methods 17, 1609406918812346.

Porter, L., 2010. Unlearning the Colonial Cultures of Planning. Ashgate Publishing Limited, Surrey, England.

Potvin, C., Tschakert, P., Lebel, F., Kirby, K., Barrios, H., Bocariza, J., Caisamo, J., Caisamo, L., Cansari, C., Casamá, J., Casamá, M., Chamorra, L., Dumasa, N., Goldenberg, S., Guainora, V., Hayes, P., Moore, T., Ruíz, J., 2006. A participatory approach to the establishment of a baseline scenario for a reforestation Clean Development Mechanism project. Mitigation and Adaptation Strategies for Global Change 12, 1341-1362.

Potvin, C., Tschakert, P., Lebel, F., Kirby, K., Barrios, H., Bocariza, J., Caisamo, J., Caisamo, L., Cansari, C., Casamá, J., Casamá, M., Chamorra, L., Dumasa, N., Goldenberg, S., Guainora, V., Hayes, P., Moore, T., Ruíz, J., 2007. A participatory approach to the

establishment of a baseline scenario for a reforestation Clean Development Mechanism project. Mitig Adapt Strat Glob Change 12, 1341-1362.
Prusak, S.Y., Walker, R., Innes, R., 2016. Toward Indigenous Planning? First Nation Community Planning in Saskatchewan, Canada. Journal of Planning Education and Research 36, 440-450.
Rainforest_Foundation_US, 2020. Panama: Securing indigenous peoples' land rights and protecting forests in the Darién Gap.
República_de_Panamá, 1996. Ley 24. "Por la cuál se crea la Comarca Kuna de Madungandi". Gaceta Oficial No. 22.951 del 15 de enero de 1996, Panama, Republic of Panama.
República_de_Panamá, 2015. Ley 66. "Que reforma la Ley 37 de 2009, que descentaliza la administración pública, y dicta otras disposiciones Gaceta Oficial No. 27901-A del 29 de octubre de 2015, Panama City, Panama.
Seddon, N., Chausson, A., Berry, P., Girardin, C.A.J., Smith, A., Turner, B., 2020. Understanding the value and limits of nature-based solutions to climate change and other global challenges. Philosophical Transactions of the Royal Society B: Biological Sciences 375, 20190120.
Seymour, F., 2020. INSIDER: 4 Reasons Why a Jurisdictional Approach for REDD+ Crediting Is Superior to a Project-Based Approach. World Resource Institute, Washington, DC, USA.
Seymour, F., La Vina, T., Hite, K., 2014. Evidence linking community- level tenure and forest condition: An annotated bibliography. Climate and Land Use Alliance, San Francisco, CA, USA.
Sharma, D., Holmes, I., Vergara-Asenjo, G., Miller, W.N., Cunampio, M., B. Cunampio, R., B. Cunampio, M., Potvin, C., 2016. A comparison of influences on the landscape of two social-ecological systems. Land Use Policy 57, 499-513.
Sharma, D., Vergara-Asenjo, G., Cunampio, M., Cunampio, R.B., Cunampio, M.B., Potvin, C., 2015. Genesis of an indigenous social-ecological landscape in eastern Panama. Ecology and Society 20.
Sherzer, J., 1987. A diversity of voices: Men's and women's speech in ethnographic perspective. In: Philips, S.U., Steele, S., Tanz, C. (Eds.), Language, Gender, and Sex in Comparative Perspective. Cambridge University Press, Cambridge, UK, pp. 95-120.

Smith, D.A., Ibáñez, A., Herrera, F., 2017. The Importance of Context: Assessing the Benefits and Limitations of Participatory Mapping for Empowering Indigenous Communities in the Comarca Ngäbe-Buglé, Panama. Cartographica: The International Journal for Geographic Information and Geovisualization 52, 49-62.

Sobrevila, C., 2008. The Role of Indigenous Peoples in Biodiversity Conservation. The Natura but Often Forgotten Partners. The International Bank for Reconstruction and Development / THE WORLD BANK, Washington, D.C., USA.

Stickler, C., Duchelle, A., Ardila, J.P., Nepstad, D., David, O., Chan, C., Rojas, J.G., Vargas, R., Bezerra, T., Pritchard, L., Simmonds, J., Durbin, J., Simonet, G., Peteru, S., Komalasari, M., DiGiano, M., Warren, M., 2018. The State of Jurisdictional Sustainability: Synthesis for practitioners and policymakers. Earth Innovation Institute, Center for International Forestry Research, and Governors' Climate and Forests Task Force, San Francisco, CA, USA.

Tice, K.E., 1995. Kuna Crafts, Gender, and the Global Economy. University of Texas Press, Austin, Texas, USA.

Tuck, E., 2009. Re-visioning Action: Participatory Action Research and Indigenous Theories of Change. The Urban Review 41, 47-65.

UNDP, 2019. Panama completes the REDD+ readiness phase to begin reducing emissions from deforestation. United Nations Development Programme, Panama City, Panama.

UNFCCC, 2011. Report of the Conference of the Parties on its sixteenth session, held in Cancun from 29 November to 10 December 2010. Addendum part two: action taken by the Conference of the Parties at its sixteenth session. FCCC/CP/2010/7/Add.1. United Nations Framework Convention on Climate Change, Cancun, Mexico.

Velásquez Runk, J., 2012. Indigenous Land and Environmental Conflicts in Panama: Neoliberal Multiculturalism, Changing Legislation, and Human Rights. Journal of Latin American Geography 11, 21-47.

Vergara-Asenjo, G., Mateo-Vega, J., Alvarado, A., Potvin, C., 2017. A participatory approach to elucidate the consequences of land invasions on REDD+ initiatives: A case study with Indigenous communities in Panama. PLOS ONE 12, e0189463.

Vergara-Asenjo, G., Sharma, D., Potvin, C., 2015. Engaging Stakeholders: Assessing Accuracy of Participatory Mapping of Land Cover in Panama. Conservation Letters 8, 432-439.

Wali, A., 1989. Kilowatts and crisis: hydroelectric power and social dislocation in eastern Panama. Westview Press, Boulder, CO, USA.

Walker, W., Baccini, A., Schwartzman, S., Ríos, S., Oliveira-Miranda, M.A., Augusto, C., Ruiz, M.R., Arrasco, C.S., Ricardo, B., Smith, R., Meyer, C., Jintiach, J.C., Campos, E.V., 2014. Forest carbon in Amazonia: the unrecognized contribution of indigenous territories and protected natural areas. Carbon Management 5, 479-485.

Watson, J.E.M., Leiper, I., Potapov, P., Evans, T.D., Burgesse, N.D., Molnárg, Z., Fernández-Llamazaresh, A., Fa, J.E., Duncan, T., Wang, S., Austin, B., Jonas, H., Robinson, C.J., Malmerm, P., Zander, K.K., Jackson, M.V., Elliso, E., Brondizio, E.S., Garnett, S.T., 2018. Policy Brief: Supporting Indigenous Peoples who manage intact forests is crucial to achieving climate goals. Wildlife Conservation Society and 15 partner organizations., New York City, New York, USA.

Yin, R., 2016. Empirical linkages between devolved tenure systems and forest conditions: An introduction to the literature review. Forest Policy and Economics 73, 271-276.

Yiwen, Z., Kant, S., Long, H., 2020. Collective Action Dilemma after China's Forest Tenure Reform: Operationalizing Forest Devolution in a Rapidly Changing Society. Land 9, 58.

4.8 Tables

Table 4.1. Favored locations (A) and landscape elements (B) identified in the workshops, with top two choices per group in bold.

A

LOCATIONS	**EMBERÁ**		**GUNA**		**TOTAL**	
	#	%	#	%	#	%
Territory (Guna)	1	7%		0%	1	4%
Territory (Emberá)	0	0%	1	11%	1	4%
Community (Guna - lake)	1	7%	2	**22%**	3	13%
Community (Guna - river)	0	0%	3	**33%**	3	13%
River (Guna)	0	0%	2	**22%**	2	9%
River (Emberá)	8	**57%**		0%	8	35%
Forest (Emberá)	4	**29%**		0%	4	17%
Forest (non-Indigenous area)	0	0%	1	11%	1	4%
TOTAL	**14**	**100%**	**9**	**100%**	**23**	**100%**

B

LANDSCAPE ELEMENT	**EMBERÁ**		**GUNA**		**TOTAL**	
	#	%	#	%	#	%
Forest	16	**36%**	11	**26%**	27	31%
Water	8	18%	12	**29%**	20	23%
Animals	18	**41%**	12	**29%**	30	35%
Restoration/Production	2	5%	0	0%	2	2%
Other (caves, boulders, fresh air)	0	0%	7	17%	7	8%
TOTAL	**44**	**100%**	**42**	**100%**	**86**	**100%**

Table 4.2. Results from the *problem tree* analyses conducted by the Gunas for Madungandi, and the Emberás for Ipetí and Piriatí, distinguishing between the causes (roots) and effects (branches and leaves) of the core problems (trunk).

EMBERÁS		GUNAS
Disappearance of traditional medicine and our knowledge about it.	**EFFECTS** (Branches and Leaves)	Loss of medicine.
Loss of credibility as protectors of nature.		Westernization.
Loss of Indigenous worldview and the ties between our culture and the forest.		Loss of traditional and cultural knowledge (botanists and production).
Loss of our language and concepts related to the forest.		Loss of traditional education (count "espave" trees).*
Loss of traditional food.		Loss of wildlife.
Loss of traditional infrastructure (homes).		Loss of communities due to lack of access to forest for their sustenance.
Loss of water.		Loss of water.
Droughts during the dry season and flooding during the rainy season (climate change and loss of crops).		Degraded lands (without nutrients).
Increase in illnesses.		Contamination of waters and lands.
		Fights between colonist farmers and Gunas.
Forest loss.		Deforestation.

Non-traditional production (agriculture).	**CORE PROBLEM** (Trunk)	Adoption of western forms of cultivation.
Poor management of our land.	**CAUSES & DRIVERS OF CHANGE** (Roots)	Commercialization of timber.
Invasions from colonist farmers.		Invasion by colonist farmers (territorial insecurity).
Loss of traditional knowledge about the care and management of the forest.		Loss of traditional land use due to western influences.
Loss of our culture and identity (external pressures).		Westernization.
Lack of economic, social and political opportunities.		Government abandonment.
Loss of our focus on "collectivity".		Use of pesticides and fertilizers.
Lack of support for the traditional authorities.		Informal, unauthorized production.
Increase of the populations in very small territories		

*This is a reference to teaching children to count using local elements (e.g. the "espavé" tree - *Anacardium excelsum* – a multipurpose tree traditionally used by Indigenous peoples) versus exotic elements.

4.9 Figures

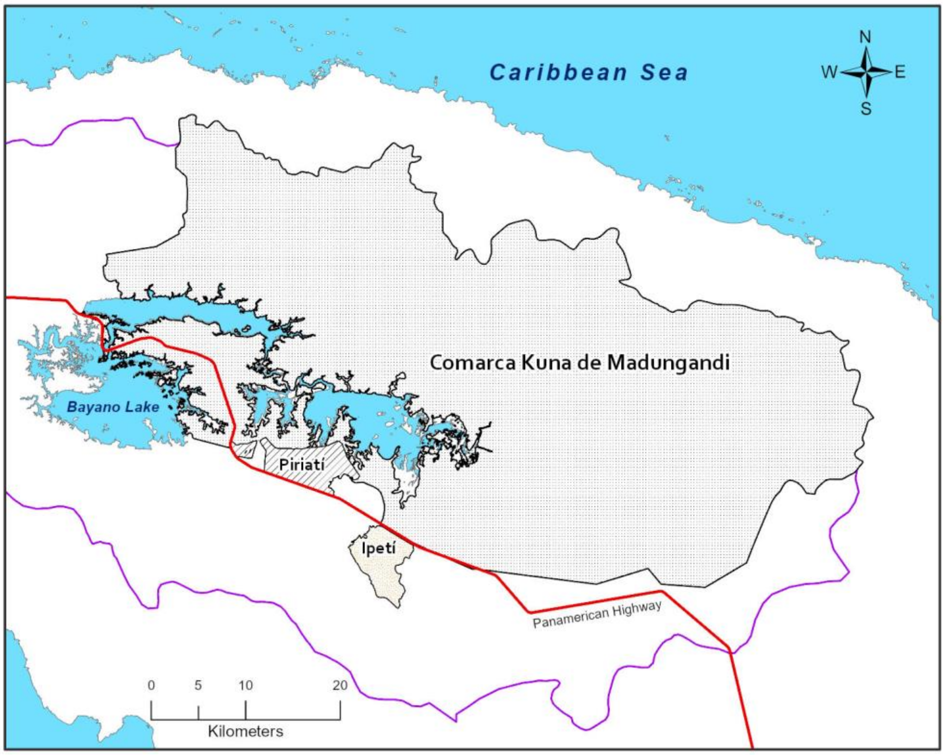

Figure 4.1. The Upper Bayano Watershed, including the Emberá territories of Ipetí and Piriatí, and the Comarca Kuna de Madungandi.

Figure 4.2. Workflow for the participatory scenario-based planning in the Upper Bayano Watershed (2013-2016).

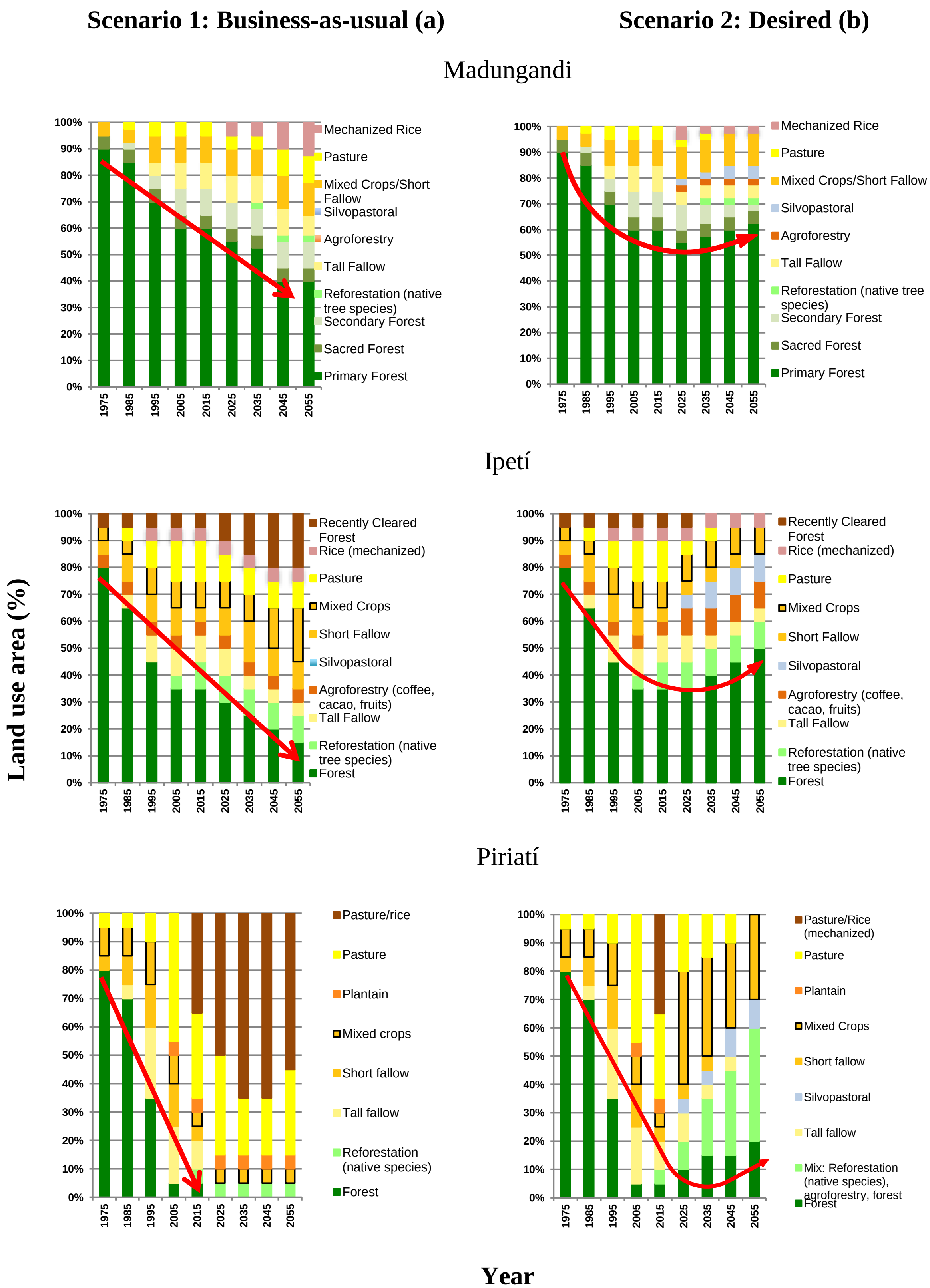
Scenario 1: Business-as-usual (a)
Scenario 2: Desired (b)
Madungandi
Mechanized Rice
Pasture
Mixed Crops/Short Fallow
Silvopastoral
Agroforestry
Tall Fallow
Reforestation (native tree species)
Secondary Forest
Sacred Forest
Primary Forest
Ipetí
Recently Cleared Forest
Rice (mechanized)
Pasture
Mixed Crops
Short Fallow
Silvopastoral
Agroforestry (coffee, cacao, fruits)
Tall Fallow
Reforestation (native tree species)
Forest
Piriatí
Pasture/rice
Pasture/Rice (mechanized)
Pasture
Plantain
Mixed crops
Short fallow
Silvopastoral
Tall fallow
Reforestation (native species)
Mix: Reforestation (native species), agroforestry, forest
Forest
Land use area (%)
Year

Figure 4.3. Perceptions of historical land use (1975-2015) and projections of future land use (2016-2055) under business-as-usual (a) and desired (b) scenarios in Madungandi, Ipetí and Piriatí. Red arrows indicate general patters of primary forest (dark green) loss and gains over time.

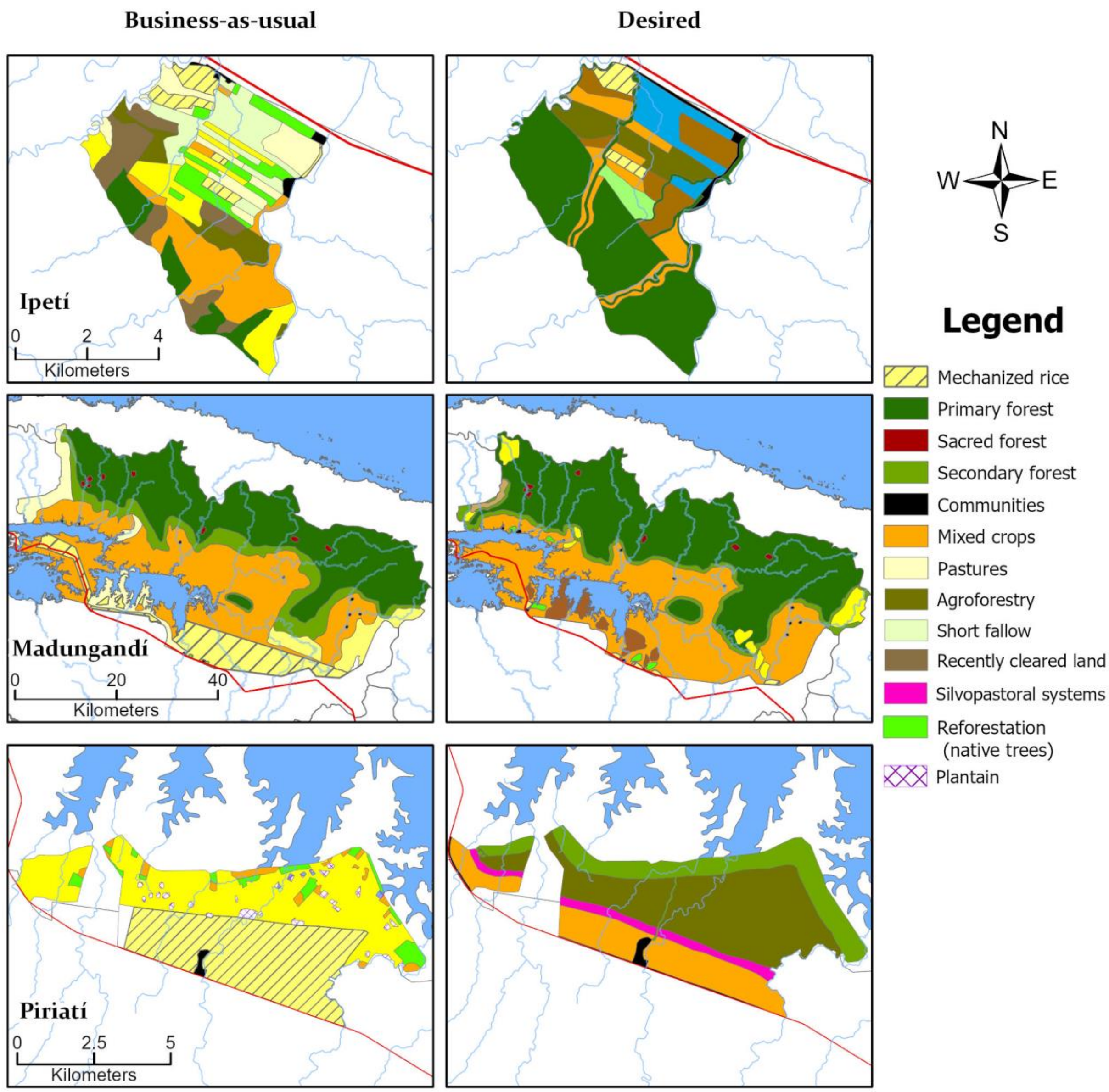

Figure 4.4. Projected land use in 2055 for the territory of Ipetí according to (a) business-as-usual and (b) desired scenarios. Note the significant difference in areas allocated to forest (dark green).

