Carbon Management

ISSN: 1758-3004 (Print) 1758-3012 (Online) Journal homepage: https://www.tandfonline.com/loi/tcmt20

Forest carbon in Amazonia: the unrecognized contribution of indigenous territories and protected natural areas

Wayne Walker, Alessandro Baccini, Stephan Schwartzman, Sandra Ríos, María A. Oliveira-Miranda, Cicero Augusto, Milton Romero Ruiz, Carla Soria Arrasco, Beto Ricardo, Richard Smith, Chris Meyer, Juan Carlos Jintiach & Edwin Vasquez Campos

To cite this article: Wayne Walker, Alessandro Baccini, Stephan Schwartzman, Sandra Ríos, María A. Oliveira-Miranda, Cicero Augusto, Milton Romero Ruiz, Carla Soria Arrasco, Beto Ricardo, Richard Smith, Chris Meyer, Juan Carlos Jintiach & Edwin Vasquez Campos (2014) Forest carbon in Amazonia: the unrecognized contribution of indigenous territories and protected natural areas, Carbon Management, 5:5-6, 479-485, DOI: 10.1080/17583004.2014.990680

To link to this article: https://doi.org/10.1080/17583004.2014.990680

© 2014 The Authors. Published by Taylor & Francis.

View supplementary material

Published online: 20 Dec 2014.

Submit your article to this journal

Article views: 6780

View related articles

View Crossmark data

Citing articles: 20 View citing articles

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=tcmt20

Forest carbon in Amazonia: the unrecognized contribution of indigenous territories and protected natural areas

A Policy Focus submission to *Carbon Management* (2015) 5(5–6), 479–485

Wayne Walker[1]*, Alessandro Baccini[1], Stephan Schwartzman[2], Sandra Ríos[3,7], María A. Oliveira-Miranda[4,7], Cicero Augusto[5,7], Milton Romero Ruiz[6,7], Carla Soria Arrasco[3,7], Beto Ricardo[5,8], Richard Smith[3,7], Chris Meyer[2], Juan Carlos Jintiach[9] & Edwin Vasquez Campos[10]

Carbon sequestration is a widely acknowledged and increasingly valued function of tropical forest ecosystems; however, until recently, the information needed to assess the carbon storage capacity of Amazonian indigenous territories (ITs) and protected natural areas (PNAs) in a global context remained either lacking or out of reach. Here, as part of a novel north–south collaboration among Amazonian indigenous and non-governmental organization (NGO) networks, scientists and policy experts, we show that the nine-nation network of nearly 3000 ITs and PNAs stores more carbon above ground than all of the Democratic Republic of the Congo and Indonesia combined, and, despite the ostensibly secure status of these cornerstones of Amazon conservation, a conservative risk assessment considering only ongoing and planned development projects puts nearly 20% of this carbon at risk, encompassing an area of tropical forest larger than that found in Colombia, Ecuador and Peru combined. International recognition of and renewed investment in these globally vital landscapes are therefore critical to ensuring their continued contribution to maintaining cultural identity, ecosystem integrity and climate stability.

More than half (52%; 4.1 million km^2) of Amazonia's tropical ecosystems are contained within an extensive network of 2344 indigenous territories (ITs) and 610 protected natural areas (PNAs) spanning nine South American nations (Figure 1). These cornerstones of Amazon conservation are widely recognized for their exceptional biological, cultural and linguistic diversity [1–3], and serve as both social and natural barriers to frontier expansion and fire [4–6]. In countries like Brazil, where deforestation has been high historically, they are also viewed as central to strategies designed to avoid atmospheric carbon emissions stemming from deforestation and forest degradation [7]. Carbon sequestration is an often-acknowledged service provided by tropical forest ecosystems worldwide, and while it is generally understood that the amount of carbon stored above ground in Amazonia is significant, until recently the information needed to quantify the contribution of Amazonian ITs and PNAs to carbon storage at the global scale remained either lacking or out of reach. A novel collaboration among scientists, Pan-Amazonian indigenous and non-governmental organization (NGO)

[1] Woods Hole Research Center/WHRC, 149 Woods Hole Road, Falmouth, MA02540USA
[2] Environmental Defense Fund/EDF, 1875 Connecticut Ave., NW, Washington, DC20009USA
[3] Instituto del Bien Común/IBC, Av. Salaverry 818, Lima11–Perú
[4] Provita, Av. Rómulo Gallegos, Edf. Pascal, Ofc 171A, Caracas, Venezuela 1071
[5] Instituto Socioambiental/ISA, Av. Higienópolis, 901 s.30, 01238-001São Paulo, SP, Brasil
[6] Fundación GAIA Amazonas, Carrera 4 # 26d – 31, Bogotá, Colombia
[7] Member – Red Amazónica de Información Socioambiental Georreferenciada/RAISG
[8] Coordinator – Red Amazónica de Información Socioambiental Georreferenciada/RAISG
[9] Regional Technical Coordinator - Coordinadora de las Organizaciones Indígenas de la Cuenca Amazónica/COICA
[10] General Coordinator – Coordinadora de las Organizaciones Indígenas de la Cuenca Amazónica/COICA
*Author for correspondence: Tel.: 508 444 1541; Fax: 508 540 9700; E-mail: wwalker@whrc.org

Taylor & Francis Group
an informa business

© 2014 The authors. Published by Taylor & Francis. This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License (http://creativecommons.org/Licenses/by-nc-nd/4.0/), which permits non-commercial re-use, distribution, and reproduction in any medium, provided the original work is properly cited, and is not altered, transformed, or built upon in any way.

Key terms

Amazonia: The most commonly referenced boundaries of the Amazon region are biophysical, related to hydrography, topography and/or vegetation, and administrative as recognized by the various nations for the application of protection and/or development policies. The limit of Amazonia used here (Figure 1) consists primarily of a biogeographical boundary of the Amazon ecosystem, with exceptions for Ecuador and Brazil where additional legal and administrative criteria are applied.

Indigenous territories: Lands of the 385 indigenous peoples living in Amazonia, which include officially recognized areas of traditional use and occupation, as well as traditionally used and occupied areas lacking official recognition and territorial reserves or intangible zones set aside for peoples living in isolation.

Protected natural areas: Lands having official conservation status including indirect use areas where natural resource extraction is prohibited, direct use areas where extraction is permitted under management plans and areas of transitory (or mixed) use.

Aboveground forest carbon density: The total amount of carbon contained above ground in the woody biomass of live vegetation. Forests contain more carbon above ground than nonforests but there can be considerable spatial variability in carbon density (e.g., megagrams of carbon per hectare) within a given forest type.

networks, and policy experts has linked newly compiled spatial data sets on pantropical aboveground forest carbon density [8], Amazonian ITs and PNAs, and risks to their integrity from current pressures and/or near-term threats [101]. Our analysis suggests that the carbon stored across these ostensibly secure landscapes is of a magnitude not previously appreciated in global terms, and is sufficient to either destabilize or contribute to the stabilization of the planet's atmosphere depending on the collective impact of ongoing and planned development projects. In this century alone, more than 253,000 km^2 of Amazonian rainforest – an area the size of the United Kingdom – have been lost [9] as a result of increasing pressures linked to climate change, agriculture expansion, road and hydroelectric plant construction and the extraction of timber, fossil fuels and precious metals [10,101]. During this same period, indigenous land rights and environmental regulation of forest land use, while largely unimplemented in some countries, have alternately advanced and come under political attack and could be compromised further under increasing demands for agricultural and energy commodities. The Government of Ecuador's signing of permits that allow for long-contested oil drilling to commence in Yasuni National Park – a UNESCO biosphere reserve containing pristine forests and uncontacted indigenous tribes – is a recent, albeit unexceptional, example of the very real and present risks to global culture, conservation and climate facing landscapes commonly perceived as being out of harm's way [102].

Carbon storage in ITs and PNAs

Amazonian indigenous leaders, cognizant of discussions centered on the role of tropical forests in international climate negotiations, called for an analysis to better understand the contribution of ITs and PNAs to global carbon storage, one increasingly acknowledged ecosystem function among the wide range of cultural and environmental services indigenous lands are recognized to provide. The investigation was an outgrowth of broader indigenous interests focused on building political, technical and institutional competencies around the complexity of issues at the intersection of international climate change policy, sustainable economic development and indigenous territorial rights. Indigenous organizations and communities actively participated in the process of data gathering and interpretation.