General Discussion

Globally, the extent and condition of forests continues to decline, with the greatest losses taking place in the tropics (FAO 2016). This climatic domain houses half of the world's remaining primary forests (FAO 2015), up to two-thirds of all known species (Bradshaw et al. 2009, Laurance et al. 2012), and approximately 25% of global carbon stocks (Poorter et al. 2015). A recent study (Goldstein et al. 2020), which examines the level of irrecoverability of carbon stocks across different ecosystems, reveals that older, intact forests would be irreplaceable from a climate perspective within the time frame (i.e., 2050) required to keep global warming below 1.5 degrees Celsius. Equally disquieting are the findings of Alroy (2017), who confirms a mass extinction underway in tropical forests by looking at data sets for trees and 10 groups of animals across 875 ecological samples. His findings reveal that disturbed forest sites contain, in general, 41% fewer species than undisturbed sites, despite maintaining some level of forest cover.

It is, thus, no surprise that forests are taking center stage again on the international agenda. Forests featured prominently in the recent COP 26 of the UNFCCC, held in Glasgow, Scotland (October 31–November 13, 2021). Noteworthy was the *Glasgow Leaders' Declaration on Forests and Land Use* signed by 141 countries, representing ~91% of remaining forests globally (UK Presidency COP26 2021). In this declaration, countries committed to "halt and reverse forest loss and degradation by 2030 while delivering sustainable development and promoting an inclusive rural transformation." The declaration was complemented by pledges of $19.2 billion, $12 billion from public sources, and $7.2 from private financing, to protect and restore forests (Taylor et al. 2021, UK Government 2021).

Both the declaration and pledges include reference and funding ($1.7 billion), respectively, in support of the rights of Indigenous peoples and local communities, and their participation in decision making and the design of climate programs and finance instruments (Ford Foundation 2021). Whether these commitments will, in effect, catalyze changes at scale is yet to be determined (Taylor et al. 2021). However, they signal the growing interest in the role of Indigenous peoples as active participants in mitigating climate change and stymieing the tide of biodiversity loss, and not as simple victims of these global phenomena—as they are frequently portrayed in the literature and development discourse (Ramos-Castillo et al. 2017). As stewards of almost half of the world's remaining forest estate (Ginsburg and Keene 2018), including more than a third of intact forest landscapes (Watson et al. 2018*b*), and customary holders of lands that overlap with areas believed to hold up to 80% of the planet's biodiversity (Sobrevila 2008), the importance of engaging Indigenous peoples in forest conservation and management cannot be overstated.

A growing body of research highlights the strong links between Indigenous land stewardship and avoided deforestation, and reduced forest disturbance and degradation (Porter-Bolland et al. 2012, WHRC and EDF 2015, Walker et al. 2020, Alejo et al. 2021). However, threats to Indigenous lands and forests are on the rise and becoming more acute, not only compromising their livelihoods and culture, but also the prospects for their territories to continue to serve as bastions for biodiversity conservation, and climate stability and resilience (FAO and FILAC 2021). Indeed, the dispossession and marginalization of Indigenous peoples not only poses moral, social and ethical problems (UN General Assembly 2007), but also has practical implications in terms of addressing the far-reaching threats of climate change and biodiversity loss. For this reason, policy innovations under the umbrella of Nature-based Solution (NbS), such as REDD+, and forest tenure reform, must consider ways to guarantee the full and effective participation of Indigenous peoples, embracing their ways of knowing, and ensuring their rights to self-determination.

In this thesis, I used eastern Panama as a case study to examine the challenges, opportunities, and outcomes of participatory approaches, involving Indigenous peoples, in forest carbon monitoring and land-use *visioning* and *pathways development* for forest conservation and management. I selected Eastern Panama because it is a pluralistic, multi-functional socio-ecological system (Wali 1989, Sharma et al. 2016, Guillemette et al. 2017) that reflects many of the complex land-use dynamics found across the tropics. I start by presenting , a new field-based forest carbon inventorying method that I designed and tested in the forests of Darién as part of a collaborative project led by Emberá Indigenous traditional authorities (Mateo-Vega et al. 2017). This particular area of Darien is remote, and for the most part, inaccessible by road. Although deforestation pressures are mounting, the area still holds large swaths of undisturbed forest, and houses Emberá, Wounaan, Guna and Afrodarienita communities dispersed across the landscape. Many of the Indigenous communities still live according to traditional norms (Heckadon-Moreno

1984). The method I devised, which was implemented with the participation of 24 trained Indigenous technicians, not only proved statistically robust, but was faster and more cost-effective than other methods employed in Panama (Melgarejo et al. 2015) and around the world (Baraloto et al. 2013). The study also contributed to further dispelling prejudices against community-generated data (Pratihast et al. 2013), provided a blueprint for engaging Indigenous peoples in forest biomass monitoring efforts in Panama and beyond, and revealed a series of direct benefits accrued by Indigenous peoples from the research process and the results.

The outcomes of this study should be useful in other countries and jurisdictions grappling with the challenges of ensuring the full and effective participation of Indigenous peoples in NbS, including REDD+. This is particularly relevant in light of the renewed and heightened global interest in forests and Indigenous peoples, as highlighted during UNFCCC's COP 26 and its related events (UK Presidency COP26 2021). Further studies on participatory approaches and strategies, barriers and opportunities for inclusion, and benefits sharing, among others, will be required to inform policy and practice in the NbS space. To hone in on further opportunities for scholarship, I contend that the literature on social safeguards might offer valuable insights (Lofts et al. 2021). For example, Arhin (2014) proposed a spectrum of social safeguards for REDD+ (i.e., preventative, mitigative, promotive, transformative), with increasing benefits and protections for local communities. The spectrum covers many of the REDD+ elements and conditions under which communities may be at risk or benefit from the mechanism, and where their direct involvement may prove crucial to success. Drawing from this body of work, areas of inquiry may include the drivers and dynamics of displacements (including invasions) and evictions; access to resource use and user rights; participation in forest governance, policy making and planning; measures for accountability and transparency in forest management; FPIC; land tenure (including reform) and security; and investment trends and capacity development for local communities. As discussed below, I also contend that additional research on participatory forest monitoring methods may be warranted.

In the second chapter of this thesis (Mateo-Vega et al. 2019), I presented the results from the forest inventorying method I devised and tested in Darién. As part of this study, I estimated aboveground biomass (AGB) across different scales (subplot, plot, and territories) and forest types (tropical moist, pre-montane wet, and tropical wet), analyzed sources of variation in AGB, and examined tree species richness. I revealed that undisturbed forest plots in Darién have the highest known mean AGB (436 Mg) per ha in the Neotropics, and among the highest tree species richness, when compared to other well-studied forest plots in the region. The significance of these findings cannot be sufficiently underscored. They confirm Darién as one of the most important remaining frontier forests in the world and redefine, in essence, what constitutes a mature, undisturbed forest in the Neotropics in terms of AGB and tree diversity. The results from this study, along with findings from a subsequent expedition in 2019, have now catalyzed the establishment of a new long-term community-driven forest-monitoring project, *Bacuru Droa* (meaning old-growth forest in Emberá). This project is being developed in partnership between the Emberá of the Balsas territory, McGill University (Neotropical Ecology Lab) and the Forest Global Earth Observatory (ForestGEO), facilitated by the Smithsonian Institution (ForestGEO 2022). Through this project, researchers expect to develop a better understanding of the dynamics, biodiversity, and ecosystem services of Darién's unique forests, while the Indigenous communities envision learning more about their lands and forests to complement their traditional ecological knowledge and derive sustainable income from taking part in studies. My hope is that my findings, and those that will result from *Bacuru Droa*, will garner the region and its people greater attention from national authorities and the international community in support of the protection and management of its forests and natural resources in a culturally appropriate manner.

As part of this study (Mateo-Vega et al. 2019), I also confirmed that in Darién's Indigenous territories, the primary source of AGB variation is anthropogenic forest disturbance. I elucidated large variations in AGB between undisturbed and disturbed forest plots, which are not discernible from non-field-based methods such as course, freely-available, satellite imagery (Sexton et al. 2013). In the context of calls for REDD+ benefits to flow Indigenous peoples (DiGiano et al. 2020), the significant variation in landscape-level AGB that I revealed between disturbed and undisturbed forests in Darién, could have implications in terms of spatially-explicit commitments by local communities to avoid forest loss and degradation, and performance-based payments (i.e. if they were to take part in the mechanism). However, more work is required to understand if disturbances across these Indigenous territories, in terms of scale, duration and frequency, in effect qualify as forest degradation. To this day, debates in academic and policy spheres about what constitutes degradation remain contentious, with an absence of clear and practical definitions (Ghazoul et al. 2015, Vásquez-Grandón et al. 2018). Despite this, there is convergence in that degradation compromises the resilience of a forest, i.e., its ability to revert to an original stable state, thus resulting in a loss of function, structure and composition (Vásquez-Grandón et al. 2018). Key characteristics of degraded forests include a loss of the canopy and impoverished biota. In the case of Darién, as revealed by my study, neither of these two key conditions is met in the forests that underwent disturbance due to traditional land management. The selective harvesting of a small number of large trees in the areas that I studied did result in a reduction in forest carbon stocks given that large trees drive variation in AGB in tropical forests (Slik et al. 2013). However, canopy structure and tree species richness were not affected. Indeed, the disturbances that I observed were more similar to natural autogenic alterations that take place in forests, such as tree falls (Vásquez-Grandón et al. 2018), that allow for natural forest succession to occur. Additional studies into Indigenous traditional land management strategies in these forests are warranted to understand if tipping points that lead to forest degradation, versus temporary ecosystem impoverishment, actually take place over time. This knowledge could prove relevant and useful for Darién's Indigenous people to engage in well-informed discussion about REDD+ and other NbS.

From a methodological perspective, the AGB variation I revealed across the landscape highlights the importance of conducting field-based inventories to ground truth remotely sensed data, particularly in forests where disturbance does not lead to marked changes in canopy structure. However, field inventories are expensive and time consuming (Asner et al. 2013), and greater work is required to further reduce their duration and costs, without compromising their validity, whilst still engaging Indigenous peoples and local communities. Technologies, such as lightweight drones, coupled with local field-based data, hold great promise (Zhang et al. 2016), especially if data is gathered and processed by Indigenous drone "pilots" and field technicians. The Rainforest Foundation-US, for example, has been training Indigenous youth and leaders in Panama to use drones, along with GPSs, smart-phones and GIS, to monitor forest cover changes related to environmental crimes in their territories (Rainforest Foundation US 2020). These skills are transferable and could be employed to monitor forest carbon stock variation over time. In tandem, field-based and remote sensing technologies will continue to play a key role in monitoring changes in forest carbon stocks (Mascaro et al. 2014). Further studies that stress test scalable combinations to achieve the triple benefits of speed and low cost, statistical validity, and community engagement, should remain an important area of inquiry.

In the third chapter (Mateo-Vega et al. 2018), I shift to the Upper Bayano Watershed in eastern Panama, and introduce its peoples and land-use dynamics. This region, which is the eastern-most part of the Darién ecological complex, still houses vast expanses of tropical forests, but unlike Darien, its forests are under much greater pressure and threats due to conflicting worldviews and land-use traditions among Indigenous peoples and colonist farmers. The region is bisected by the Pan-American Highway, making forests near the road much more accessible and vulnerable to deforestation and degradation. In this chapter, I captured the complex interactions between the groups, including territorial invasions in Indigenous territories carried out by *colonos* that results in deforestation, loss of livelihoods, and social conflict, including violent and deadly confrontations on occasion. The role of the state, in this case the Government of Panama's Ministry of Environment, is considered in relation to their commitment to implement REDD+, and their interest in the Darién region. Through this study, I examined the positioning of Emberá and Guna Indigenous peoples, and *colonos*, with regards to the REDD+. This financial mechanism, due to its complex technical, financial, and political dimensions, has forced these groups to confront and deal with a series of challenging related issues including land tenure and security, power imbalances, identity, and social justice, among others. Through this study, I set the stage for the participatory scenario-based planning exercises covered in the following chapter, which provides insights to the future of the region's forests and land use dynamics.

In the final chapter, as mentioned above, I present the results of a participatory scenario-based planning exercise, in which I employed *visioning* and *pathways development* to elucidate potential futures for the region's forest estate under Indigenous tenure. The results revealed that both the Emberá and Guna projected significant forest loss in their territories by 2055 under a business-as-usual scenario. This contrasts markedly with their desired scenario of land use, in which the forest estate expands. Through a process of reflection, data collection and action, (also known as participatory action research (Below et al. 2021)), this study resulted in social learning and a series of proposed strategies by both groups to take corrective steps to protect and recover their forests, i.e. avoid the business-as-usual scenario from unfolding. In this regard, the study's results differ from linear, computer-based approaches to modeling land-use change and deforestation, which do not consider the aspirations and needs of the people who inhabit these landscapes (Walker et al. 2014, Vergara-Asenjo et al. 2017, Alejo et al. 2021). The question that naturally emerges from my study, and which can only be addressed *ex post* and assuming equal conditions—e.g., the business-as-usual scenario plays out in similar fashion to computer-based models that project a trend of continued forest attrition—is whether the participatory scenarios align with computer models. As a starting point for such an exercise, one would have to compare the baselines and projections of forest cover change for both approaches. This falls beyond the scope of this study, so is not considered in the final chapter, but I conducted, and report here, a complementary analysis to illustrate differences, their practical implications for NbS, such as REDD+, and make a case for future areas of inquiry.

A previous study by Vergara-Asenjo et al. (2017) (hereafter, V-A Study) projected deforestation in Indigenous and non-Indigenous lands in the Upper Bayano Watershed for the period of 2014–2024 using a computer model. This study, like others of a similar nature (Walker et al. 2014), derived its estimates of land-use change based on well-understood drivers of deforestation (*e.g.* slope, elevation, distance to roads and other forest patches). In contrast, my study considered the Emberás and Gunas vision of future land use under the two aforementioned scenarios. After aligning the data to cover the same time period and areas, I compared the results of projected tree cover loss from the V-A study with mine for the period of 2015–2025, in the three Indigenous territories (Appendix A). My analyses revealed that the Emberás and Gunas envisioned that by 2025, 4,654 ha of more land will have been deforested across their territories compared the V-A study under a business-as-usual scenario. Surprisingly, even under their desired scenario of future land use, both Indigenous groups envisioned their territories collectively having 2,978 ha less forest compared the V-A study. As such, both groups envisioned having 2.42 and 1.55% less tree cover than that projected by the V-A study, respectively. This analysis reveals the divergence between participatory and non-participatory approaches for elucidating the potential futures of the forest estate in the Indigenous territories of the Upper Bayano Watershed.

In the context of current incentive mechanisms for transitions to low-emissions rural development models, such a REDD+, the results derived from both studies would have resulted in divergent outcomes in terms of forest reference emissions levels estimates (i.e., against which future emissions and removals from a specified results period could be compared), and therefore, potential performance-based payments for beneficiaries. Given deep-rooted prejudices against community-generated data (Danielsen et al. 2014), the question arises whether the visions for future land-use from Indigenous peoples would carry the same weight and be afforded the same level of consideration as the computer-based models in informing decision making and investment. Despite international calls for the full and effective participation of Indigenous peoples and local communities in REDD+ (UNFCCC 2011), tensions remain between the use of conventional Western science versus— or with—other ways of knowing, including traditional knowledge, to inform policy, investment and practice (Smith and Sharp 2012, Sutherland et al. 2013). Healthy debates and research on how to reconcile these should remain a priority among Indigenous and non-Indigenous scholars, policymakers, and practitioners.

Final Conclusion and Summary

The research for this thesis took place during a time in which the NbS, REDD+, dominated the attention of governments, civil society organizations, international financial institutions, multi-lateral development agencies and academic institutions engaged in forest-related climate change mitigation and biodiversity conservation. The result at that time was a deluge of research, policy interventions, conferences, and other forums where every aspect of the mechanism was examined, tested, and advocated for or against, including its role in ongoing processes of forest devolution to local communities and Indigenous peoples. It afforded me an overarching framework through which to examine the question of how Indigenous peoples can participate fully and effectively at the local level in policy processes of global concern and reach, namely the NbS, REDD+, and devolved forest management in the context of land tenure reforms.

Through the research I conducted, I was able to address calls for the full and effective participation of local communities, including Indigenous peoples, in REDD+, in this case through a new participatory method for forest biomass monitoring that I developed. I revealed that Darien's forests are amongst the most carbon and species rich in the Neotropics, highlighting their importance in forest-based climate-change mitigation and biodiversity conservation, and the critical role that Indigenous peoples play in safeguarding these natural resources. I examined how REDD+ has evolved in the context of Panama and how Indigenous peoples, farmers and government agencies have positioned themselves within this financial mechanism in the context of land tenure insecurity. I also elucidated, through participatory scenario-based planning exercises, the vision of Indigenous peoples for the future of their forest estate in devolved territories, and the prospects of their visions for REDD+.

Although REDD+ remains a prevalent policy intervention, and is still considered in ongoing forest tenure reform efforts and low-emissions development pathways, over the past five years there has been growing attention paid to the broader concept of NbS (Nesshöver et al. 2017). NbS have emerged as an integrative approach that tackles climate change, conserves biodiversity, and delivers sustainable development (Seddon et al. 2021). In effect, the term has emerged as an umbrella for a wide range of approaches and associated concepts, such as ecological engineering, ecosystem-based approaches, natural capital, payments-for-ecosystem services, and REDD+, among many others (Nesshöver et al. 2017, Seddon et al. 2021).

Redford et al. (2013) warned of the perils of conservation fads, and their tendency to reject, reinvent or repackage, instead of learn from and build off, existing interventions. It is probably too early to tell if NbS if the next fad in the climate, biodiversity, and sustainable livelihoods space, but its burgeoning adoption in academic, governmental, civil society and corporate parlance signals its rising influence. A growing body of research is now attempting to bring greater clarity to the concept, to ensure that it is deployed under a set of clearly defined principles, and that it results in discernible benefits to people and planet with the least amount of trade-offs (Cohen-Shacham et al. 2019, Seddon et al. 2020).

Given its integrative nature, NbS poses a new framework for examining complex socio-ecological systems and considering if combinations of different approaches under the NbS umbrella may overcome the challenges of managing these systems at multiple spatial, temporal, and organizational scales, as well as in an adaptive manner, involving all relevant stakeholders, drawing evidence from the natural and social sciences, and ensuring that they become more resilient to shocks and change. Given the urgency to meet the UN Sustainable Development Goals by 2030, and revert global forest loss, areas of inquiry should focus on elucidating opportunities for removing barriers and bottlenecks for implementation, unlocking finance, and maximizing adoption, adaptability and learning at scale.

General References

Alejo C., et al. 2021. Are indigenous territories effective natural climate solutions? A neotropical analysis using matching methods and geographic discontinuity designs. PLoS ONE **16**:e0245110.

ANAM, 2008. Forest Carbon Partnership Facility. Readiness Plan Idea Note (R-Pin) Template. Forest Carbon Partnership Facility (FCPF), World Bank.

ANAM, 2011. Atlas Ambiental de Panamá. Autoridad Nacional del Ambiente (ANAM), Panama.

Anderies, J.M., Janssen, M.A., Ostrom, E., 2004. A Framework to Analyze the Robustness of Social-ecological Systems from an Institutional Perspective. Ecology & Society 9, 186-202.