The results of the analysis reveal that the Amazonian region stores nearly 38% (86,121 MtC; Figure 1) of the 228,700 MtC found above ground in the woody vegetation of tropical America, Africa and Asia [8]. By themselves, Amazonian ITs are responsible for storing nearly one third (32.8%) of the region's aboveground carbon (28,247 MtC; Table S1) on roughly 30% (2.4 million km^2; Table S2) of the land area. This result is noteworthy when considering that more carbon is stored in Amazonian ITs than is found in all of the forests of the Democratic Republic of the Congo (DRC; 22,128 MtC) or the Republic of Indonesia (18,851 MtC; Table S1), two countries where considerable international attention and investment are now being directed toward the long-term protection of these large yet vulnerable expanses of remaining tropical forest. The analysis was conducted by combining a pantropical data set of aboveground carbon density derived from a novel combination of field and satellite measurements [8] with the most comprehensive database of IT and PNA limits available for the nine-nation region [see supporting online material (SOM), available from the article's Taylor & Francis Online page at http://dx.doi.org/10.1080/17583004.2014.990680.]. Expanding the scope of the analysis to include not only the aboveground carbon stocks of Amazonian ITs but also those of PNAs, we find that well over half (55%; 47,363 MtC; Figure 1) of the region's carbon is contained within this multi-nation network of forest-dominated landscapes. Remarkably, this is more carbon than is stored above ground in all of the DRC and Indonesia combined (40,979 MtC; Table S1) and, by recent accounts, sufficient to irreversibly alter continental-scale rainfall and climate regimes if released [11].

Assessing pressures and threats

While there is little debate about the impending risks to the Amazonian forest estate, its carbon stores or any of the broad range of ecosystem services the region's forests provide at local to global scales, forecasting the likely areal extent of these risks across such an economically and politically diverse landscape is not without its inherent uncertainty. Here, we performed a conservative yet spatially explicit risk assessment focused on the carbon currently stored above ground in Amazonian ITs and PNAs (Figure 1; SOM). Areas directly impacted by current (i.e., active and ongoing) development across primary production and infrastructure sectors, i.e., agriculture, grazing, mining, petroleum, timber

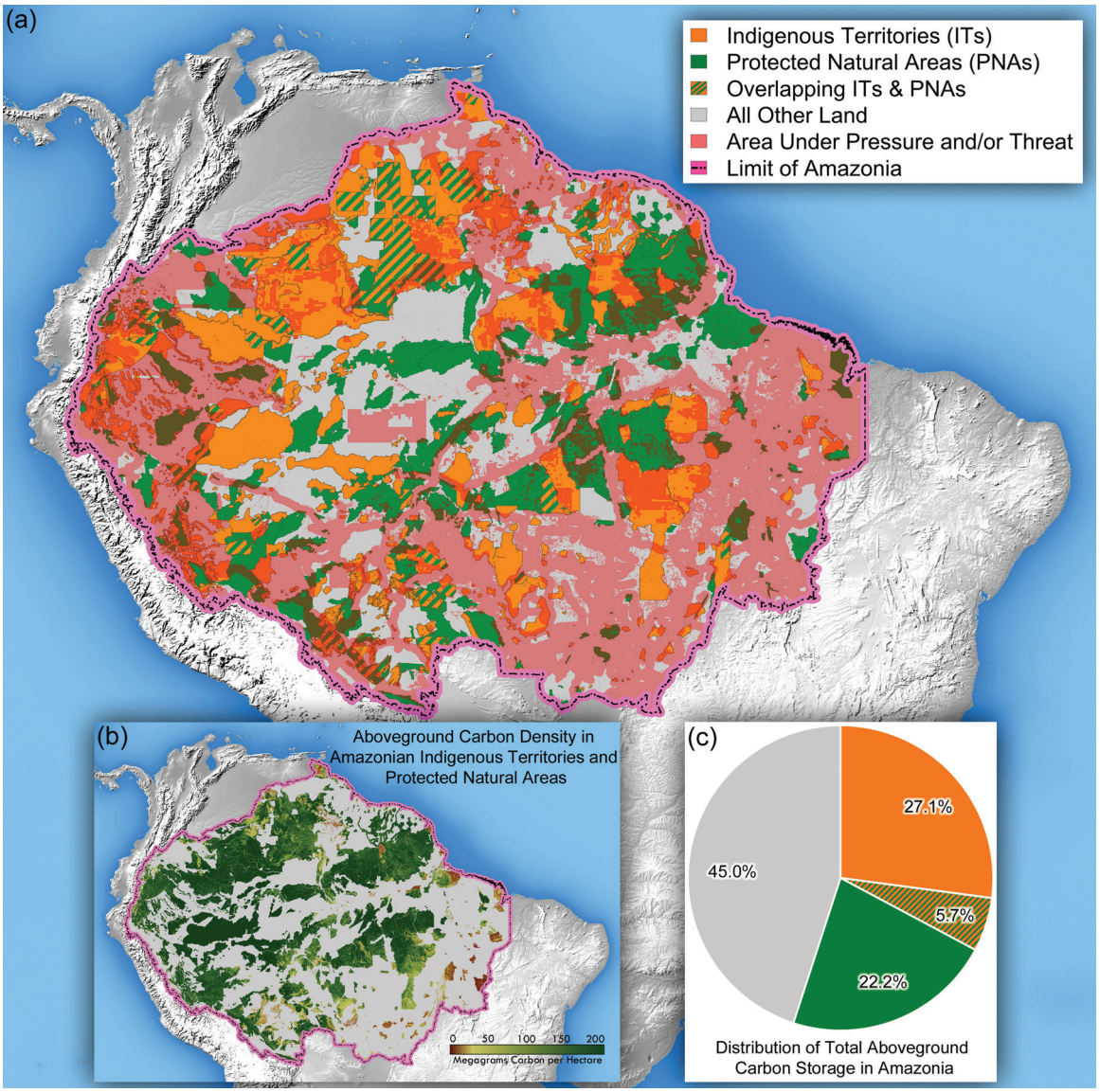

Figure 1. Amazon forest carbon at risk. (A) Risks (i.e., current pressures and near-term threats; see Table S3) to the distribution of **(B)** carbon stored above ground in the woody biomass of Amazonian tropical forests **(C)** as a percentage of the basin-wide total (i.e., 86,120 million metric tons carbon, MtC): ITs – 23,380 MtC (27.1%), PNAs – 19,116 MtC (22.2%), areas of overlapping ITs and PNAs – 4867 MtC (5.7%) and all other land – 39,376 MtC (45.0%) (see Table S1).

and transportation, were classified as *under pressure*, while areas likely to be impacted in the near term by projects or concessions described in current government and/or development agency planning documents were characterized as *under threat* [101]. Risk (i.e., pressure and/or threat) was then quantified based on the overlap with, and/or relative proximity to, current or planned development activities (SOM).

Our analysis indicates that more than half (53%) of the Amazonian region by area (i.e., approximately 4.2 million km^2) is at risk from either current pressures (65%) or near-term threats (35%; Figure 1; Table S3). In total, this vast expanse of at-risk land – equal to half the size of Brazil – is currently responsible for storing nearly 46% (39,743 MtC) of Amazonian aboveground carbon, which is more carbon than is stored above ground in all of Russia (32,500 MtC) and more than twice that stored in the United States (19,308 MtC; Table S1). Approximately 43% of this at-risk carbon, or 17,017 MtC, an amount equivalent to 90% of the aboveground carbon stock of Indonesia, is contained within the borders of Amazonian ITs and PNAs, lands

that are commonly assumed to be all but free from risk, if only by virtue of their protected status. In fact, a remarkably large proportion of the land contained within Amazonian ITs and PNAs is at risk, including 40% (794,030 km^2) of ITs, 30% (514,879 km^2) of PNAs and 24% (90,280 km^2) of regions where the two overlap (Table S3). In total, the combined area of ITs and PNAs under either pressure or threat constitutes 18% (1.4 million km^2) of Amazonia, an area larger than the Amazonian regions of Colombia, Ecuador and Peru combined (Table S2).

This assessment was designed to be intentionally conservative where risks to IT and PNA carbon stocks are concerned, insofar as it does not attempt to quantify illegal extractive activities or future deforestation threats (legal or illegal). For example, the analysis does not consider the loss of forest that predictably follows planned road construction or improvement, and the expanded access to the forest interior that naturally accompanies such infrastructure development. Historically, the majority of Amazon infrastructure development and associated official government investment has been geopolitically motivated rather than economically driven [12]. Because the analysis was limited to development activities that were either active or planned, the results are likely to more accurately reflect investments – and the accompanying risks – stemming from geopolitical decision-making, which might otherwise be unaccounted for by more theoretically based economic models.