Angelsen, A., Brockhaus, M., Duchelle, A.E., Larson, A., Martius, C., Sunderlin, W.D., Verchot, L., Wong, G., Wunder, S., 2017. Learning from REDD+: a response to Fletcher et al. Conservation Biology 31, 718-720.

Alroy J. 2017. Effects of habitat disturbance on tropical forest biodiversity. Proceedings of the National Academy of Sciences of the United States of America **114**:6056-6061.

Arhin A. A. 2014. Safeguards and Dangerguards: A Framework for Unpacking the Black Box of Safeguards for REDD+. Forest Policy and Economics **45**:24-31.

Armitage, D.R., Plummer, R., Berkes, F., Arthur, R.I., Charles, A.T., Davidson-Hunt, I.J., Diduck, A.P., Doubleday, N.C., Johnson, D.S., Marschke, M., McConney, P., Pinkerton, E.W., Wollenberg, E.K., 2009. Adaptive Co-Management for Social-Ecological Complexity. Frontiers in Ecology and the Environment 7, 95-102.

Asiyanbi, A., Lund, J.F., 2020. Policy persistence: REDD+ between stabilization and contestation. Journal of Political Ecology 27.

Asner G. P., et al. 2013. High-fidelity national carbon mapping for resource management and REDD+. Carbon Balance and Management **8**.

Baraloto C., Molto Q., Rabaud S., Hérault B., Valencia R., Blanc L., Fine P. V. A.Thompson J. 2013. Rapid Simultaneous Estimation of Aboveground Biomass and Tree Diversity Across Neotropical Forests: A Comparison of Field Inventory Methods. Biotropica **45**:288-298.

Below J. v., Nahuelhual L., Eleuterio A. A.Laterra P. 2021. Can participatory action research foster social learning in communities struggling for land tenure? Land Use Policy **101**:105192.

Berkes, F., Turner, N.J., 2006. Knowledge, Learning and the Evolution of Conservation Practice for Social-Ecological System Resilience. Hum Ecol 34, 479-494.

Bilbao, G., 2019. Darién, Bajo Amenaza. La Prensa. La Prensa, Panama City, Panama.

Blackman, A., Corral, L., Lima, E.S., Asner, G.P., 2017. Titling indigenous communities protects forests in the Peruvian Amazon. Proceedings of the National Academy of Sciences 114, 4123-4128.

Blackman, A., Veit, P., 2018. Titled Amazon Indigenous Communities Cut Forest Carbon Emissions. Ecological Economics 153, 56-67.

Bongers, F., Chazdon, R., Poorter, L., Peña-Claros, M., 2015. The potential of secondary forests. Science 348, 642-643.

Boyd, W., Stickler, C., Duchelle, A., Seymore, F., Nepstad, D., Bahar, N.H.A., Rodriguez-Ward, D., 2018. Jurisdictional Approaches to REDD+ and Low Emissions Development: Progress and Prospects." Working Paper. World Resources Institute, Washington, DC, USA.

Bradshaw C. J. A., Sodhi N. S.Brook B. W. 2009. Tropical Turmoil: A Biodiversity Tragedy in Progress. Frontiers in Ecology and the Environment **7**:79-87.

Buntaine, M.T., Hamilton, S.E., Millones, M., 2015. Titling community land to prevent deforestation: An evaluation of a best-case program in Morona-Santiago, Ecuador. Global Environmental Change 33, 32-43.

Carpenter, S.R., Mooney, H.A., Agard, J., Capistrano, D., DeFries, R.S., Díaz, S., Dietz, T., Duraiappah, A.K., Oteng-Yeboah, A., Pereira, H.M., Perrings, C., Reid, W.V., Sarukhan, J., Scholes, R.J., Whyte, A., 2009. Science for managing ecosystem services: Beyond the Millennium Ecosystem Assessment. Proceedings of the National Academy of Sciences 106, 1305-1312.

Carson, S.L., Kentatchime, F., Nana, E.D., Njabo, K.Y., Cole, B.L., Godwin, H.A., 2018. Indigenous Peoples' Concerns About Loss of Forest Knowledge: Implications for Forest Management. Conservation and Society 16, 431-440.

Ceddia, M.G., Gunter, U., Corriveau-Bourque, A., 2015. Land tenure and agricultural expansion in Latin America: The role of Indigenous Peoples' and local communities' forest rights. Global Environmental Change 35, 316-322.

CEPF, n.d. Tumbes-Chocó-Magdalena. Critical Ecosystem Partnership Fund (CEPF). l'Agence Française de Développement, Conservation International, the European Union, the Global Environment Facility, the Government of Japan, the MacArthur Foundation and the World Bank., Washington, D.C. .

Chao, S., 2012. Forest peoples: numbers across the world. Forest Peoples Programme, UK. , p. 27pp.

Chazdon, R.L., Broadbent, E.N., Rozendaal, D.M.A., Bongers, F., Zambrano, A.M.A., Aide, T.M., Balvanera, P., Becknell, J.M., Boukili, V., Brancalion, P.H.S., Craven, D., Almeida-Cortez, J.S., Cabral, G.A.L., de Jong, B., Denslow, J.S., Dent, D.H., DeWalt, S.J., Dupuy, J.M., Durán, S.M., Espírito-Santo, M.M., Fandino, M.C., César, R.G., Hall, J.S., Hernández-Stefanoni, J.L., Jakovac, C.C., Junqueira, A.B., Kennard, D., Letcher, S.G., Lohbeck, M., Martínez-Ramos, M., Massoca, P., Meave, J.A., Mesquita, R., Mora, F., Muñoz, R., Muscarella, R., Nunes, Y.R.F., Ochoa-Gaona, S., Orihuela-Belmonte, E., Peña-Claros, M., Pérez-García, E.A., Piotto, D., Powers, J.S., Rodríguez-Velazquez, J., Romero-Pérez, I.E., Ruíz, J., Saldarriaga, J.G., Sanchez-Azofeifa, A., Schwartz, N.B., Steininger, M.K., Swenson, N.G., Uriarte, M., van Breugel, M., van der Wal, H., Veloso, M.D.M., Vester, H., Vieira, I.C.G., Bentos, T.V., Williamson, G.B., Poorter, L., 2016. Carbon sequestration potential of second-growth forest regeneration in the Latin American tropics. Science Advances 2.

Cohen-Shacham E., et al. 2019. Core principles for successfully implementing and upscaling Nature-based Solutions. Environmental Science & Policy **98**:20-29.

Danielsen F., et al. 2014. A Multicountry Assessment of Tropical Resource Monitoring by Local Communities. BioScience **64**:236-251.

Dawson, N.M., Mason, M., Mwayafu, D.M., Dhungana, H., Satyal, P., Fisher, J.A., Zeitoun, M., Schroeder, H., 2018. Barriers to equity in REDD+: Deficiencies in national interpretation processes constrain adaptation to context. Environmental Science & Policy 88, 1-9.

DiGiano M., Stickler C.David O. 2020. How Can Jurisdictional Approaches to Sustainability Protect and Enhance the Rights and Livelihoods of Indigenous Peoples and Local Communities? Frontiers in Forests and Global Change **3:40**.

Ding, H., Veit, P.G., Blackman, A., Gray, E., Reytar, K., Altamirano, J.C., Hodgdon, B., 2016. Climate Benefits, Tenure Costs. The Economic Case For Securing Indigenous Land Rights in the Amazon. World Resources Institute, Washington, DC.

Duchelle, A.E., Simonet, G., Sunderlin, W.D., Wunder, S., 2018. What is REDD+ achieving on the ground? Curr. Opin. Environ. Sustain. 32, 134-140.

Edwards, D.P., Socolar, J.B., Mills, S.C., Burivalova, Z., Koh, L.P., Wilcove, D.S., 2019. Conservation of Tropical Forests in the Anthropocene. Current Biology 29, R1008-R1020.

Eliasch, J., 2008. Climate Change: financing global forests: the Eliasch Review. In: Change., U.O.o.C. (Ed.).

FAO. 1995. Forest resources assessment 1990. Global Synthesis. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO. 2015. Global Forest Resources Assessment 2015. Desk Reference. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO. 2016. Global Forest Resources Assessment 2015. How are the world's forests changing? Second edition. Food and Agriculture Organization of the United Nations, Rome.

FAO, 2018. The State of the World's Forests 2018 - Forest pathways to sustainable development. Rome, Italy.

FAO, 2020. Global Forest Resources Assessment 2020: Main report. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAOFILAC. 2021. Los pueblos indígenas y tribales y la gobernanza de los bosques. Una oportunidad para la acción climática en América Latina y el Caribe. FAO, Santiago, Chile.

Fletcher, R., Dressler, W., Büscher, B., Anderson, Z.R., 2016. Questioning REDD+ and the future of market-based conservation. Conservation Biology 30, 673-675.

Folke, C., 2006. Resilience: The emergence of a perspective for social–ecological systems analyses. Global Environmental Change 16, 253-267.

Folke, C., 2007. Social–ecological systems and adaptive governance of the commons. Ecol Res 22, 14-15.

Ford Foundation. 2021. Governments and private funders announce historic US$1.7 billion pledge at COP26 in support of Indigenous Peoples and local communities. Ford Foundation, New York City, NY, USA.

ForestGEO. 2022. ForestGEO Team Collaborates with Emberá Community at BCI. Forest Global Earth Observatory, Panama City, Panama.

Frechette, A., Ginsburg, C., Walker, W., 2018. A Global Baseline of Carbon Storage in Collective Lands. Indigenous and local community contributions to climate change mitigation. Rights and Resources Initiative, Washington, D.C.

Garnett, S.T., Burgess, N.D., Fa, J.E., Fernández-Llamazares, Á., Molnár, Z., Robinson, C.J., Watson, J.E.M., Zander, K.K., Austin, B., Brondizio, E.S., Collier, N.F., Duncan, T., Ellis, E., Geyle, H., Jackson, M.V., Jonas, H., Malmer, P., McGowan, B., Sivongxay, A., Leiper, I., 2018. A spatial overview of the global importance of Indigenous lands for conservation. Nature Sustainability 1, 369-374.

Gebara, M.F., 2018. Tenure reforms in indigenous lands: decentralized forest management or illegalism? Curr. Opin. Environ. Sustain. 32, 60-67.

Ghazoul J., Burivalova Z., Garcia-Ulloa J.King L. A. 2015. Conceptualizing Forest Degradation. Trends in Ecology & Evolution **30**:622-632.

Ginsburg C.Keene S. 2018. At a Crossroads: Consequential Trends in Recogntion of Community- Based Forest Tenure, From 2002-2017. Rights and Resources Initiative, Washington, D.C.

Global Forest Watch, 2019. Tree Cover Loss in Panama. Accessed on August 1, 2020 from http://www.globalforestwatch.org.

Goldstein A., et al. 2020. Protecting irrecoverable carbon in Earth's ecosystems. Nature Climate Change **10**:287-295.

Griscom, B.W., Adams, J., Ellis, P.W., Houghton, R.A., Lomax, G., Miteva, D.A., Schlesinger, W.H., Shoch, D., Siikamäki, J.V., Smith, P., Woodbury, P., Zganjar, C., Blackman, A., Campari, J., Conant, R.T., Delgado, C., Elias, P., Gopalakrishna, T., Hamsik, M.R., Herrero, M., Kiesecker, J., Landis, E., Laestadius, L., Leavitt, S.M., Minnemeyer, S., Polasky, S., Potapov, P., Putz, F.E., Sanderman, J., Silvius, M., Wollenberg, E., Fargione, J., 2017. Natural climate solutions. Proceedings of the National Academy of Sciences 114, 11645-11650.

Griscom, B.W., Busch, J., Cook-Patton, S.C., Ellis, P.W., Funk, J., Leavitt, S.M., Lomax, G., Turner, W.R., Chapman, M., Engelmann, J., Gurwick, N.P., Landis, E., Lawrence, D., Malhi, Y., Schindler Murray, L., Navarrete, D., Roe, S., Scull, S., Smith, P., Streck, C., Walker, W.S., Worthington, T., 2020. National mitigation potential from natural climate solutions in the tropics. Philosophical Transactions of the Royal Society B: Biological Sciences 375, 20190126.

Guillemette M., Potvin C., Martinez L., Pacheco B., Caño D.Pérez I. 2017. Building a common description of land cover in a tropical watershed plagued with intercultural conflicts: The value of participatory 3D modelling. FACETS **2**:195-211.

Heckadon-Moreno S., Herrera F.Pastor Nuñez A. 1984. Breve estudio de los grupos humanos del Darién. Pages 81-104. in Heckadon-Moreno S.McKay A., editors. Colonización y Destrucción de Bosques en Panamá. Asociación Panameña de Antropología, Panama.

Herrera-MacBryde, O., ANCON, 1997. Darién Province and Darién National Park, Panama. In: Davis, S., Heywood, V.H., Herrera-MacBryde, O., Villa-Lobos, J., Hamilton, A.C. (Eds.), Centres of Plant Diversity: A Guide and Strategy for their Conservation. . World Wildlife Fund For Nature (WWF) and IUCN-The World Conservation Union., Washington, D.C., pp. 226-232.

Holland, M.B., Jones, K.W., Naughton-Treves, L., Freire, J.-L., Morales, M., Suárez, L., 2017. Titling land to conserve forests: The case of Cuyabeno Reserve in Ecuador. Global Environmental Change 44, 27-38.

Houghton, R.A., Nassikas, A.A., 2018. Negative emissions from stopping deforestation and forest degradation, globally. Global Change Biology 24, 350-359.

ICSU-UNESCO-UNU, 2008. Ecosystem Change and Human Well-being: Research and Monitoring Priorities Based on the Millennium Ecosystem Assessment. International Council for Science., Paris.

IFAD, 2012. Indigenous peoples: valuing, respecting and supporting diversity. In: Development, I.F.f.A. (Ed.), Rome, Italy.

IPCC, 2019. Climate Change and Land. An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. Summary for Policymakers. Intergovernmental Panel on Climate Change, Geneva, Switzerland.

Kanninen, M., Murdiyarso, D., Seymour, F., Angelsen, A., Wunder, S., German, L., 2007. Do Trees Grow on Money? The implications of deforestation research for policies to promote REDD. Center for International Forestry Research (CIFOR). Bogor, Indonesia.

Karsenty, A., Ongolo, S., 2012. Can "fragile states" decide to reduce their deforestation? The inappropriate use of the theory of incentives with respect to the REDD mechanism. Forest Policy and Economics 18, 38-45.

Larson, A.M., Petkova, E., 2011. An Introduction to Forest Governance, People and REDD+ in Latin America: Obstacles and Opportunities. Forests 2, 86-111.

Laurance W. F., et al. 2012. Averting biodiversity collapse in tropical forest protected areas. Nature **489**:290.

Le Quéré, C., Andrew, R.M., Friedlingstein, P., Sitch, S., Hauck, J., Pongratz, J., Pickers, P.A., Korsbakken, J.I., Peters, G.P., Canadell, J.G., Arneth, A., Arora, V.K., Barbero, L., Bastos, A., Bopp, L., Chevallier, F., Chini, L.P., Ciais, P., Doney, S.C., Gkritzalis, T., Goll, D.S., Harris, I., Haverd, V., Hoffman, F.M., Hoppema, M., Houghton, R.A., Hurtt, G., Ilyina, T., Jain, A.K., Johannessen, T., Jones, C.D., Kato, E., Keeling, R.F., Goldewijk, K.K., Landschützer, P., Lefèvre, N., Lienert, S., Liu, Z., Lombardozzi, D., Metzl, N., Munro, D.R., Nabel, J.E.M.S., Nakaoka, S.I., Neill, C., Olsen, A., Ono, T., Patra, P., Peregon, A., Peters, W., Peylin, P., Pfeil, B., Pierrot, D., Poulter, B., Rehder, G., Resplandy, L., Robertson, E., Rocher, M., Rödenbeck, C., Schuster, U., Schwinger, J., Séférian, R., Skjelvan, I., Steinhoff, T., Sutton, A., Tans, P.P., Tian, H., Tilbrook, B., Tubiello, F.N., van der Laan-Luijkx, I.T., van der Werf, G.R., Viovy, N., Walker, A.P., Wiltshire, A.J., Wright, R., Zaehle, S., Zheng, B., 2018. Global Carbon Budget 2018. Earth Syst. Sci. Data 10, 2141-2194.

Liscow, Z.D., 2013. Do property rights promote investment but cause deforestation? Quasi-experimental evidence from Nicaragua. Journal of Environmental Economics and Management 65, 241-261.

Lofts K., Sarmiento Barletti J. P.Larson A. M. 2021. Lessons towards rights-responsive REDD+ safeguards from a literature review. CIFOR Working Paper 280. Bogor, Indonesia: CIFOR.

Luttrell, C., Loft, L., Fernanda Gebara, M., Kweka, D., Brockhaus, M., Angelsen, A., Sunderlin, W.D., 2013. Who Should Benefit from REDD+? Rationales and Realities. Ecology and Society 18.

Mascaro J., Asner G. P., Davies S., Dehgan A.Saatchi S. 2014. These are the days of lasers in the jungle. Carbon Balance and Management **9**.

Martínez-Fernández, J., Banos-González, I., Esteve-Selma, M.Á., 2021. An integral approach to address socio-ecological systems sustainability and their uncertainties. Science of The Total Environment 762, 144457.

Massarella, K., Sallu, S.M., Ensor, J.E., Marchant, R., 2018. REDD+, hype, hope and disappointment: The dynamics of expectations in conservation and development pilot projects. World Development 109, 375-385.

Mateo-Vega J., et al. 2017. Full and effective participation of indigenous peoples in forest monitoring for reducing emissions from deforestation and forest degradation (REDD+): trial in Panama's Darién. Ecosphere **8**:e01635-n/a.

Mateo-Vega J., Spalding A. K., Hickey G. M.Potvin C. 2018. Deforestation, Territorial Conflicts, and Pluralism in the Forests of Eastern Panama: A Place for Reducing Emissions from Deforestation and Forest Degradation? Case Studies in the Environment:1-12.

Mateo-Vega J., Arroyo-Mora J. P.Potvin C. 2019. Tree aboveground biomass and species richness of the mature tropical forests of Darién, Panama, and their role in global climate change mitigation and biodiversity conservation. Conservation Science and Practice **1**:e42.

Melgarejo C., Calderón A.Ruiz-Jaén M. C. 2015. Inventario Nacional Forestal y de Carbono de Panamá. Diseño de la fase piloto 2013-2015 y propuesta para la fase final., UN-REDD and Ministerio de Ambiente de Panamá Panama.

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis., Washington, D.C.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., Kent, J., 2000. Biodiversity hotspots for conservation priorities. Nature 403, 853-858.

Nepstad, D.C., Boyd, W., Stickler, C.M., Bezerra, T., Azevedo, A.A., 2013. Responding to climate change and the global land crisis: REDD+, market transformation and low-emissions rural development. Philosophical Transactions of the Royal Society B: Biological Sciences 368.

Nesshöver C., et al. 2017. The science, policy and practice of nature-based solutions: An interdisciplinary perspective. Science of The Total Environment **579**:1215-1227.

Olander, L.P., Galik, C.S., Kissinger, G.A., 2012. Operationalizing REDD+: scope of reduced emissions from deforestation and forest degradation. Curr. Opin. Environ. Sustain. 4, 661-669.

Ostrom, E., 2009. A General Framework for Analyzing Sustainability of Social-Ecological Systems. Science 325, 419-422.

Peltier, C., 2018. An Application of Two-Eyed Seeing: Indigenous Research Methods With Participatory Action Research. International Journal of Qualitative Methods 17, 1609406918812346.

Peterson St-Laurent, G., Gélinas, N., Potvin, C., 2012. REDD+ and the agriculture frontier: Understanding colonists' utilization of the land. Land Use Policy.

Phillips, H.R.P., Newbold, T., Purvis, A., 2017. Land-use effects on local biodiversity in tropical forests vary between continents. Biodiversity and Conservation 26, 2251-2270.

Pistorius, T., 2012. From RED to REDD+: the evolution of a forest-based mitigation approach for developing countries. Curr. Opin. Environ. Sustain. 4, 638-645.

Poorter L., et al. 2015. Diversity enhances carbon storage in tropical forests. Global Ecology and Biogeography **24**:1314-1328.

Porter-Bolland L., Ellis E. A., Guariguata M. R., Ruiz-Mallén I., Negrete-Yankelevich S.Reyes-García V. 2012. Community managed forests and forest protected areas: An assessment of their conservation effectiveness across the tropics. Forest Ecology and Management **268**:6-17.

Potapov, P., Hansen, M.C., Laestadius, L., Turubanova, S., Yaroshenko, A., Thies, C., Smith, W., Zhuravleva, I., Komarova, A., Minnemeyer, S., Esipova, E., 2017. The last frontiers of wilderness: Tracking loss of intact forest landscapes from 2000 to 2013. Science Advances 3.