Amazonian protected lands and forest/climate policy

Tropical deforestation continued unabated globally over the period 2000–2012, increasing by approximately 2100 $km^2\ yr^{-1}$, notwithstanding Brazil's recent successes in curtailing large-scale forest losses [9]. The results of recent modeling efforts suggest that halting tropical deforestation, which accounts for 6–17% of global anthropogenic CO_2 emissions to the atmosphere [13], when combined with substantial reductions in emissions from fossil fuels and other sectors, would increase to 65% the probability of maintaining global warming below the UNFCCC target of 2°C above pre-industrial levels [103]. Given the enormous amount of carbon stored in Amazonian ITs and PNAs alone, maintaining the ecological integrity of these landscapes is a critical, albeit insufficient, step toward reducing emissions of CO_2 from land use change.

Recent research emphasizes that stemming the tide of large-scale tropical forest loss will depend on increasing the agricultural yield on existing farmland and degraded areas [14,15]. However, most estimates of the costs of reducing deforestation focus on opportunity costs of forgone agriculture production and omit the costs not only of maintaining ITs and PNAs [104], but also of creating the necessary sustainable development opportunities for their resident populations (Table S4). While corporate commitments to "zero deforestation" commodity supply chains together with multi-stakeholder processes such as The Consumer Goods Forum and commodity roundtables (e.g., Roundtable for Sustainable Palm Oil, Roundtable for Responsible Soy, Global Roundtable for Sustainable Beef and Brazilian Roundtable on Sustainable Livestock) may reduce deforestation pressures on some forest landscapes, ITs and PNAs are not directly linked to commodity supply chains and these efforts will not, by themselves, achieve the development goals of indigenous and forest-dwelling peoples, or provide for the effective implementation and maintenance of conservation areas. It follows that specific policies and investments in support of effective forest protection, sustainable development pathways for the populations that inhabit ITs and PNAs, and equitable valuation of their social and environmental services, are fundamental to realizing robust, large-scale reductions in emissions from land use change. In short, strategies – and national and international funding initiatives – for large-scale forest conservation need to include actions and investments on both sides of the agricultural frontier. While our analysis has focused on Amazonia, this conclusion is relevant to Indonesia as well, particularly in light of the widespread presence of indigenous peoples in its remaining forests as well as the extensive literature documenting the centrality of local community control over land and resources for sustainable management practices in the region [16].

The sheer scale of Amazonian ITs and PNAs, the forests they contain and the carbon they store, combined with the substantial risks posed by present and near-future development, suggests that basin-wide incentives to upwardly harmonize and implement indigenous land and resource rights, together with forest protection and sustainable use policies, are justified on the basis of the climate benefits alone, but would also produce multiple social, cultural and ecological co-benefits. Given that nearly 14% of the carbon stored above ground in Amazonian ITs is contained within territories lacking official government recognition, legally recognizing these territories as well as settling private land claims in PNAs is, by any measure, an urgent priority. While management systems for territories under indigenous control vary considerably across the region, they tend to be closely adapted to, and based on extensive knowledge of, local ecosystems. As a result, indigenous territorial management practices contribute directly to

the development and maintenance of ecosystem composition, structure and function [17–19]. Although the maintenance of forest carbon stocks in ITs cannot be attributed to indigenous management per se, the inextricable relationship between Amazonian indigenous cultural identity and tropical forest ecosystems, including their flora and fauna, forms the basis of indigenous peoples' ongoing political struggle for recognition of their land and resource rights and the extant indigenous territories. Whereas indigenous management systems have proved largely sustainable at least since the colonial era, they will require new technologies, capacities – and political alliances – in order to successfully meet the development challenges and market pressures of the 21st century. In recent years, indigenous peoples and their civil society supporters have had considerable success in incorporating social safeguards into existing and proposed guidelines for REDD+ [105–107], and Peru's inclusion of indigenous land titling and community forestry governance in its National Investment Plan for the Forest Investment Partnership financing offers a template for ongoing indigenous territorial rights discussions basin-wide.