Potvin, C., Mateo-Vega, J., 2013. Panama: Curb indigenous fears of REDD+. Nature 500, 400-400.

Pratihast A. K., Herold M., De Sy V., Murdiyarso D.Skutsch M. 2013. Linking community-based and national REDD+ monitoring: a review of the potential. Carbon Management **4**:91-104.

Rainforest Foundation US. 2020. Panama: Securing indigenous peoples' land rights and protecting forests in the Darién Gap.

Ramos-Castillo A., Castellanos E. J.Galloway McLean K. 2017. Indigenous peoples, local communities and climate change mitigation. Climatic Change **140**:1-4.

Redford K. H., Padoch C.Sunderland T. 2013. Fads, Funding, and Forgetting in Three Decades of Conservation. Conservation Biology **27**:437-438.

Reyes-García, V., Fernández-Llamazares, Á., McElwee, P., Molnár, Z., Öllerer, K., Wilson, S.J., Brondizio, E.S., 2019. The contributions of Indigenous Peoples and local communities to ecological restoration. Restoration Ecology 27, 3-8.

Robinson, B.E., Holland, M.B., Naughton-Treves, L., 2014. Does secure land tenure save forests? A meta-analysis of the relationship between land tenure and tropical deforestation. Global Environmental Change 29, 281-293.

Robinson, B.E., Masuda, Y.J., Kelly, A., Holland, M.B., Bedford, C., Childress, M., Fletschner, D., Game, E.T., Ginsburg, C., Hilhorst, T., Lawry, S., Miteva, D.A., Musengezi, J., Naughton-Treves, L., Nolte, C., Sunderlin, W.D., Veit, P., 2018. Incorporating Land Tenure Security into Conservation. Conservation Letters 11, e12383.

Rodriguez, O., 2021. Ministerio Público investiga deforestación de 188 hectáreas en áreas protegidas de Darién. La Prensa, Panama City, Panama.

RRI, 2015. Who Owns the World’s Land? A global baseline of formally recognized indigenous and community land rights. . Rights and Resource Initiative, Washington, DC.

Sayer, J., Sunderland, T., Ghazoul, J., Pfund, J.-L., Sheil, D., Meijaard, E., Venter, M., Boedhihartono, A.K., Day, M., Garcia, C., van Oosten, C., Buck, L.E., 2013. Ten principles for a landscape approach to reconciling agriculture, conservation, and other competing land uses. Proceedings of the National Academy of Sciences 110, 8349-8356.

Seddon N., Chausson A., Berry P., Girardin C. A. J., Smith A.Turner B. 2020. Understanding the value and limits of nature-based solutions to climate change and other global challenges. Philosophical Transactions of the Royal Society B: Biological Sciences **375**:20190120.

Seddon N., Smith A., Smith P., Key I., Chausson A., Girardin C., House J., Srivastava S.Turner B. 2021. Getting the message right on nature-based solutions to climate change. Global Change Biology **27**:1518-1546.

Sexton J. O., et al. 2013. Global, 30-m resolution continuous fields of tree cover: Landsat-based rescaling of MODIS Vegetation Continuous Fields with lidar-based estimates of error.

International Journal of Digital Earth 130321031236007. doi:10.1080/17538947.2013.786146.

Seymour, F., 2020. INSIDER: 4 Reasons Why a Jurisdictional Approach for REDD+ Crediting Is Superior to a Project-Based Approach. World Resource Institute, Washington, DC, USA.

Sharma D., Holmes I., Vergara-Asenjo G., Miller W. N., Cunampio M., B. Cunampio R., B. Cunampio M.Potvin C. 2016. A comparison of influences on the landscape of two social-ecological systems. Land Use Policy **57**:499-513.

Slik J. W. F., et al. 2013. Large trees drive forest aboveground biomass variation in moist lowland forests across the tropics. Global Ecology and Biogeography **22**:1261-1271.

Smith H. A.Sharp K. 2012. Indigenous climate knowledges. WIREs Climate Change **3**:467-476.

Sobrevila C. 2008. The Role of Indigenous Peoples in Biodiversity Conservation. The Natura but Often Forgotten Partners. The International Bank for Reconstruction and Development / THE WORLD BANK, Washington, D.C., USA.

Stevens, C., Winterbottom, R., Springer, J., Reytar, K., 2014. Securing Rights, Combating Climate Change: How Strengthening Community Forest Rights Mitigates Climate Change. World Resources Institute. Accessible at http://www.wri.org/securing-rights., Washington, DC.

Suiseeya, K.R.M., 2017. Contesting Justice in Global Forest Governance: The Promises and Pitfalls of REDD+ 15. Conservation & Society 15, 189-200.

Sutherland W. J., Gardner T. A., Haider L. J.Dicks L. V. 2013. How can local and traditional knowledge be effectively incorporated into international assessments? Oryx **48**:1-2.

Taylor R., Sims M., Burns D.Lyons K. 2021. What COP26 Means for Forests and the Climate. World Resources Institute, Washington, D.C., USA.

Turnhout, E., Gupta, A., Weatherley-Singh, J., Vijge, M.J., de Koning, J., Visseren-Hamakers, I.J., Herold, M., Lederer, M., 2017. Envisioning REDD+ in a post-Paris era: between evolving expectations and current practice. Wiley Interdisciplinary Reviews: Climate Change 8, e425-n/a.

UK Government. 2021. Over 100 leaders make landmark pledge to end deforestation at COP26. UK Government, Prime Minister's Office, 10 Downing Street and The Rt Hon Boris Johnson MP, London, England, UK.

UK Presidency COP26. 2021. Glasgow Leaders' Declaration on Forests and Land use. Glasgow, Scotland, UK.

UNDP, 2017. Human Development Report 2016. United Nations Development Programme, New York, USA.

UN General Assembly. 2007. United Nations Declaration on the Rights of Indigenous Peoples : resolution/adopted by the General Assembly, 2 October 2007, A/RES/61/295.in United_Nations, editor., New York, USA.

UNFCCC, 2008. Report of the Conference of the Parties on its thirteenth session, held in Bali from 3 to 15 December 2007. Addendum Part Two: Action taken by the Conference of the Parties at its thirteenth session. United Nations Framework Convention on Climate Change, Bali, Indonesia.

UNFCCC, 2010. Report of the Conference of the Parties on its fifteenth session, held in Copenhagen from 7 to 19 December 2009. Addendum. Part Two: Action taken by the Conference of the Parties at its fifteenth session. FCCC/CP/2009/11/Add.1. United Nations Framework Convention on Climate Change, Copenhagen, Denmark.

UNFCCC. 2011. Report of the Conference of the Parties on its sixteenth session, held in Cancun from 29 November to 10 December 2010. Addendum part two: action taken by the Conference of the Parties at its sixteenth session. FCCC/CP/2010/7/Add.1. United Nations Framework Convention on Climate Change, Cancun, Mexico.

UNFCCC, 2015. Report of the Conference of the Parties on its twenty-first session, held in Paris from 30 November to 13 December 2015. Addendum. Part two: Action taken by the Conference of the Parties at its twenty-first session. Decision 1/CP.21 (Adoption of the Paris Agreement). United Nations Framework Convention on Climate Change, Paris, France.

UNFCCC, 2021. Decision -/CP.26. Glasgow Climate Pact. Advance undedited version. United Nations Framework Convention on Climate Change, Glasgow, Scotland.

Vásquez-Grandón A., Donoso P. J.Gerding V. 2018. Forest Degradation: When Is a Forest Degraded? Forests **9**:726.

Vergara-Asenjo G., Mateo-Vega J., Alvarado A.Potvin C. 2017. A participatory approach to elucidate the consequences of land invasions on REDD+ initiatives: A case study with Indigenous communities in Panama. PLoS ONE **12**:e0189463.

Visseren-Hamakers, I.J., McDermott, C., Vijge, M.J., Cashore, B., 2012. Trade-offs, co-benefits and safeguaWali A. 1989. Kilowatts and crisis: hydroelectric power and social dislocation in eastern Panama. Westview Press, Boulder, CO, USA.

Walker, B., Gunderson, L., Kinzig, A., Folke, C., Carpenter, S., Schultz, L., 2006. A Handful of Heuristics and Some Propositions for Understanding Resilience in Social-Ecological Systems. Ecology and Society 11.

Walker W., et al. 2014. Forest carbon in Amazonia: the unrecognized contribution of indigenous territories and protected natural areas. Carbon Management **5**:479-485.

Walker W. S., et al. 2020. The role of forest conversion, degradation, and disturbance in the carbon dynamics of Amazon indigenous territories and protected areas. Proceedings of the National Academy of Sciences **117**:3015-3025.

Watson, J.E.M., Evans, T., Venter, O., Williams, B., Tulloch, A., Stewart, C., Thompson, I., Ray, J.C., Murray, K., Salazar, A., McAlpine, C., Potapov, P., Walston, J., Robinson, J.G., Painter, M., Wilkie, D., Filardi, C., Laurance, W.F., Houghton, R.A., Maxwell, S., Grantham, H., Samper, C., Wang, S., Laestadius, L., Runting, R.K., Silva-Chávez, G.A., Ervin, J., Lindenmayer, D., 2018a. The exceptional value of intact forest ecosystems. Nature Ecology & Evolution 2, 599-610.

Watson, J.E.M., Leiper, I., Potapov, P., Evans, T.D., Burgesse, N.D., Molnárg, Z., Fernández-Llamazaresh, A., Fa, J.E., Duncan, T., Wang, S., Austin, B., Jonas, H., Robinson, C.J., Malmerm, P., Zander, K.K., Jackson, M.V., Elliso, E., Brondizio, E.S., Garnett, S.T., 2018b. Policy Brief: Supporting Indigenous Peoples who manage intact forests is crucial to achieving climate goals. Wildlife Conservation Society and 15 partner organizations., New York City, New York, USA.

WHRC, EDF. 2015. Tropical Forest Carbon in Indigenous Territories: A Global Analysis. A report prepared for UNFCCC COP 21. The Woods Hole Research Center and Environmental Defense Fund.

Wily, L.A., 2011. The tragedy of public lands: The fate of the commons under global commercial pressure. International Land Coalition and CIRAD, Rome, Italy.

Yin, R., 2016. Empirical linkages between devolved tenure systems and forest conditions: An introduction to the literature review. Forest Policy and Economics 73, 271-276.

Zentner, E., Kecinski, M., Letourneau, A., Davidson, D., 2019. Ignoring Indigenous peoples—climate change, oil development, and Indigenous rights clash in the Arctic National Wildlife Refuge. Climatic Change 155, 533-544.

Zhang J., Hu J., Lian J., Fan Z., Ouyang X.Ye W. 2016. Seeing the forest from drones: Testing the potential of lightweight drones as a tool for long-term forest monitoring. Biological Conservation **198**:60-69.

Appendix A: Supplementary Materials for Discussion

Comparative analysis of tree cover loss/gains, and annual rates of tree cover change from 2015–2025 between the current study and Vergara-Asenjo et al. (2017) for the Emberá territories of Ipetí and Piriatí, and the Comarca Kuna de Madungandi. UBW = Upper Bayano Watershed; *q*= Annual Rate of Tree Cover Change (FAO 1995)

DATA	Tree Cover (ha) 2014	% of Yearly Loss in UBW (2001-2014)	Tree Cover (ha) 2015	Projected Loss (ha/yr) (2015-2025)	Loss (ha) 2015-2025	Tree Cover (ha) 2025	Change (%)	Change/yr (%)	Annual Rate of Tree Cover Change – *q*
Based on Vergara-Asenjo (V-A) et al. (2017)									
Ipeti	2353	6%	2318	32	323	1995	14.0	1.55	-1.49%
Madungandi	191689	59%	191342	324	3238	188103	1.7	0.19	-0.17%
Piriati	2477	7%	2437	37	373	2064	15.3	1.70	-1.65%
TOTAL	**196519**	**71%**	**196097**	**393**	**3935**	**192162**			**-0.20%**
BAU Scenario – current study									
Ipeti	N.A.	N.A.	1971	16	164	1807	8.33	0.83	-0.87%
Madungandi	N.A.	N.A.	197098	1159	11594	185504	5.88	0.59	-0.60%

Piriati	N.A.	N.A.	789	59	592	197	75.00	7.50	-12.94%
TOTAL	N.A.	N.A.	**199858**	**1235**	**12350**	**187508**			**-0.64%**
Ideal Scenario – current study									
Ipeti	N.A.	N.A.	1971	-33	-329	2300	-16.67	-1.67	1.55%
Madungandi	N.A.	N.A.	197098	1159	11594	185504	5.88	0.59	-0.60%
Piriati	N.A.	N.A.	789	-59	-592	1380	-75.00	-7.50	5.76%
TOTAL	**N.A.**	**N.A.**	**199858**	**1067**	**10674**	**189184**			**-0.55%**

ANALYSIS	Tree cover (ha) 2015	Projected Loss (ha/yr) 2015-2025	Loss (ha) 2015-2025	Tree Cover (ha) 2025
Ipeti				
Diff. V-A & BAU (ha)	347	16	159	188
BAU: % less than V-A	15	49	49	9
Diff. V-A & Ideal (ha)	347	65	652	-305
Ideal: % less than V-A	15	202	202	-15
Madungandi				
Diff. V-A & BAU (ha)	-5756	-836	-8356	2599
BAU: % less than V-A	-3	-258	-258	1
Diff. V-A & Ideal (ha)	-5756	-836	-8356	2599
Ideal: % less than V-A	-3	-258	-258	1
Piriati				
Diff. V-A & BAU (ha)	1648	-22	-219	1867
BAU: % less than V-A	68	-59	-59	90
Diff. V-A & Ideal (ha)	1648	96	965	-235

Ideal: % less than V-A	68	259	259	-11
All Territories				
Diff. V-A & BAU (ha)	-3761	-842	-8415	4654
BAU: % less than V-A	-1.92	-213.86	-213.86	2.42
Diff. V-A & Ideal (ha)	-3761	-674	-6739	2978
Ideal: % less than V-A	-1.92	-171.27	-171.27	1.55

	Tree Cover (ha) 2015	Projected Loss (ha/yr) (2015-2055)	Loss (ha) 2015-2055	Tree Cover (ha) 2055	Change (%)	Change/yr (%)	Annual Rate of Tree Cover Change - *q*
BAU Scenario - current study							
Ipeti	1971	21	821	1150	42%	4.2%	-5.25%
Madungandi	197098	1159	46376	150722	24%	2.4%	-2.65%
Piriati	789	15	592	197	75%	7.5%	-12.94%
TOTAL	**199858**	**1195**	**47789**	**152069**			**-2.70%**
Ideal Scenario - current study							
Ipeti	1971	-21	-821	2792	-42%	-4.2%	3.54%
Madungandi	197098	0	0	197098	0%	0.0%	0.00%
Piriati	789	-49	-1972	2761	-250%	-25.0%	13.35%
TOTAL	**199858**	**-70**	**-2793**	**202651**			**0.14%**
Analysis							

Appendix B: Chapter 2 Supplementary Materials

The Landsat Vegetation Continuous Fields (VCF) tree cover (TC) (Sexton et al. 2013) provides an estimate of the percentage of horizontal ground covered by woody vegetation greater than 5 meters in height (spatial resolution 30-m pixel). Based on the plot data, two tiles from VCF tree cover were selected from 2015 (p011r054_TC_2015, p011r055_TC_2015). Tiles were mosaicked in ArcGIS 10.4 and the pixel value for the tree cover was extracted based on the location of the plots (Figure B1).

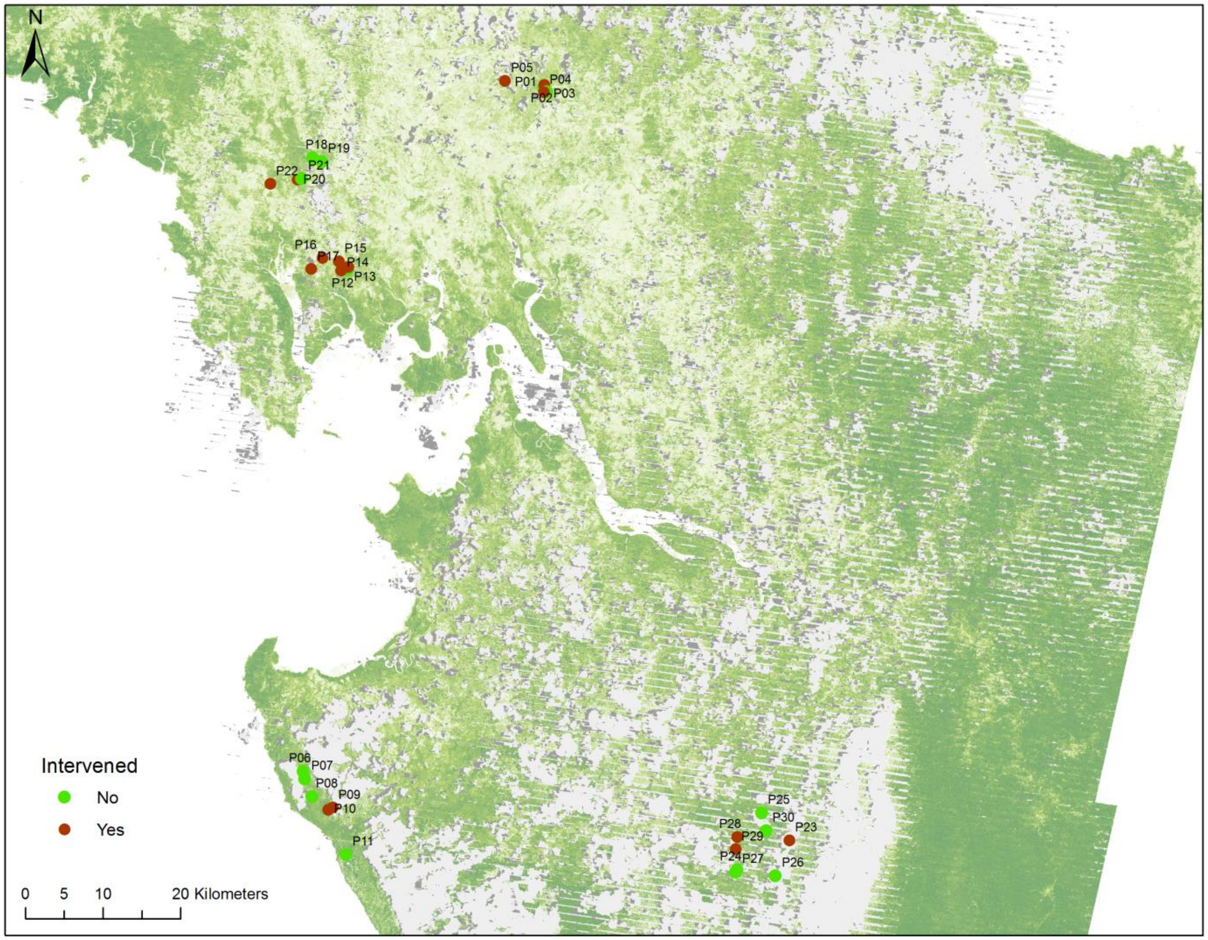

Figure B1. Tree cover layer for the year 2015 for study area based on Sexton et al. 2013. Shades of green represent percent of pixel area covered by tree cover from 1-100 (darker green indicates higher tree cover covered by woody vegetation greater than 5 meters in height). White areas indicate cloud cover and gray areas shadows.

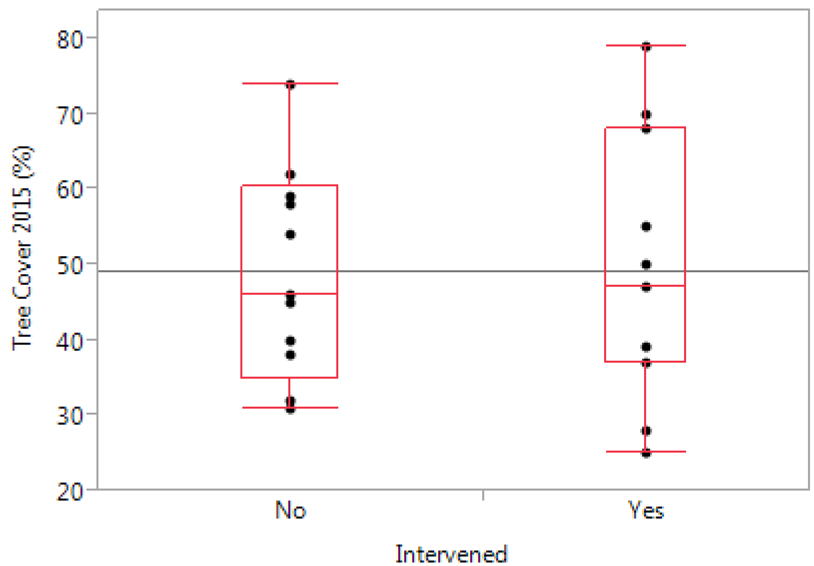

Figure B2. Intervened vs. non-intervened total tree cover (%) for the year 2015 VCF layer. A Wilconxon/Kruskal Wallis test indicates no significant differences in tree cover. Six values were excluded as they were in a cloud covered area.

Table B1. Tree cover (%) for intervened and non-intervened forest areas in Panama. Values were extracted with a point layer (plots) and a raster layer (tree cover) in ArcGIS 10.4

Name	**Plot #**	**Total_AGB**	**Intervened**	**TC_2015**	**TC_2015 Interpolated**	**TC_2015 Error**	**TC_2015 Error Interpolated**	**TC_2010**	**TC_2010 Interpolated**	**TC_2010 Error**	**TC_2010 Error Interpolated**
P1NO	P01	359.65	No	45	40	26	22	44	42	27	27
P2NO	P02	178.60	Yes	55	53	15	16	35	42	30	30
P3NO	P03	304.08	No	32	32	22	21	26	45	28	28
P4NO	P04	188.93	Yes	68	64	17	18	34	37	28	28
P5NO	P05	309.96	Yes	210	210	-9999	-9999	211	211	21	21
P10N	P10	331.67	Yes	211	211	-9999	-9999	63	63	20	22
P11N	P11	379.74	No	74	74	8	8	77	76	19	20
P6NO	P06	337.22	No	74	72	18	16	67	67	23	23
P7NO	P07	459.74	No	54	55	6	7	69	69	20	20
P8NO	P08	399.76	No	62	65	7	7	87	69	23	23
P9NO	P09	287.14	Yes	79	78	22	20	63	65	24	23
P12N	P12	369.55	No	46	48	19	19	38	43	26	25
P13N	P13	194.67	Yes	47	46	19	18	23	31	26	25
P14N	P14	87.45	Yes	39	42	19	20	73	71	23	24
P15N	P15	241.68	Yes	25	25	12	13	211	211	21	21
P16N	P16	101.44	Yes	37	85	12	16	60	62	24	23
P17N	P17	240.93	Yes	28	28	25	25	38	44	26	26
P18N	P18	314.28	No	32	32	18	18	211	211	21	21
P19N	P19	202.52	No	58	39	21	21	54	51	31	31
P20N	P20	231.89	Yes	70	66	11	11	56	57	24	25
P21N	P21	289.16	No	40	41	22	20	39	41	29	28
P22N	P22	263.94	Yes	50	49	11	14	210	210	21	23
P23N	P23	250.65	Yes	211	211	-9999	-9999	211	211	21	21
P24N	P24	282.18	No	31	43	28	28	66	68	21	23

P25N	P25	296.96	No	211	211	-9999	-9999	210	210	30	30
P26N	P26	365.34	No	211	211	-9999	-9999	8	27	28	28
P27N	P27	349.80	No	59	64	5	5	17	15	29	28
P28N	P28	190.01	Yes	39	41	18	17	211	211	27	27
P29N	P29	233.29	Yes	211	211	-9999	-9999	211	116	21	24
P30N	P30	424.55	No	38	49	10	10	17	27	31	30

References

Sexton J. O., et al. 2013. Global, 30-m resolution continuous fields of tree cover: Landsat-based rescaling of MODIS Vegetation Continuous Fields with lidar-based estimates of error. . International Journal of Digital Earth **130321031236007. doi:10.1080/17538947.2013.786146**.

Appendix C: Chapter 3 Supplementary Materials

Appendix C1: Teaching Notes

Deforestation, territorial conflicts, and pluralism in the forests of eastern Panama: a place for Reducing Emissions from Deforestation and Forest Degradation (REDD+)?

Questions about the Teaching Notes

Contact the authors for enquiries about teaching this case, including answers to any questions posed by the case, the Teaching Notes, or Case Study Questions

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Target Group

This case study is primarily directed towards graduate-level students taking courses in Conservation Biology, Forestry, Natural Resource Management, Geography, Political Ecology, International Development, Environmental Studies, Ecological Economics, Development and the Environment in Latin America. However, the case may be suitable for upper-level undergraduate students with adjustments as described below, or for policy-makers and field practitioners taking part in professional training.

Learning Objectives and Key Issues:

Users of this case study will:

1. Develop an understanding of the complex interactions between socio-economic, cultural, political components of coupled natural and human forest ecosystems in eastern Panama;

2. Learn to articulate different stakeholder perspectives on tropical forests and climate change policy issues using the case of REDD+ in Panama; and

3. Gain insight into some of the challenges and opportunities facing coordinated policy responses to tropical deforestation.

Teaching Strategy

This case explores the complexities of tropical deforestation and considers the potential role of REDD+ in developing countries. Using the Upper Bayano Watershed in eastern Panama as a stage, this case confronts participants with the challenges of implementing ambitious, international, and often prescriptive natural resource policies at local levels. It serves to highlight the complexity of social-ecological systems (SES) by exploring how different stakeholders (Kuna, Emberá and *colonos*), who share a common landscape, and value forests in fundamentally different ways, interpret their main forest-related issues and view the potential for REDD+ to contribute to sustainable development. The case study is structured around Ostrom's [1] framework for analyzing SES, with a focus on stakeholders (i.e. resource users) and how they may exercise their agency to either accept or reject REDD+.

This case is built through the experience of a public hearing on the potential implementation of REDD+ in the Upper Bayano Watershed. It is meant to stimulate discussions about access to land, tenure security, biodiversity conservation, poverty reduction, identity, power, and social justice. Combining role-playing and problem-based learning, this case is designed to take place in a classroom setting, requiring preparatory readings, viewing videos, and group work.

The case can be run in a single session, as described in the Case Study, or in two sessions, as described below, with the inclusion of an extra component involving the development of a Driver-Pressure-State-Impact-Response (DPSIR) framework to conceptualize and analyze the complex SES underlying problems such as tropical deforestation. The DPSIR framework can help to better identify the challenges and opportunities for policy responses such as REDD+. Each session requires approximately two hours of preparatory time for participants and three hours for each session.

The course instructor will serve as the facilitator and chairperson of the public hearing, through both the role-playing and problem-based learning processes. Participants will work in groups and space should be allocated for the groups to react to each other's position or observations. The facilitator's role will be to ask questions in order to stimulate collective reflection and co-learning around desired themes. No previous knowledge of REDD+, or Indigenous peoples and farmers in Panama is required. Detailed instructions for classroom management are provided in Appendix C2, along with a proposed grading rubric (Appendix C3).

Anticipated Results

Although based on an ongoing situation taking place in the Upper Bayano Watershed, the specific scenario setting of a public hearing is fictional. Reflecting the situation facing policy-makers “on the ground”, there is no ideal resolution to the issues being raised in this case, and therefore, no specific anticipated results. Instead, this case aims to encourage participants to grapple with the elements of conflict, complexity, change and uncertainty that are inherent to resource management decision making in any SES [2]. The case study has been successfully implemented in graduate and undergraduate-level courses, and in a workshop with a mixed audience of professional participants (policy makers and field practitioners) and graduate students.

Background Reading

Users of this case are encouraged to examine the background to the case study (Appendix C4) and extensive bibliography included in the Case Study article. However, recognizing that much of this material is not open source, a list of public access readings available on-line are listed below, along with their links. This list is broken down according to each section of the case study, with the exception of the Stakeholders in Bayano section.

Forests and climate change

- UNFCCC, 2009. Fact Sheet: The Need for Mitigation. United Nations. https://unfccc.int/files/press/backgrounders/application/pdf/press_factsh_mitigation.pdf

Introduction to REDD+

- Angelsen, A., 2008. Moving ahead with REDD: Issues, options and implications. CIFOR, Bogor, Indonesia. http://www.cifor.org/publications/pdf_files/Books/BAngelsen1201.pdf

- REDD-Monitor, 2011. REDD: An Introduction. http://www.redd-monitor.org/redd-an-introduction/

- UNFCCC, 2011. Report of the Conference of the Parties on its sixteenth session, held in Cancun from 29 November to 10 December 2010. Addendum part two: action

taken by the Conference of the Parties at its sixteenth session. FCCC/CP/2010/7/Add.1. United Nations Framework Convention on Climate Change. http://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf#page=2 (***Read Section III C*).**

REDD+ opportunities and challenges

- Peskett, L., Yanda, P., 2009. The REDD+ outlook: how different interests shape the future. ODI Background Notes. Overseas Development Institute, United Kingdom. http://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/5531.pdf

- Stevens, C., Winterbottom, R., Springer, J., Reytar, K., 2014. Securing Rights, Combating Climate Change: How Strengthening Community Forest Rights Mitigates Climate Change. World Resources Institute. Washington, DC. http://www.wri.org/sites/default/files/securingrights-full-report-english.pdf

REDD+ in Panama with Indigenous peoples

- Feiring, B., Abbott, E., 2013. Preliminary note on findings, conclusions and recommendations. . Independent team for the investigation and evaluation of the UN--REDD Panama Programme, Panama.

  The "link "to report appears on the July 4, 2013 note. http://www.un-redd.org/UNREDD_Launches_Panama_NP_Evaluation_EN/tabid/106063/Default.aspx#DraftReport

- Tuckman, J., 2013. Panama's indigenous people see Redd over UN forest conservation scheme. The Guardian, United Kingdom. http://www.theguardian.com/global-development/2013/may/24/panama-indigenous-people-un-forest-conservation

The Upper Bayano Watershed social-ecological system

- Wali, A., 1989a. In Eastern Panama, Land Is the Key to Survival. Cultural Survival Quarterly 13, 25-29. http://www.culturalsurvival.org/ourpublications/csq/article/in-eastern-panama-land-is-key-survival

- Suman, D., 2007. Globalization and the Pan-American Highway: Concerns for the Panama-Colombia Border Region of Darién-Chocó and its Peoples. University of Miami Inter-American Law Review 38, 539-614. http://repository.law.miami.edu/cgi/viewcontent.cgi?article=1067&context=umialr

- Peterson St-Laurent, G., Gélinas, N., Potvin, C., 2013. Diversity of Perceptions on REDD+ Implementation at the Agriculture Frontier in Panama. International Journal of Forestry Research. http://www.hindawi.com/journals/ijfr/2013/657846/

- Sharma, D., Vergara-Asenjo, G., Cunampio, M., Cunampio, R.B., Cunampio, M.B, Potvin, C., 2015. Genesis of an indigenous social-ecological landscape in eastern Panama. Ecology and Society 20 (4); article 37 https://www.ecologyandsociety.org/vol20/iss4/art37/

References

1. Ostrom E. A General Framework for Analyzing Sustainability of Social-Ecological Systems. Science. 2009;325(5939):419-22.
2. Mitchell B. Resource and Environmental Management. Essex: Addison Wesley Longman Limited; 1997.

Appendix C2: Classroom management

This case has been designed to be taught intensively over one or two 180 minute sessions, but can be modified to suit different teaching schedules and needs. Participants will need to complete the assigned pre-class readings and watch several videos, all of which require internet access and approximately two hours of dedicated time. If Session 2 is included, they will also need to download the free software CmapTools to develop their concept maps.

Teaching the Case

For this case study, participants should be divided in four groups that represent the Emberás, Kunas, *colonos* and government officials. Each group will be asked to develop and represent a position on REDD+ while role-playing. Other actors may also be considered (see "Others" section below for a list) in this case study, but these are not fully discussed and would require additional work by the instructor and participants. Like in real life, those representing the Kunas, Emberás and *colonos* will either opt in or out of REDD+, conditioning their participation or justifying their non-engagement. The government's role is to encourage the participation of the other three groups. Each group should be prepared to present and defend why they believe REDD+ is or is not a valid land management strategy and potential source of income. If divergent views are presented – which should be the case – they will be asked to develop recommendations on how to potentially reconcile these contrasting perspectives on REDD+, if possible. In other words, what conditions would have to be met for REDD+ to be adopted in the Upper Bayano Watershed by the different groups and what actions would be required for these conditions to be met? This latter question may be answered in a group setting, or each group may first discuss their ideas and then present them in a plenary session. For this, participants will receive background information on each one of the groups. They will also be encouraged to conduct their own research about the cultural and social factors that may influence their position on REDD+. In addition to background information that is included in the Case Study, instructors are encouraged to share with participants the table of stakeholders below (print or project on a screen), and highlight the points outlined below (some already covered in the Case Study), which include additional useful details found in the literature and/or observations by the authors:

Case Study Stakeholders (in order of appearance)

Government of Panama	Responsible for developing and implementing the national REDD+ strategy.
United Nations Collaborative Programme on REDD+ (UN-REDD)	Provides financial and technical support to the Government of Panama in preparing their national REDD+ strategy.
National Coordinating Body of Indigenous Peoples of Panama (COONAPIP)	Organization that represents all seven Indigenous groups in Panama.
Inter-American Court of Human Rights	Autonomous judicial system of the Organization of American States. Ruled in favor of the Emberás and Kunas who were seeking indemnification for the loss of ancestral lands due to the construction of the Bayano Hydroelectric Complex.
Emberás	Indigenous peoples that reside primarily in eastern Panama.
Kunas	Indigenous peoples that reside primarily in eastern Panama.
Colonos	Farmers of mestizo origin that migrated to eastern Panama from the central and western provinces of the country in search of land.

Upper Bayano Watershed

- At the time of the displacement of groups residing in the Upper Bayano Watershed for the construction of the hydroelectric project, *colonos*, were the most populous, followed by the Kunas and Emberás [1].

- The *colonos* were supposed to abandon the area completely, while the Kunas and Emberás were to be relocated, as the belief – at the time – is that they would protect the forests, necessary to regulate water flow to produce energy [1].

- The re-entry of *colonos* to the region after the hydroelectric dam went into operation, and the Government of Panama's inability and/or unwillingness to demarcate, title and guarantee collective tenure of Indigenous lands in a timely manner, led the Kunas and Emberás to jointly bring these issues forward to the Inter-American Commission of Human Rights. The Commission then filed an application with the Inter-American Court of Human Rights, who in October 2014 ordered the Government of Panama to indemnify both groups for damages (both material and immaterial) and to resolve the issues of land title and secure tenure [2]. The problem of land invasions persists in the Upper Bayano Watershed [3].

- The Bayano hydroelectric complex produces approximately 7.3% of the energy that enters the National Interconnection System of Panama, but has the installed capacity to produce up to 11% of the country's energy [4]. Therefore, it plays an important role in the country's development.

Emberá

- The Emberás hold title of two small territories and claim to a third medium-sized territory. Collectively, the three territories add up to a little less than a fifth of the land that was allocated to the Kunas.

- One of the territories with title, Piriati, has virtually no forest left, while the second titled territory, Ipeti, has some remnants in the hilly areas of the territory[5]. The third territory under claim, Maje, still has large swaths of forest, but illegal loggers, sometimes working in coordination with community members, are rapidly stripping these.

- Many Emberás, particularly in Piriati, no longer work the land, and instead rent it out to cattle ranchers and mechanized rice producers.

- Most generations born in the 1980s and onwards, speak little Emberá. Women still partially wear their traditional garb, while men only during ceremonies.

Kunas

- Most people in the Comarca speak Kuna, women and men regularly – if not constantly - wear their traditional garbs, and they tend to be less open to interactions with outsiders.

- The notion of viewing trees as carbon storage units is incongruent with their beliefs that trees are their “brothers”. Yet many communities, particularly those along the lake or its tributaries, have signed concessions with logging companies.

- As the holders of most land in the Upper Bayano Watershed, they have been hit hardest by land invasions by colonist farmers, also resulting in deforestation.

Colonos

- *Colonos* started to re-enter the Bayano region shortly after the hydroelectric dam went operational, contravening agreements with the government and Indigenous leaders [1].

- Over time, government officials have turned a blind eye to these incursions, and in some cases, actively incentivized the invasion of Indigenous territories (even until recently).

- Some farmers reached agreements with the Indigenous authorities to work the land, but were forbidden from selling or renting it, or even passing it onto their children.

- Farmers have regularly broken these agreements and engaged in illegal real estate transactions, in many cases with wealthy and unscrupulous landowners actively engaged in land hoarding and grabbing, and deforestation.

- Waves of migrants continue to arrive into the Upper Bayano Watershed and move deeper into the Darién due to the lack of available, affordable, arable land in other parts of the country.

Government of Panama

- The government and multilateral agencies have operated as a single entity in practice. Their mandate is to make REDD+ operational.

- During the initial phases of the Panama REDD Readiness process, missteps resulted in ruptures with traditional Indigenous authorities, and eventually a third party assessment [6], which revealed procedural shortfalls.

- Although amends were eventually made with the National Coordination Body of Indigenous Peoples of Panama (COONAPIP), which – in principle – represents all seven Indigenous ethnic groups, several of the Indigenous congresses saw this as an illegitimate act and severed their ties with COONAPIP. The REDD+ process was the catalyst.

- The government and multilateral agencies have continued with their REDD Readiness process and instead of dealing with the COONAPIP only, they are now also engaging directly with individual Indigenous congresses.

- The government has launched an initiative called the Alliance for One Million Hectares, and have expressed interest to restore deforested and degraded lands in Indigenous territories.

Others

This category has been added in order to provide opportunities for participants to explore other entities that are often embedded in rural settings like the Upper Bayano Watershed, and that may have an interest, influence and/or be affected by the deployment of a mechanism like REDD+. Participants can be encouraged to delve into the literature to further explore the role or position of these stakeholders. The following are examples of potential additional actors:

- Non-governmental organizations

- Religious organizations

- Forestry industries

- Local entrepreneurs who sell equipment, tools, machinery for agriculture and forestry.

Session 1 (180 minutes):

Prior to class:

Participants will need to read the case introduction and background readings listed above. They should also consult the following document and videos:

- Golder, B., Gawler, M., 2005. Cross-Cutting Tool: Stakeholder Analysis. WWF Standards of Conservation Project and Programme Management. http://www.panda.org/standards/1_4_stakeholder_analysis

Videos:

- UN-REDD Programme, 2014. Panama's National Forest Inventory. https://www.youtube.com/watch?v=nskGQgYInyM&index=1&list=UUz5rINjAhdCQbe0HVlelfDA

- A series of short videos produced by youth that partook in documentary-film making workshops facilitated by the Neotropical Ecology Lab (McGill/Smithsonian) in collaboration with the Canadian-based NGO, Wapikoni mobile.

http://www.wapikoni.ca/films/en?nation=8d9284f0-7234-4477-add5-939315f69c63&community=&genre=&language=&year=&sort=0

  - *The house of our grandparents*: the Emberá narrate the cultural changes they have experienced as a result of the loss of their forests.

  - *Our home*: a brief clip that touches on the challenges that the Emberá have faced in securing their territorial rights.

  - *Akua Yala*: provides a glimpse into the lives of the Kuna after the construction of the Bayano Hydroelectric Complex and the impact it has had on their lives (no translated subtitles, but even the images offer a sense of place and culture).

  - *Discrimination*: highlights the social tensions, but also shared sentiments about discrimination, among the three main groups that inhabit the Bayano region.

  - *Deforestation*: showcases the issue of forest loss and the role that various actors play.

- *Retratos del Bayano* (Portraits of Bayano): audiovisual presentation of the Emberá and farmer (*colono*) cultures in the Bayano.

- The REDD Desk and Global Canopy Programme. Introduction to REDD+, 2012. https://www.youtube.com/watch?v=D0WeGw3h2yU

When reviewing the case material, participants should take notes on the various aspirations of different forest-related stakeholders in the Bayano region and their relative positions of influence/power and stake/interest in REDD+ projects, following the structure provided by Golder and Gawler [7].

In class:

1. Introduction (5 min.): The instructor should begin the class with a brief summary of the background readings/videos highlighting the broad characteristics of this case that make it relevant to the biodiversity conservation, natural resource management and climate change mitigation challenges being faced in different contexts internationally.

2. Breakout groups (55 min.): The class should then be divided into groups (the number of participants per group will depend on class size),and assigned a stakeholder group (i.e. Kuna, Emberá, *Colono*, Government, Other) whose perspective they will seek to represent. Drawing on their assigned readings and the videos watched, each group will prepare their stakeholder position on REDD+ policy in the Upper Bayano Watershed, detailing their key issues and concerns.

3. Public hearing (10 min. per group; 60 min. maximum depending on the number of groups): The instructor will then act as the chairperson of a public hearing session, which is being held to understand if and how to proceed with REDD+. Each stakeholder group will be given just 10 minutes to formally present their position, aspirations, arguments and justifications in order to try and influence the policy process.

4. Debate (45 min.): There will then be a facilitated general discussion period to allow each stakeholder group to directly ask and respond to questions arising from other stakeholder perspectives with a view to clarifying areas of agreement and disagreement.

5. Debriefing (15 min.): The instructor will then facilitate a debriefing session on the main points arising and, in discussion with the participants, identify some of the key lessons for

natural resource management and policy. These issues may include (1) the lack of trust among the various groups due to previous interactions, (2) asymmetries in power due to differences in access to knowledge, experience in advocacy, and stakes in participating in a mechanism such as REDD+, and (3) and challenges in implementing global initiatives at the local scale.

Session 2 (180 minutes):

Prior to class:

Participants will need to have completed following pre-class readings and assignments:

- Lindsey, R., 2007. Tropical Deforestation. NASA

http://earthobservatory.nasa.gov/Features/Deforestation/

- Bradford, A., 2015. Deforestation: Facts, Causes & Effects. LiveScience. http://www.livescience.com/27692-deforestation.html

- Explore the Panama Country Data on www.globalforestwatch.com focusing on forest cover changes that have taken place in the Bayano region over time.

- US EPA Tutorials on Systems Thinking using the DPSIR Framework (Modules 1 to 4): http://archive.epa.gov/ged/tutorial/web/html/index.html

In class:

1. Introduction (10 min.): The instructor should begin by setting the scene for tropical deforestation, identifying the wicked nature of the problem and the need for complex systems approaches to help with identifying the different components and interactions affecting outcomes so as to improve policy design and learning (responses). While there are different tools available, the Driver-Pressure-State-Impact-Response (DPSIR) framework has been widely used in government to facilitate more systems-based approaches to public policy thinking. The framework serves to show the causal links between human actions (drivers), the effects these generate (pressures), the resulting condition on the environment (state), the impacts of this condition (impacts) and the policy choices (responses) to address the problem.

2. DPSIR matrix (60 min.): The class should then be divided into breakout groups to develop a detailed DPSIR matrix (example available from the corresponding author upon request by instructors) on the different issues affecting tropical deforestation in Panama, drawing on their assigned readings, including the tutorial on the DPSIR framework, and any additional internet research they may wish to do. Within the 'Responses' category, REDD+ should be included as one possible option.

3. DPSIR concept map (80 min.): Each group will then work on translating their matrix into a conceptual map using the freely available software CmapTools (following the direction of the US EPA training modules). This will involve identifying the direction of relationships, potential feedbacks (positive and negative) and the implications for different policy responses. See module 4 in EPA readings for further guidance. An example of an Integrated DPSIR CMap may be downloaded to explain the framework to the participants.

4. Class presentation (30 min.): Once completed, each group will present their conceptual map to the class for critical feedback and further discussion.

5. Debriefing (30 min.): The instructor will then facilitate a collective debriefing session on the main points arising from the discussion of the concept maps and consider the potential for REDD+ to achieve the desired impacts in Panama through a DPSIR lens. An example of a DPSIR on deforestation for the Upper Bayano Watershed may be requested from the corresponding author.

Suggested modifications:

For an undergraduate version of the course, instead of having student groups generate the conceptual map using the DPSIR framework, the instructor could generate the conceptual map with input from all students, as part of an in-class exercise. Additionally, more time could be allotted to explaining the various approaches (*e.g.* stakeholder analysis, DPSIR framework) and where they have been used previously in order to tease out important issues for policy to consider.

Another suggested modification would include asking students to submit a critical essay on the role of REDD+ in the Upper Bayano Watershed that requires them to do additional literature research beyond the material and references provided in this case study. Students could also be asked to critically examine the various possible "R: Responses" to tropical deforestation using the DPSIR framework and discuss the regulatory challenges associated with sustainable forest management in Panama.

Assessment

Participants will be evaluated based on their degree of class participation and the quality of their contributions to the various tasks assigned in the sessions (see Appendix C3, proposed Grading Rubric). Neither the stakeholder position statement from Session 1, nor the DPSIR conceptual map from Session 2, have correct answers, as these represent a group thought process. However, in order to facilitate the development of the DPSIR matrix and conceptual map we have produced examples for the instructor to use as a guide, which may be requested from the corresponding author.

Learning objectives (LO – see Appendix C3, proposed Grading Rubric) will be assessed through the use of the following formative and summative assessments for each of the two proposed activities:

Session 1 (180 minutes):

Formative Assessments:

- Using literature and videos from the case, participant groups will generate a "position statement" on REDD+ from the perspective of their assigned stakeholder group, to be delivered orally in class.

Summative Assessment:

Following the general discussion (public meeting) in which stakeholder positions are presented through role-play, and debriefing about key lessons in natural resource management and policy, the instructor will evaluate the participant's preparation for and participation in group question periods and discussions. (LO-1 and 2)

Session 2 (180 minutes):

Formative Assessments:

- During the in-class group work to produce the DPSIR concept map, participants will be given a notecard and asked to reflect, over a short period of time (e.g. 5 minutes), on the usefulness of framework for: (a) synthesis of the problem; (b) operationalization of the case; or (c) explore their reactions to the complexity and challenges of development work. (LO-1 and 3) (This assessment is optional. It allows participants to express their feelings of frustration about the wicked and complex nature of coupled social-environmental problems).

- Following the group work and presentations on the DPSIR matrix, instructors will facilitate a 5-7 minute discussion around issues of: feedback, causality, scale, and the emergence of conflict as they relate to the various challenges associated with the implementation of forest and climate change mitigation-related policy in Panama.

Summative Assessment:

Final group discussions about the difficulties of breaking down SES, linking components, and bringing in responses. Individual contributions to discussion will be graded. (LO-1, 2, and 3)

References

1. Wali A. Kilowatts and crisis: hydroelectric power and social dislocation in eastern Panama. Boulder, CO, USA: Westview Press; 1989.
2. IACHR. Caso Pueblos Indígenas Kuna de Madungandí y Emberá de Bayano y sus Miembros Vs. Panamá. Sentencia de 14 de octubre de 2014. (Excepciones Preliminares, Fondo, Reparaciones y Costas). Resumen oficial emitido por la Corte Interamericana. . San José, Costa Rica: Inter-American Court of Human Rights.; 2014.
3. Vergara-Asenjo G, Mateo-Vega J, Alvarado A & Potvin C. A participatory approach to elucidate the consequences of land invasions on forests and REDD+ initiatives. submitted.
4. AES_Panama. Comunicación de Progreso para el Pacto Global de las Naciones Unidas 2012-2013. Panama City, Republic of Panama: AES Panama; 2013.
5. Sharma D, Holmes I, Vergara-Asenjo G, Miller WN, Cunampio M, B. Cunampio R, et al. A comparison of influences on the landscape of two social-ecological systems. Land Use Policy. 2016;57:499-513.
6. Feiring B & Abbott E. Preliminary note on findings, conclusions and recommendations. Panama: Independent team for the investigation and evaluation of the UN--REDD Panama Programme; 2013.

7. Golder B & Gawler M. Cross-Cutting Tool. Stakeholder Analysis. Washington, DC, USA: WWF; 2005.

Appendix C3: Proposed Grading Rubric

LEARNING OBJECTIVES			
1. Participants will develop an understanding of the complex interactions between socio-economic, cultural, and political components of coupled natural and human forest ecosystems in eastern Panama.			
2. Participants will learn to articulate different stakeholder perspectives on tropical forests and climate change policy issues using the case of REDD+ in Panama.			
3. Participants will gain insight into some of the challenges and opportunities facing coordinated policy responses to tropical deforestation.			
	LEVELS OF ACHIEVEMENT		
ASSESSMENT/CLASS ACTIVITIES	**HIGH**	**MEDIUM**	**LOW**
Stakeholder REDD+ “position statement” role-playing exercise, to be delivered orally and debated in class. (LO 2)			
Facilitated discussion session on the some of the key lessons for natural resource management and policy, in the context of a forest socio-ecological system. (LO 1 and 2)			
Group work to create and present on DPSIR matrix, with discussions on: feedback, causality, scale, and the emergence of conflict as they relate to the various challenges associated with the implementation of international natural resource policies. (LO 3)			
Final group discussion about difficulties of breaking down SES, linking components, and bringing in responses. Individual contributions to discussion will be graded. (LO 1, 2, and 3)			

* HIGH: Participant has clearly done the readings and understood the materials provided for the class. In addition to engagement with the literature, the participant contributed interesting and thoughtful insight to the benefit of the class.
* MEDIUM: Participant understands the material and is engaged with the class, but contributions falls short of providing the useful, insightful, and critical questions about the topics covered, that would contribute to the broader SES learning goals outlined in the teaching notes.
* LOW: Participant is able to present information from readings, but without an opinion or analysis of the content.

Appendix C4: Background to the case study

This case study builds on more than a decade of participatory research with indigenous peoples and farmers in the Upper Bayano watershed in eastern Panama by the *Neotropical Ecology Lab* of McGill University and the Smithsonian Tropical Research Institute (STRI), led by Prof. Catherine Potvin. In the mid-2000s, studies focused geographically on Ipeti, an Emberá indigenous community whose traditional authorities had expressed interest in carbon (C) sink projects (i.e. afforestation/ reforestation – AR) under the Clean Development Mechanism1 (CDM) of the Kyoto Protocol2. A study by Kirby and Potvin [1] explored the potential for above and below-ground carbon storage in managed forests, agroforests and pastures, and the implications of land use on these stocks. Although protecting managed forests from conversion to pastures was clearly the best option for sequestering carbon, given the scope of the CDM, which did not consider "avoided deforestation" (i.e. precursor concept to REDD+), agroforests appeared to be the next best option. This study found that agroforests in Ipeti were comparable in C stocks to teak plantations, but provided additional livelihood benefits that plantations could not. A parallel study by Tschakert et al. [2] explored the socio-economic potential for C-sink projects in Ipeti. Although improved management of fallows proved to have great C-sequestering capacity, heterogeneous assets and livelihood strategies among families in Ipeti suggested that only the better-endowed families would be able to participate in such schemes, thus further widening existing inequalities.

Alongside both of the aforementioned studies, Potvin et al. [3] showed the value of using local knowledge of land cover and land use in establishing a baseline for CDM projects and estimating changes in C stocks over time. This study suggested that Ipeti would undergo a process of significant C stock impoverishment in the absence of C-sink projects. The question remained, however, if CDM-AR projects were truly a viable option for Ipeti and other rural communities throughout the tropics. This motivated a study by Coomes et al. [4], which examined the opportunities, challenges and obstacles rural communities would face in adopting CDM-AR projects. The financial analyses suggested that under CDM conditions, AR projects would be prohibitive to low-income households such as those in Ipeti due to economic costs and risks, while "avoided deforestation" projects showed more promise in

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[1] http://unfccc.int/kyoto_protocol/mechanisms/clean_development_mechanism/items/2718.php
[2] http://unfccc.int/kyoto_protocol/items/2830.php

meeting multiple objectives such as carbon sequestration and storage, improving rural incomes, and generating additional ecosystem services. By then, “avoided deforestation” was morphing into what is now known as REDD+ (initially, RED, then REDD, an finally REDD+), and Potvin et al. [5] examined the financially feasibility of this proposed climate change mitigation mechanism, using Panama as a case study. Their findings suggested that the two proposed funding strategies for REDD projects, carbon markets and designated funds, where unlikely to stimulate action, and that the costs of implementing REDD would double the conservation expenses of the country, in addition to incurring other opportunity, transaction and administration costs.

In 2008, Panama initiated activities to prepare for the REDD+ mechanism, a process known as ‘REDD readiness’, funded by the Forest Carbon Partnership Facility (FCPF) of the World Bank and the United Nations Programme on REDD (UN-REDD). The *Neotropical Ecology Lab* played an active role in providing training, along with local and international partners, for indigenous leaders and technicians, government officials and farmers on the technical, social, economic and governance dimensions of REDD+, with a strong focus on conflict resolution [6]. From this, the *Consultative Council on Conflict Resolution and REDD+* was created with participation of all sectors of society. This group led an unprecedented effort to outline a series of recommendations to address territorial disputes, one of the primary obstacles to REDD+ implementation in Panama, using the Upper Bayano watershed as an example [7]. These recommendations were brought forward to the Government of Panama. To significantly improve the access for indigenous peoples and rural communities to information about climate change and REDD+, Ventocilla and Potvin [8] led a fully participatory process that resulted in an educational, illustrated book (i.e. by renown Panamanian indigenous artist, Ologwagdi) that has been distributed throughout Panama. Representatives from all of Panama’s indigenous groups reviewed this book more than 15 times prior to publication.

Researchers, students and collaborators from McGill and STRI have continued to carry out research on, or related to, REDD+. For example, Pelletier et al. [9] made important progress in elucidating the primary sources of uncertainty in quantifying emissions from deforestation (*e.g.* measures of carbon stocks in mature forests, and reliability and quality of land cover maps). They highlighted, among key challenges, the difficulties in assessing fallow land dynamics, which cover significant portions of the country. A series of recommendations for addressing these uncertainties were put forward. Peterson St-Laurent et al. [10] engaged small-scale colonist farmers in eastern Panama to understand if and how they may be included in a national REDD+ strategy. They found that farmers are willing to consider protecting forests, but their participation would be contingent on adequate financial compensation, irrespective of whether it is under a REDD+ mechanism or not.

Drawing from people-centered conservation and rural development projects, Holmes and Potvin [11], produced a framework of best practices (BP) with indicators to improve the design, monitoring and evaluation of REDD+ projects, particularly in indigenous and rural communities. This study found that many BPs were either deficient or absent in community-level REDD+ projects in Latin America according to development practitioners and researchers. Holmes et al. [12] went on to examine the implementation of a REDD+ project in the community of Ipeti, and found that, even though economic benefits and the equitable distribution of these are important motivators for REDD+ adoption, that the presence of "bridging institutions" (i.e. those that liaise between REDD+ project funders and the community), as well as the use of REDD+ as a land tenure conflict resolution mechanism, was also very important.

Sharma et al. [13] advanced our understanding of the linked ecological and social interactions that influence land-use decisions that lead to the loss of forests, using the Emberá community of Piriati as an example. This study elucidated the importance of considering cultural norms, gendered perspectives, and social organization, among other factors, in defining future land uses such as reforestation schemes. Sharma et al. [14] then compared the divergent land-use trajectories of two Emberá communities that, at time of settlement, were very similar, i.e. one that lost almost all of its forests, and another that as able to maintain a sizeable portion of it. Results indicate that pre-settlement logging was a key factor in leaving remaining forests susceptible to clearing in the former, while the presence of local-based organizations interacting with active research projects likely resulted in the protection of forests in the latter.

More recently, Vergara-Asenjo et al. [15] examined how participatory mapping with indigenous peoples in the Upper Bayano watershed can significantly improve land cover classification, which is necessary for monitoring changes in forest carbon stocks in the context of REDD+. This study found that maps produced with local knowledge were more accurate than those that relied only on remotely sensed data. Along the same lines, Mateo-

Vega et al. [16] designed and tested a participatory method for inventorying above-ground biomass in heterogeneous forest landscapes in eastern Panama. Both studies align with the UNFCCC's call for the full and effective participation of indigenous peoples in REDD+ [17].

The *Neotropical Ecology Lab* is now engaged in an effort to facilitate a participatory, multi-cultural land-use planning effort for the Upper Bayano watershed, working with the Emberá, Kuna and colonist farmers. This initiative is focused on identifying opportunities for forest conservation, sustainable agricultural production and addressing the long-standing social tensions surrounding land invasions and tenure. REDD+ may be a future land-use option for some of these groups. This case study was possible due to the long and rich body of work that has been carried out in this region.

References

1. Kirby KR & Potvin C. Variation in carbon storage among tree species: Implications for the management of a small-scale carbon sink project. Forest Ecol Manag. 2007;246(2–3):208-21.
2. Tschakert P, Coomes OT & Potvin C. Indigenous livelihoods, slash-and-burn agriculture, and carbon stocks in Eastern Panama. Ecol Econ. 2007;60:807- 20.
3. Potvin C, Tschakert P, Lebel F. et al. A participatory approach to the establishment of a baseline scenario for a reforestation Clean Development Mechanism project. Mitig Adapt Strat GL. 2007;12(8):1341-62.
4. Coomes OT, Grimard F, Potvin C. et al. The fate of the tropical forest: Carbon or cattle? Ecol Econ. 2008;65(2):207-12.
5. Potvin C, Guay B & Pedroni L. Is reducing emissions from deforestation financially feasible? A Panamanian case study. Clim Policy. 2008;8(1):23-40.
6. Amado A, Peterson St-Laurent G, Potvin. et al. Conflictos Territoriales: Modelo para su resolución en preparación para la protección de bosques. In: Pfund A, editor. Experiencias Latinoamericanas en el Abordaje de Conflictos. Universidad para la Paz; 2014. pp. 81-97.
7. Foro y Observatorio de Sostenibilidad. Recomendaciones del Consejo Consultivo en Resolución de Conflictos en REDD+, para solucionar conflictos territoriales en Panamá. Dirigidas al Consejo Nacional de Tierras, a través del Ministerio de Gobierno, y a la Autoridad Nacional del Ambiente. INDICASAT, USMA, STRI, McGill University, UNITWIN/UNESCO; 2015. Available: .

8. Ventocilla J & Potvin C. Nuestra casa en el universo, pueblos indígenas, cambio climático y la propuesta REDD+. Smithsonian Tropical Research Institute; 2011. Available: http://biology.mcgill.ca/faculty/potvin/Nuestra_Casa_en el Universo.pdf.
9. Pelletier J, Ramankutty N & Potvin C. Diagnosing the uncertainty and detectability of emission reductions for REDD + under current capabilities: an example for Panama. Environ Res Lett. 2011;6(2):024005.
10. Peterson St-Laurent G, Gélinas N & Potvin C. REDD+ and the agriculture frontier: Understanding colonists' utilization of the land. Land Use Policy. 2013;31:516-525.
11. Holmes I & Potvin C. Avoiding Re-Inventing the Wheel in a People-Centered Approach to REDD+. Conserv Biol. 2014;28(5):1380-93.
12. Holmes I, Potvin C & Coomes O. Early REDD+ Implementation: The Journey of an Indigenous Community in Eastern Panama. Forests. 2017;8(3):67.
13. Sharma D, Vergara-Asenjo G, Cunampio M. et al. Genesis of an indigenous social-ecological landscape in eastern Panama. Ecol Soc. 2015;20(4).
14. Sharma D, Holmes I, Vergara-Asenjo G. et al. A comparison of influences on the landscape of two social-ecological systems. Land Use Policy. 2016;57:499-513.
15. Vergara-Asenjo G, Sharma D & Potvin C. Engaging Stakeholders: Assessing Accuracy of Participatory Mapping of Land Cover in Panama. Conserv Lett. 2015;8(6):432-9.
16. Mateo-Vega J, Potvin C, Monteza J. et al. Full and effective participation of indigenous peoples in forest monitoring for reducing emissions from deforestation and forest degradation (REDD+): trial in Panama's Darién. Ecosphere. 2017;8(2):e01635-n/a.
17. UNFCCC. Report of the Conference of the Parties on its sixteenth session, held in Cancun from 29 November to 10 December 2010. Addendum part two: action taken by the Conference of the Parties at its sixteenth session. FCCC/CP/2010/7/Add.1: United Nations Framework Convention on Climate Change; 2011.

Appendix D: Chapter 4 Supplementary Materials

Appendix D1

Scope of the study and procedural issues convened upon and implemented with the Indigenous traditional authorities.

First, we established that the study would focus on Indigenous territories within the Upper Bayano Watershed, with the exception of the Emberá territory of Majé, and that the principal subject of the study was to be the forest estate within the Indigenous territories. However, as the visioning and planning exercises considered future land-use trajectories within the territories, other land-uses across the landscape were naturally included.

Second, the primary goal of the visioning and planning exercises was to provide decision support to the Emberá and Guna traditional authorities and community members with regards to future land management, including their forest resources. But, the group also agreed on the importance of these exercises serving as a mechanism to encourage reflexivity from participants about drivers of change (i.e. deforestation), and raise awareness about the potential future of their forests and lands.

Third, the group agreed that the *visioning* exercise should depict an ideal, yet achievable future, capturing what *should* happen to their forests and territories based on their aspirations and needs, i.e. a normative scenario (Oteros-Rozas *et al.*, 2015). But the group also determined that they would like to develop, for comparative purposes, a vision of what their territories would be like under a business-as-usual scenario, consisting of a description of what *could* happen in the absence of any decisions to change the course of current land use, i.e. explorative scenario (Oteros-Rozas *et al.*, 2015). So, in effect, the study produced two scenarios of future land use for the three territories, but was driven by a single ideal *vision* of the future. As such, *pathways* for achieving this aspirational future were only defined for the normative scenario. Neither the ideal nor the business-as-usual scenarios were given a particular name as is common in scenario-based planning, but were rather called by the unequivocal terms of “ideal” (the term is the same in Spanish and English) and “tendencial” (trend in Spanish), respectively.

Finally, in compliance with ethics protocols (Appendix D3), all outputs and results from the workshops were given back, presented and discussed with the traditional authorities, their advisors and technicians, and more broadly with the communities. All documents were given to them in printed copy and in digital format on a USB drive. In the case of the Emberás, community-wide meetings were convened by the traditional authorities in both Ipetí and Piriatí, and more than 100 people participated in both events. In particular, the copies of the maps of the Emberá territories and the composite map with the results from the three territories (i.e. including the Comarca), depicting the ideal *vision* of future land use, and the business-as-usual scenario were well received based on comments from the participants and traditional authorities, and our personal observations. In the *Comarca*, we returned results to the traditional authorities, their advisors and members of ORKUM (~10 people) in a workshop in Akua Yala (the political center of the *Comarca*), as well as to four of the 14 communities (Akua Yala, Tabardi, Naka and Nargandi). Nine of the other communities received copies directly through a Guna technician who visited them, or during a General Congress held shortly thereafter. All communities received copies of the maps of their communities, the entire *Comarca*, and the composite map with all three Indigenous territories. In the case of Puerto Limón, they only received copies of the latter two types of maps, as a community-level map was never produced given that the *Saila* did not authorize us to work in the community due to confusions about the authorization provided by the *Caciques*.

Appendix D2

Visioning through land-use planning: steps and methods

The workshops initiated with 1-1.5 hours dedicated to discussing objectives, gauging expectations, introducing all participants, establishing rules of engagement, reviewing and confirming the agenda, defining the mechanisms to monitor progress, and discussing logistical issues. In addition, we provided a short training on climate change, its links to deforestation and forest degradation, and the current status of REDD+ discussions in Panama. A brief introduction to the project, *Juntos para Proteger Nuestra Cuenca* was also given by the focal points, and a space was provided to address any questions from the participants. This component of the workshop was co-led by the research team with the *Caciques* for both the Emberás and Gunas and the project focal points. In the case of the Emberás, the President of the Congress and senior advisors also co-facilitated, while in the case of the Gunas, the Director of ORKUM.

Identification of highly valued landscape features and locations

Guillemette *et al.* (2017) produced, with the participation of Emberás, Gunas and *colonos*, a three-dimensional model of the Upper Bayano Watershed as part of a project to define a consensus-based understanding of land use and land-use conflicts in the region. This large-scale model (5 x 9.9 feet; 1.52 x 3.02m) was used in our study to initiate a conversation with the workshop participants about what elements of their territories they value and why. The purpose of this discussion was to prepare them for the process of developing a *vision*, in a later stage of the workshop, of an ideal future for their territories. Participants were asked to congregate around the model and, after guiding them in getting their bearings, including identifying the location of their community and other key landscape features (*e.g.* Pan-American Highway, Lake Bayano and Tortí, the largest town in the region), identify their favorite place in the Upper Bayano Watershed and elaborate as to why it holds special meaning to them. They were encouraged to identify a place that they hope future generations will have the chance to visit, experience, and appreciate as much as they do. A few minutes for individual reflection were afforded to each group prior to opening up the discussion. As reported in the paper, between all 90 participants, 109 valued landscape features and locations were identified.

Historical reconstruction, current, and visioning of future land use

To support the participants in contextualizing and calibrating their ideas for developing their *vision* of the future, it was determined, as suggested by the literature (Evans *et al.*, 2006), that the groups should consider how land use in the territories has evolved over time and currently stands. As such, during this second stage of the workshop we facilitated the reconstruction of land use 40 years into the past, as well as defined current land use in the three territories (i.e. 1975 to 2015). Both the Emberá and Guna traditional authorities, and their advisors, settled on this 40-year timeframe during the preparatory meetings, because their communities were forcefully displaced from their ancestral lands 40 years prior, in 1975, due to the construction of the Ascanio Villalaz Hydroelectric complex. It is a timeframe that is meaningful and well understood in their collective memory due to the traumatic nature of the experience.

For the reconstruction of land-use exercise, participants were asked to prepare a list of historical and current land-use categories. The starting point were land-use categories previously defined in a complementary participatory baseline mapping exercises carried out with the Emberá and Gunas between 2013 and 2016 as part of this and other studies (Vergara-Asenjo *et al.*, 2015; Guillemette *et al.*, 2017). A preliminary list of land-use categories was produced, exhibited on poster paper to be shared with all present, and after a round of deliberations, the final list of land use categories for each territory was produced. Collectively, these included primary forest, intervened (i.e. secondary) forest, sacred forest, agriculture comprised of mix cropping systems, cemeteries, pastures, recently cut forests, fallows, rice, agroforestry with cacao and coffee, plantains, reforestation with native tree species, and a combination of mechanized rice with pastures grown at different times of the year, but on the same parcel of land. Each territory produced their own list of land-use categories, and these were incorporated into a chart – depicted on poster paper – of a matrix of (1) land-uses (y axis), and (2) ten-year time series (x axis), starting in 1975 and running up to 2015. Hereafter, these charts are referred to as "matrix" or "matrices".

Following, using round, colored stickers (~1cm diameter), each equivalent to 5% of the territory, participants were asked to allocate the percentage of land that was and is under each land use category, up to a maximum sum of 100% for every decade on the matrix. During the exercise, participants gathered around the matrix, and deliberated about the percentage allocation to different land use categories. Although the analyses were done collectively with all participants, elders played a preponderant role in this historical reconstruction of land use as would be expected. During this stage, our role as facilitators was primarily to ensure that the sum of stickers did not exceed the 100% maximum. In all three territories, consensus was reached among participants.

Once this step was completed, we expanded the timeline of the matrix by 40 years into the future, up to 2055, also broken down by decades, and asked the participants to add any other desirable land uses to the list of categories on the matrix. The traditional authorities predetermined the 40-year horizon into the future during the preparatory meetings based on the time horizon used for the historical reconstruction, but also considering, as noted by an Emberá leader, their interest to cover a time frame of at least two more generations of descendants, which falls in line with the premises of *Buen* Vivir and the multi-generational dimensions of Indigenous land-use planning (Patrick *et al.*, 2017). The only new land use category added was silvopastoral systems, and in the case of Piriatí, they lumped agroforestry, reforestation and forest into a single category. As in the previous exercise, using stickers (equivalent to 5% of their territory), and through a collective deliberative and consensus-based process, participants proposed what percentage of each land use category would cover their territories for each decade up to 2055 based on (1) their ideal vision of the future; and (2) a business-as-usual scenario, developed for comparative purposes. In the case of the Gunas, they opted to allocate half stickers, each equivalent to 2.5% of their territory, for the decades of 2035 – 2055, as they felt a more granular analysis would better reflect their desires for future land use. As the exercise was carried out, once again, we verified that the sum of stickers did not exceed 100%.

Visualization of visions of future land use through participatory mapping

To complement the aforementioned matrices, participants in the three workshops were asked to produce in a participatory manner, a map of their ideal *vision* of their territories for the year 2055 to spatially depict how they would apportion different land uses across these. They complemented this exercise by also producing a map, for comparative purposes, of the business-as-usual scenario of land use for 2055. For the preparation of these maps, they were provided with poster-sized blank maps of their territories to draw on with colored pencils and crayons, which only depicted the borders of the territories, main rivers, roads and the location of communities. In the case of Ipetí and Piriatí, preparation of the maps was carried out by the core teams of participants (21 and 11, respectively), who congregated around a large table and provided guidance to 2-3 youth who were charged with the actual drawing and coloring. In the case of the Comarca, at least 15 participants were present during the preparation of the maps to guide two young women and two men (technicians of ORKUM) in drawing the maps. At no point, based on our observations, did any particular individual or group of individuals dominate the discussion or mapping of land-use categories.

Narrative description or listing of key elements of future land use

To complete and complement the *visioning* exercise, each group was asked to draft a narrative description of their territory, in the form of a story, or produce a list of elements that are of key importance to them for the year 2055, based on their ideal *vision* for land use. For the Emberás and Gunas, this was done by the core groups, sometimes with some additional participants, drawing from ideas that had been discussed in the two previous moments: (1) the identification of valued locations and landscape features in the Upper Bayano Watershed, and (2) the discussion regarding their hopes for future land use developed during the *visioning* exercise. To elicit this *vision*, participants were also asked to imagine themselves in the year 2055 in company of their grandchildren, or great grandchildren, and to describe what they would find in the territory. In both cases, a person was asked to volunteer to capture the ideas of the participants and, through an iterative process of writing and reading back to the group, prepare the statement or list of elements. The Emberás produced a statement during the workshop in Ipetí, which was later shared with the participants of Piriatí per suggestion of the *Cacique*. This latter community adopted the version produced in Ipetí with no changes, thus resulting in a single *vision* statement of land use from the Emberás. The Gunas produced a list of key elements as part of their *vision* for their territory in 2055.

Appendix D3

Ethics protocols

We followed McGill University's Policy on the Ethical Conduct of Research Involving Human Subjects (Certificate: REB #24-0615), and McGill University's Protocol for Research in Panama's Indigenous Communities (McGill_University, 2006). Also, in line with Panamanian rules for conducting research in Indigenous territories, we sought and secured approval from the *Instituto Nacional de Cultura* (National Institute of Culture) to carry out the study (Resolución No. 03-13/DNPH del 4 de enero de 2013).

Appendix D4

Full results of the exercises to identify highly valued locations and landscape elements in the Upper Bayano Watershed. The notes include complementary quotes that were in some instances made by the participants and are registered as such.

LOCATIONS	EMBERÁ		GUNA	TOTAL	NOTES
	Ipetí	Piriatí	Madungandi		
COMARCA KUNA DE MADUNGANDI	2	0	7	9	
Comarca	1			1	Territory
Tabardi			1	1	Community (lake)
Pintupo			1	1	Community (lake)
Ikandi (Aguas Claras)	1			1	Community (lake)
Diwarsicua			1	1	Community (river)
Capandi (Río Diablo)			1	1	Community (river)
Piriá			1	1	Community (river)
Río Irmani/Irmadi			2	2	River (river mouth, no communities nearby)
IPETI AND PIRIATI	10	2	1	13	
Ipetí Emberá			1	1	Territory
Río Ambroya (Ipetí)	4			4	River
Río Ipetí	1			1	River

Río Piriatí		1		1	River
Quebrada Grande (Piriatí)	1	1		2	River
Curticito (Ipetí)	4			4	Forest
NON-INDIGENOUS AREAS	0	0	1	1	
Cañazas (uplands)			1	1	Forest
TOTAL	**12**	**2**	**9**	**23**	
LANDSCAPE ELEMENT	**EMBERÁ**		**GUNA**	**TOTAL**	**NOTES**
	Ipetí	Piriatí	Madungandi		
FOREST	**11**	**5**	**11**	**27**	
Forest	8	2	7	17	“they are full of flora”; *Kalu* (Guna sacred forest); “because they provide tranquility”; “enjoy the silence”; “for our grandchildren to enjoy”; mountains
Trees	2	1	1	4	“ located by streams” ; “good for timber”; “we like big trees”

Espavé (wild cashew)		1		1	*Anacardium excelsum*
Higuerón (fig)		1		1	*Ficus sp.*
Plants			1	1	
Medicinal plants			2	2	
Fruits	1			1	
WATER	**5**	**3**	**12**	**20**	
Water			1	1	" the water is green, not brown"; "the water is now too hot [near the community]"
Rivers, streams and pools	5	3	10	18	"the riversis fresh"; "the river is cold"; "the rivers have 'live' rocks and boulders"
Rain			1	1	"is nice in the summer"
ANIMALS	**17**	**1**	**12**	**30**	
Animals	1	1	6	8	
Monkey	1		1	2	
Fish	2		3	5	
Guacuco	1			1	*Chaetostoma sp.*
Peccary (white-lipped)			1	1	*Tayassu pecari*
Deer	3		1	4	*Odocoileus virginianus*

Birds	2			2	
Great tinamou	1			1	*Tinamus major*
Crested guan and/or currasow	2			2	*Penelope purpurascens* and/or *Crax rubra*
Lowland paca	3			3	*Cuniculus paca*
Agouti	1			1	*Dasyprocta punctata*
RESTORATION /PRODUCTION	**2**	**0**	**0**	**2**	
Reforestation (rosewood)	1			1	*Dalbergia retusa*
Silvopastoral	1			1	
OTHER	**0**	**0**	**7**	**7**	
Boulders and caves			5	5	
Air			2	2	“ the air is fresh”
TOTAL	**35**	**9**	**42**	**86**	
TOTAL RESPONSES - FAVORED LOCATIONS AND LANDSCAPE FEATURES				**109**	

Appendix D5

Results from the historical reconstruction (green), current (purple) and future (blue) visioning of land use (1975-2055) in the Emberá territories of Piriatí and Ipetí, and the Comarca Kuna of Madungandi in the Upper Bayano Watershed (Figure 4.4). The visioning exercises, covering 2016-2055, were carried out considering two scenarios:

1. Business-as-usual (BAU): current trends of land use remain in effect with no corrective actions taken by those residing in the territories.

2. Ideal: desired future that is achievable, but requires concerted actions by residents of the territories.

PIRIATI-EMBERÁ – BAU Scenario										
Land Use Category	**Land use (%)**									**Net loss/gain in land use**
	1975	**1985**	**1995**	**2005**	**2015**	**2025**	**2035**	**2045**	**2055**	**1975-2055**
Forest	80%	70%	35%	5%	5%	0%	0%	0%	0%	-80%
Reforestation (native species)	0%	0%	0%	0%	5%	5%	5%	5%	5%	5%
Tall fallow	0%	5%	25%	20%	10%	0%	0%	0%	0%	0%
Short fallow	5%	10%	15%	15%	5%	0%	0%	0%	0%	-5%
Mixed crops	10%	10%	15%	10%	5%	5%	5%	5%	5%	-5%
Plantain	0%	0%	0%	5%	5%	5%	5%	5%	5%	5%

Pasture	5%	5%	10%	45%	30%	35%	20%	20%	30%	25%
Pasture/rice	0%	0%	0%	0%	35%	50%	65%	65%	55%	55%
TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	
SUMMARY										
% Tree cover (Forest → Silvopastoral)	80%	75%	60%	25%	20%	5%	5%	5%	5%	
Net Loss of Tree Cover: 1975 – 2055	75%									
% Loss of Tree Cover: 1975 – 2055	94%									
% Forest Cover	80%	70%	35%	5%	5%	0%	0%	0%	0%	
Net Loss of Forest Cover: 1975 – 2055	80%									
% Loss of Forest: 1975 – 2055	100%									

PIRIATI-EMBERÁ - Ideal Scenario										
	Land use (%)									**Net loss/gain in land use**
Uso del suelo (Español)	**1975**	**1985**	**1995**	**2005**	**2015**	**2025**	**2035**	**2045**	**2055**	**1975-2055**
Forest	80%	70%	35%	5%	5%	10%	15%	15%	20%	-60%

Mix: Reforestation (native species), agroforestry, forest	0%	0%	0%	0%	5%	10%	20%	30%	40%	40%
Tall fallow	0%	5%	25%	20%	10%	10%	5%	5%	0%	0%
Silvopastoral	0%	0%	0%	0%	0%	5%	5%	10%	10%	10%
Short fallow	5%	10%	15%	15%	5%	5%	5%	0%	0%	-5%
Mixed Crops	10%	10%	15%	10%	5%	40%	35%	30%	30%	20%
Plantain	0%	0%	0%	5%	5%	0%	0%	0%	0%	0%
Pasture	5%	5%	10%	45%	30%	20%	15%	10%	0%	-5%
Pasture/Rice (mechanized)	0%	0%	0%	0%	35%	0%	0%	0%	0%	0%
TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	
SUMMARY										
% Tree cover (Forest → Silvopastoral)	80%	75%	60%	25%	20%	35%	45%	60%	70%	
Net Loss of Tree Cover: 1975 - 2055	10%									
% Loss of Tree Cover: 1975 - 2055	13%									
% Forest Cover	80%	70%	35%	5%	5%	10%	15%	15%	20%	
Net Loss of Forest Cover: 1975 - 2055	60%									
% Loss of Forest: 1975 - 2055	75%									

IPETI-EMBERÁ - BAU Scenario										
Land Use Category	**Land use (%)**									**Net loss/gain in land use**
	1975	**1985**	**1995**	**2005**	**2015**	**2025**	**2035**	**2045**	**2055**	**1975-2055**
Forest	80%	65%	45%	35%	35%	30%	25%	20%	15%	-65%
Reforestation (native tree species)	0%	0%	0%	5%	10%	10%	10%	10%	10%	10%
Tall Fallow	0%	5%	10%	10%	10%	10%	5%	5%	5%	5%
Agroforestry (coffee, cacao, fruits)	5%	5%	5%	5%	5%	5%	5%	5%	5%	0%
Silvopastoral	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Short Fallow	5%	10%	10%	10%	5%	10%	15%	10%	10%	5%
Mixed Crops	5%	5%	10%	10%	10%	10%	10%	15%	20%	15%
Pasture	0%	5%	10%	15%	15%	10%	10%	10%	10%	10%
Rice (mechanized)	0%	0%	5%	5%	5%	5%	5%	5%	5%	5%
Recently Cleared Forest	5%	5%	5%	5%	5%	10%	15%	20%	20%	15%
TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	
SUMMARY										
% Tree cover (Forest → Silvopastoral)	85%	75%	60%	55%	60%	55%	45%	40%	35%	
Net Loss of Tree Cover: 1975 - 2055	50%									

% Loss of Tree Cover: 1975 - 2055	59%									
% Forest Cover	80%	65%	45%	35%	35%	30%	25%	20%	15%	
Net Loss of Forest Cover: 1975 - 2055	65%									
% Loss of Forest: 1975 - 2055	81%									

IPETI-EMBERÁ - Ideal Scenario										
Land Use Category	**Land use (%)**									**Net loss/gain in land use**
	1975	**1985**	**1995**	**2005**	**2015**	**2025**	**2035**	**2045**	**2055**	**1975-2055**
Forest	80%	65%	45%	35%	35%	35%	40%	45%	50%	-30%
Reforestation (native tree species)	0%	0%	0%	5%	10%	10%	10%	10%	10%	10%
Tall Fallow	0%	5%	10%	10%	10%	10%	5%	5%	5%	5%
Agroforestry (coffee, cacao, fruits)	5%	5%	5%	5%	5%	10%	10%	10%	10%	5%
Silvopastoral	0%	0%	0%	0%	0%	5%	10%	10%	10%	10%
Short Fallow	5%	10%	10%	10%	5%	5%	5%	5%	0%	-5%
Mixed Crops	5%	5%	10%	10%	10%	10%	10%	10%	10%	5%
Pasture	0%	5%	10%	15%	15%	5%	5%	0%	0%	0%
Rice (mechanized)	0%	0%	5%	5%	5%	5%	5%	5%	5%	5%
Recently Cleared Forest	5%	5%	5%	5%	5%	5%	0%	0%	0%	-5%

TOTAL	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	
SUMMARY										
% Tree cover (Forest → Silvopastoral)	85%	75%	60%	55%	60%	70%	75%	80%	85%	
Net Loss of Tree Cover: 1975 - 2055	0%									
% Loss of Tree Cover: 1975 - 2055	0%									
% Forest Cover	80%	65%	45%	35%	35%	35%	40%	45%	50%	
Net Loss of Forest Cover: 1975 - 2055	30%									
% Loss of Forest: 1975 - 2055	38%									

MADUNGANDI- BAU Scenario										
Land Use Category	**Land use (%)**									**Net loss/gain in land use**
	1975	**1985**	**1995**	**2005**	**2015**	**2025**	**2035**	**2045**	**2055**	**1975-2055**
Primary Forest	90%	85%	70%	60%	60%	55%	53%	40%	40%	-50%
Sacred Forest	5%	5%	5%	5%	5%	5%	5%	5%	5%	0%
Secondary Forest	0%	3%	5%	10%	10%	10%	10%	10%	10%	10%
Reforestation (native tree species)	0%	0%	0%	0%	0%	0%	3%	3%	3%	3%
Tall Fallow	0%	0%	5%	10%	10%	10%	10%	10%	8%	8%
Agroforestry	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Silvopastoral	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mixed Crops/Short Fallow	5%	5%	10%	10%	10%	10%	10%	13%	13%	8%
Pasture	0%	3%	5%	5%	5%	5%	5%	10%	10%	10%
Mechanized Rice	0%	0%	0%	0%	0%	5%	5%	10%	13%	13%
TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	
SUMMARY										
% Tree cover (Primary Forest → Silvopastoral)	95%	93%	85%	85%	85%	80%	80%	68%	65%	
Net Loss of Tree Cover: 1975 - 2055	30%									
% Loss of Tree Cover: 1975 - 2055	32%									

% Forest Cover	95%	93%	80%	75%	75%	70%	68%	55%	55%	
Net Loss of Forest Cover: 1975 - 2055	40%									
% Loss of Forest: 1975 - 2055	42%									
Note: mechanized rice managed by Guna famers										

MADUNGANDI-Ideal Scenario										
Land Use Category	**Land use (%)**									**Net loss/gain in land use**
	1975	**1985**	**1995**	**2005**	**2015**	**2025**	**2035**	**2045**	**2055**	**1975-2055**
Primary Forest	90%	85%	70%	60%	60%	55%	58%	60%	63%	-28%
Sacred Forest	5%	5%	5%	5%	5%	5%	5%	5%	5%	0%
Secondary Forest	0%	3%	5%	10%	10%	10%	8%	5%	3%	3%
Reforestation (native tree species)	0%	0%	0%	0%	0%	0%	3%	3%	3%	3%
Tall Fallow	0%	0%	5%	10%	10%	5%	5%	5%	5%	5%
Agroforestry	0%	0%	0%	0%	0%	3%	3%	3%	3%	3%
Silvopastoral	0%	0%	0%	0%	0%	3%	3%	5%	5%	5%
Mixed Crops/Short Fallow	5%	5%	10%	10%	10%	13%	13%	13%	13%	8%
Pasture	0%	3%	5%	5%	5%	3%	3%	0%	0%	0%

Mechanized Rice	0%	0%	0%	0%	0%	5%	3%	3%	3%	3%
TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	
SUMMARY										
% Tree cover (Primary Forest → Silvopastoral)	95%	93%	85%	85%	85%	80%	83%	85%	85%	
Net Loss of Tree Cover: 1975 - 2055	10%									
% Loss of Tree Cover: 1975 - 2055	11%									
% Forest Cover	95%	93%	80%	75%	75%	70%	70%	70%	70%	
Net Loss of Forest Cover: 1975 - 2055	25%									
% Loss of Forest: 1975 - 2055	26%									
Note: mechanized rice managed by Guna famers										

Appendix D6

Table D6.1: Results from the GIS-based analysis of land-use allocation drawn from the digitalized participatory maps produced for the Comarca de Madungandi, Piriatí and Ipetí, under the business-as-usual and desired scenarios for the year 2055.

MADUGANDI								
BAU			**DESIRED**			**DIFF. BAU vs DESIRED**		**Δ BAU vs DESIRED**
Land Use	**Area (ha)**	**Area (%)**	**Land Use**	**Area (ha)**	**Area (%)**	**Area (ha)**	**Area (%)**	**(%)**
Mechanized rice	23366.3	10.1	Mechanized rice	1126.5	0.5	-22239.8	-9.6	-95.2
Primary forest	87362.2	37.7	Primary forest	114044.1	49.2	26681.9	11.5	30.5
Sacred forest	822.3	0.4	Sacred forest	804.0	0.3	-18.4	0.0	-2.2
Secondary forest	24192.0	10.4	Secondary forest	13856.7	6.0	-10335.3	-4.5	-42.7
Communities	306.5	0.1	Communities	471.9	0.2	165.4	0.1	54.0
Mixed crops	72222.9	31.1	Mixed crops	84613.6	36.5	12390.7	5.3	17.2
Pasture	13076.2	5.6	Pastures	0.0	0.0	-13076.2	-5.6	-100.0

Tall fallow	10425.7	4.5	Tall fallow	8162.5	3.5	-2263.2	-1.0	-21.7
Reforestation	105.7	0.0	Reforestation	1078.6	0.5	972.8	0.4	920.1
			Agroforestry	1140.0	0.5	1140.0	0.5	NA
			Silvopastoral systems	6582.1	2.8	6582.1	2.8	NA
TOTAL	**231880**	**100**		**231880**	**100**			

PIRIATI								
BAU			**DESIRED**			**Δ BAU vs DESIRED**		**Δ BAU vs DESIRED**
Land Use	**Area (ha)**	**Area (%)**	**Land Use**	**Area (ha)**	**Area (%)**	**Area (ha)**	**Area (%)**	**(%)**
Community	22.3	0.6	Community	65.8	1.7	43.5	1.1	195.1
Mixed crops	123.9	3.1	Mixed crops	934.6	23.7	810.7	20.6	654.4
Reforestation	173.8	4.4	Reforestation	0.0	0.0	-173.8	-4.4	-100.0
Plantain	99.6	2.5	Plantain	0.0	0.0	-99.6	-2.5	-100.0
Pasture	1833.3	46.5	Pasture	0.0	0.0	-1833.3	-46.5	-100.0
Pasture/mechanized rice	1691.2	42.9	Pasture/mechanized rice	0.0	0.0	-1691.2	-42.9	-100.0
			Agroforestry, Reforestation, Forest	1838.3	46.6	1838.3	46.6	NA
			Silvopastoral systems	242.6	6.2	242.6	6.2	NA

			Secondary forest	862.7	21.9	862.7	21.9	NA
TOTAL	**3944**	**100**		**3944.0**	**100.0**	**0.0**		

IPETI								
BAU			**DESIRED**			**Δ BAU vs DESIRED**		**Δ BAU vs DESIRED**
Land Use	**Area (ha)**	**Area (%)**	**Land Use**	**Area (ha)**	**Area (%)**	**Area (ha)**	**Area (%)**	**(%)**
Agroforestry (coffee, cacao)	149.2	4.5	Agroforestry (coffee, cacao)	298.2	9.1	149.0	4.5	99.9
Mechanized rice	201.3	6.1	Mechanized rice	110.5	3.4	-90.8	-2.8	-45.1
Forest	315.1	9.6	Forest	1700.8	51.8	1385.7	42.2	439.7
Community	38.1	1.2	Community	59.0	1.8	20.9	0.6	54.9
Mixed crops	638.0	19.4	Mixed crops	385.8	11.7	-252.1	-7.7	-39.5
Pasture	353.1	10.7	Pasture	0.0	0.0	-353.1	-10.7	-100.0
Tall fallow	453.0	13.8	Tall fallow	96.6	2.9	-356.4	-10.8	-78.7
Short fallow	447.3	13.6	Short fallow	0.0	0.0	-447.3	-13.6	-100.0
Reforestation	273.8	8.3	Reforestation	288.9	8.8	15.1	0.5	5.5
Recent clearing	416.1	12.7	Recent clearing	0.0	0.0	-416.1	-12.7	-100.0
			Silvopastoral systems	345.3	10.5	345.3	10.5	NA
TOTAL	**3285**	**100**		**3285**	**100**			

Table D6.2: Summary of desired land use allocations to forest cover, tree cover and other land uses in 2055.

MADUGANDI

Scenario	Forest Cover		Additional Tree Cover		Other		Total	
	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
BAU	112376.6	48.5	10531.4	4.5	108972.0	47.0	231880.0	100
Desired	128704.8	55.5	16963.2	7.3	86212.0	37.2	231880.0	100
Difference	16328.2	7.0	6431.8	2.8	-22759.9	-15.5		

PIRIATI

	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
BAU	0	0	173.8	4.4	3770.2	95.6	3944.0	100
Desired	862.7	21.9	2080.9	52.8	1000.4	25.4	3944.0	100
Difference	862.7	21.9	1907.1	48.4	-2769.8	-70.2		

IPETI

	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
BAU	315.1	9.6	875.9	26.7	2094.0	63.7	3285.0	100
Desired	1700.8	51.8	1028.9	31.3	555.3	16.9	3285.0	100
Difference	1385.7	42.2	153.0	4.7	-1538.6	-46.8		

Appendix D7

Table D7.1: Results from the comparison of land-use allocations between the "land-use versus time matrix", and "participatory maps" for 2055 under business-as-usual (BAU) and desired scenarios. From both the matrices and mapping exercises, we were are able to draw ranges of allocations for individual land uses (Appendix D5 and D6) under both scenarios for the three territories.

MADUNGANDI	BAU				DESIRED			
Land Use Category	Matrix	Maps	RANGE	DIFFERENCE	Matrix	Maps	RANGE	DIFFERENCE
Primary Forest	40.0%	37.7%	37.7 - 40.0%	2.3%	62.5%	49.2%	49.2 - 62.5%	13.3%
Sacred Forest	5.0%	0.4%	0.4 - 5.0%	4.6%	5.0%	0.3%	0.3 - 5%	4.7%
Secondary Forest	10.0%	10.4%	10.0 - 10.4%	-0.4%	2.5%	6.0%	2.5 - 6%	-3.5%
Reforestation (native tree species)	2.5%	0.0%	0.0 - 2.5%	2.5%	2.5%	0.5%	0.5 - 2.5%	2.0%
Tall Fallow	7.5%	4.5%	4.5 - 7.5%	3.0%	5.0%	3.5%	3.5 - 5.0%	1.5%
Agroforestry	0.0%	0.0%	0%	0.0%	2.5%	0.5%	0.5 - 2.5%	2.0%

Silvopastoral	0.0%	0.0%	0%	0.0%	5.0%	2.8%	2.8 - 5.0%	2.2%
Mixed Crops/Short Fallow	12.5%	31.1%	12.5 - 31.1%	-18.6%	12.5%	36.5%	12.5 - 36.5%	-24.0%
Pasture	10.0%	5.6%	5.6 - 10.0%	4.4%	0.0%	0.0%	0%	0.0%
Mechanized Rice	12.5%	10.1%	10.1 - 12.5%	2.4%	2.5%	0.5%	0.5 - 2.5%	2.0%
Communities		0.1%	0.1%	-0.1%		0.2%	0.20%	-0.2%
TOTAL	100.0%	100.0%			100.0%	100.0%		

IPETI	**BAU**				**DESIRED**			
Land Use Category	Matrix	Maps	RANGE	DIFFERENCE	Matrix	Maps	RANGE	DIFFERENCE
Forest	15.0%	9.6%	9.6 - 15.0%	5.4%	50.0%	51.8%	50.0 - 51.8%	-1.8%
Reforestation (native tree species)	10.0%	8.3%	8.3 - 10.0%	1.7%	10.0%	8.8%	8.8 - 10.0%	1.2%
Tall Fallow	5.0%	13.8%	5.0 - 13.8%	-8.8%	5.0%	2.9%	2.9 - 5.0%	2.1%

Agroforestry (coffee, cacao, fruits)	5.0%	4.5%	4.5 - 5.0%	0.5%	10.0%	9.1%	9.1 - 10.0%	0.9%
Silvopastoral	0.0%	0.0%	0%	0.0%	10.0%	10.5%	10.0 - 10.5%	-0.5%
Short Fallow	10.0%	13.6%	10.0 - 13.6%	-3.6%	0.0%	0.0%	0%	0.0%
Mixed Crops	20.0%	19.4%	19.4 - 20.0%	0.6%	10.0%	11.7%	10.0 - 11.7%	-1.7%
Pasture	10.0%	10.7%	10.0 - 10.7%	-0.7%	0.0%	0.0%	0%	0.0%
Rice (mechanized)	5.0%	6.1%	5.0 - 6.1%	-1.1%	5.0%	3.4%	3.4 - 5.0%	1.6%
Recently Cleared Forest	20.0%	12.7%	12.7 - 20.0%	7.3%	0.0%	0.0%	0%	0.0%
Community		1.2%	1.2%	-1.2%		1.8%	1.8%	-1.8%
TOTAL	100%	100%			100%	100%		

PIRIATI	**BAU**				**DESIRED**			
Land Use Category	Matrix	Maps	RANGE	DIFFERENCE	Matrix	Maps	RANGE	DIFFERENCE
Forest	0.0%	0.0%	0%	0.0%	20.0%	46.6%		9%

Agroforesty	0.0%	0.0%	0%	0.0%				
Reforestation (native species)	5.0%	4.4%	4.4 - 5.0%	0.6%	40.0%		60.0 - 68.5%	
Secondary forest	0.0%	0.0%	0%	0.0%		21.9%		
Silvopastoral	0.0%	0.0%	0%	0.0%	10.0%	6.2%	6.2 - 10.0%	3.8%
Tall fallow	0.0%	0.0%	0%	0.0%	0.0%	0.0%	0%	0.0%
Short fallow	0.0%	0.0%	0%	0.0%	0.0%	0.0%	0%	0.0%
Mixed crops	5.0%	3.1%	3.1 - 5.0%	1.9%	30.0%	23.7%	23.7 - 30.0%	6.3%
Plantain	5.0%	2.5%	2.5 - 5.0%	2.5%	0.0%	0.0%	0%	0.0%
Pasture	30.0%	46.5%	30.0 - 46.5%	-16.5%	0.0%	0.0%	0%	0.0%
Pasture/rice (mechanized)	55.0%	42.9%	42.9 - 55.0%	12.1%	0.0%	0.0%	0%	0.0%
Community		0.6%	0.6%	-0.6%		1.7%	1.7%	-1.7%
TOTAL	100%	100%			100%	100%		

Table D7.2: Summary of the findings using the categories of forest cover, tree cover, and other land uses. In the case of the Emberás, with one exception, the lower and upper values for each range were ≤5%. In the case of the Gunas, the ranges had greater variation between minimum and maximum values, but with one exception (i.e. other land use under the Desired scenario), all were <15%.

<table>
<tr><th>MADUNGANDI</th><th colspan="3">BAU</th><th colspan="3">DESIRED</th></tr>
<tr><td>Land Use</td><td>Matrix</td><td>Maps</td><td>Range</td><td>Matrix</td><td>Maps</td><td>Range</td></tr>
<tr><td>Forest Cover</td><td>55%</td><td>48%</td><td>48 - 55%</td><td>70%</td><td>56%</td><td>56 - 70%</td></tr>
<tr><td>Additional Tree Cover</td><td>10%</td><td>5%</td><td>5 - 10%</td><td>15%</td><td>7%</td><td>7 - 15%</td></tr>
<tr><td>Other</td><td>35%</td><td>47%</td><td>35 - 47%</td><td>15%</td><td>37%</td><td>15 - 37%</td></tr>
<tr><td>TOTAL</td><td>100%</td><td>100%</td><td></td><td>100%</td><td>100%</td><td></td></tr>
<tr><td>PIRIATI</td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td>Land Use</td><td>Matrix</td><td>Maps</td><td>Range</td><td>Matrix</td><td>Maps</td><td>Range</td></tr>
<tr><td>Forest Cover</td><td>0%</td><td>0%</td><td>0%</td><td rowspan="2">70%</td><td rowspan="2">75%</td><td rowspan="2">70 - 75%</td></tr>
<tr><td>Additional Tree Cover</td><td>5%</td><td>4%</td><td>4 - 5%</td></tr>
<tr><td>Other</td><td>95%</td><td>96%</td><td>95 - 96%</td><td>30%</td><td>25%</td><td>25 - 30%</td></tr>
<tr><td>TOTAL</td><td>100%</td><td>100%</td><td></td><td></td><td></td><td></td></tr>
<tr><td>IPETI</td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td>Land Use</td><td>Matrix</td><td>Maps</td><td>Range</td><td>Matrix</td><td>Maps</td><td>Range</td></tr>
<tr><td>Forest Cover</td><td>15%</td><td>10%</td><td>10 - 15%</td><td>50%</td><td>52%</td><td>50 - 52%</td></tr>
<tr><td>Additional Tree Cover</td><td>20%</td><td>27%</td><td>20 - 27%</td><td>35%</td><td>31%</td><td>31 - 35%</td></tr>
<tr><td>Other</td><td>65%</td><td>64%</td><td>64 - 65%</td><td>15%</td><td>17%</td><td>15 - 17%</td></tr>
</table>

TOTAL	100%	100%		100%	100%	

Appendix D8

Narrative descriptions (quasi-verbatim) prepared by the the Gunas (Madungandi) and Emberás (Piriatí and Ipetí collectively) of their territories based on their ideal, yet realistic, visions for the year 2055.

1. Vision of the Emberás

We want that in the year 2055, we can observe in our communities, which are part of the Emberá Collective Lands, a transformation in which we have more forest; with a culture that is in line with our traditional roots; where we can see a complete change in the deforested areas turning into reforested areas; in which the waters of our rivers are conserved clean and flowing; where there is an abundance of wildlife that will serve as food for the inhabitants of these communities; in which agricultural production is developed more sustainably, and is never lacking; where forests still have medicinal plants that our "botanists" can continue to use; villages with leaders that think about the development of their communities, where children, youth and adults conserve their culture, language, dress, foods, rituals, dances, crafts, and in which we are all more unified.

We are certain that is in this manner, as dreamers, we can contribute and move forward work that will benefit our children, and the children of our children, to continue conserving what we portray today in our dream.

We have looked at the maps, have analyzed what we have today, and this is what we want to have in the future.

2. Vision of the leaders of Madungandi

Today is June 5, 2055

Our dream

The Comarca Kuna de Madungandi in 40 years

Social

1. Education is free, open and intercultural

2. Traditional education is strengthened based on ancestral ideology
3. There are more teachers with traditional knowledge in each community
4. More food with typical dishes of meat and fish
5. Men conserve the use of traditional dress
6. Cultural dance groups of children and adults
7. Traditional chants are taught to our children
8. Exchanges of traditional technologies

Health

1. More traditional doctors and midwives
2. First aid facilities
3. Traditional clinics
4. Midwives clinics
5. More "botanists"

Population

1. A larger population in 40 years
2. Modern, yet traditional physical structure aligned with national development
3. The Kuna language will prevail in the region of the Comarca

Strengthening of internal laws for the Comarca in 4 pillars

1. Education
2. Environment
3. Health

4. Organizational structure

Environment

1. Our natural resources are conserved
2. There is no pollution in the rivers
3. The Comarca applies land uses for production
4. The boundaries of the territory are marked with natural fences
5. Greater amount of wildlife

Gender

1. Women are empowered and strengthend organizationally, participating in social, cultural and political activities
2. More active participation of Kuna women, until they occupy administrative positions in our social, political and cultural structures
3. Women conserve their traditional dress

In conclusion:

- A Comarca that is clean socially in aspects related to its way of living inside and outside of its organizational ambit
- Strengthened political administration contributing to national development
- Natural resources are used according to traditional forms of land use

Appendix D9

Pathways – i.e. strategies and actions – devised by the Emberás and Gunas to achieve their desired future *vision* of land use by 2055.

Emberá

Strategic Objective 1: Conserve and restore forests

Actions:

1. REDD+, respecting Emberá traditions and human rights
2. Sanitation of territorial invasions by colonist farmers
3. Traditional park rangers
4. Land-use planning to identify priority areas (e.g. sacred sites, protection of riverbanks)
5. Strengthening of traditional knowledge about the value and importance of forests
6. Strengthening of traditional structures and leadership to guarantee that policies for the protection and restoration of forests are complied with
7. Ecological and cultural tourism related to the forest
8. Building of native tree species nurseries for internal use and sale
9. Reforest degraded lands with native tree species
10. Program to acquire or annex lands abutting the territories to conserve or restore forests
11. Signage on the boundaries of the territories to avoid invasions by colonist farmers
12. Capacity development program about traditional medicines from the forest

Strategic Objective 2: Boost traditional and sustainable agricultural production

Actions:

1. Capacity development program on sustainable production systems (e.g. agroforestry and silvopastoral)
2. Capacity development program on traditional production (imparted by community wise elders)
3. Establish a "model farm" of traditional and sustainable farming
4. Program to finance the establishment of sustainable production systems
5. Identification and creation of markets and mechanisms (e.g. transportation) to commercialize sustainable products

Guna

Strategic Objective 1: Conserve forests and natural resources, and reforest

Actions:

1. Reforest with native tree species
2. Train park rangers to patrol the territory and protect the forest
3. Evict al invading colonist farmers (reforest or produce sustainably on their lands)
4. REDD+ with regulations that respect Kuna world views and tradition (currently questioned)
5. Uptake again traditional knowledge (world views)
6. Eco-ethno tourism (cultural and natural tourism)
7. Traditional agro-tourism
8. Strengthening of internal laws to protect the forest and reforest

Strategic Objective 2: Uptake again traditional production

Actions:

1. Establish a cooperative to commercialize our products (eliminate middlemen)

2. Education about mixed traditional agricultural production

3. Raise awareness in the communities to produce and sell (personal commitment)

4. Create institutional structures (regional) to regulate and guide production

5. Rescue and strengthen our production