Given the recognized potential of ITs and PNAs to limit or prevent deforestation and forest degradation [7], while at the same time acknowledging the widespread near-term risk to their forests, the indigenous and traditional communities that inhabit many of them and the vast stocks of carbon they contain, bilateral and multilateral donors should devote a significant portion of capacity building and "payment for performance" funding to a comprehensive, integrated strategy for the protection and sustainable development of these landscapes. Amazonian nations that officially recognize indigenous territorial and resource rights, invest in sustainable livelihoods for forest peoples, develop and implement national protected area management plans and participatory national policies for indigenous territorial management (i.e., akin to Brazil's National Program for Environmental Management of Indigenous Lands – PNGATI) and commit national funds to match international donor investments, should be allowed to count some proportion of their IT and PNA carbon stocks toward post-2020 emissions reductions targets under the UNFCCC, and should be preferentially eligible for both REDD+ and climate adaptation financing. These resources should be complemented by infrastructure compensation funds, fines for environmental infractions and government investment in monitoring and law enforcement.

Estimates of the costs of protecting Amazonian ITs and PNAs while developing sustainable economic development alternatives for local communities are inherently uncertain, and merit further research and analysis. However, a conservative approximation of the costs – likely on the order of US $2–4 billion – required to create and consolidate ITs and PNAs, while at the same time establishing endowments to support fixed recurring costs, including administrative and monitoring operations, puts them easily within the scale of bilateral and multilateral funding presently committed to reducing deforestation (Table S5). Indigenous territories and inhabited PNAs also need budgetary outlays for social services such as healthcare and education. Ultimately, the sustainability of ITs and PNAs will depend on the strength and stability of the economies surrounding them. While a basin-wide transition to sustainable economic development pathways for rural and urban economies is likely to come at a significantly higher cost, it could also generate correspondingly higher benefits over time [11]. Bilateral and multilateral donor funds, philanthropy, private carbon finance, infrastructure development compensation and impact mitigation funds, as well as fines for environmental infractions, are all potential sources of financing.

Future perspective

Previous attempts to predict the broad impacts of development on tropical forest cover, CO_2 emissions trajectories and lands with conservation status have been either characterized by high uncertainties in the absence of consistent and accurate region-wide estimates of carbon density or restricted geographically (e.g., to the Brazilian Amazon) in the absence of a comprehensive basin-wide database of spatially explicit IT and PNA limits [7]. Efforts to model the potential feedbacks among climate change, fire and forest loss while evaluating the probability of future large-scale Amazon drought and forest dieback have similarly been hampered by uncertainties surrounding the availability of data such as those compiled here [108]. Despite the uncertainty surrounding the mid- to long-term impacts of climate change on the Amazon, including changing regional temperature and precipitation regimes, releasing the carbon currently at risk in Amazon ITs alone – equivalent to clearing all of Peru's forests – would increase the probability of Amazon dieback [20], with deleterious and potentially irreversible effects on the atmosphere and the planet.

At the 2013 UNFCCC Climate Change Conference, 19th Conference of the Parties (COP 19), countries agreed to the Warsaw Framework for REDD+, establishing the principles and guidelines necessary for REDD+ to become operational (Decisions 9–16/COP 19). At the 2014 conference (COP 20) in Lima, Peru, negotiators are expected to agree that significant REDD+

financing should be part of the international climate change treaty scheduled for ratification at COP 21 in Paris, France. Some $8.5 billion in bilateral and multilateral funding has already been committed to REDD+ with only a fraction allocated to ITs and PNAs (Table S5) [109]. Policies to address climate change, including efforts to measure and monitor forest loss and associated carbon emissions, will inevitably continue to be national and subnational prerogatives, and, consequently, forest protection and sustainable development programs will be designed and implemented, as current policy frameworks mandate, at national and subnational levels. However, the global importance of Amazonian ITs and PNAs, not only to the planet's atmosphere, but also in consideration of the broad range of social and ecological benefits they provide, merits international recognition through the UNFCCC as well as large-scale, integrated investment in these landscapes and the people who inhabit them. While ITs and PNAs provide numerous environmental and social services with multiple material and immaterial values that extend well beyond carbon, these landscapes are of critical global importance on the basis of their carbon stocks alone and the role they necessarily have to play in maintaining the stability of the planet's climate.

Acknowledgements

The authors wish to thank Juan Calles, Saúl Cuellar, Fernando Espíndola, Mary Farina, Carol Franco, Humberto Gómez, Erica Johnson, Daniel Larrea, Víctor López, Alicia Rolla, Márcio Santilli, Adriana Sarmiento, Percy Summers, Pedro Tipula, Janette Ulloa, Lisa Walker, Allison White and Sergio Zambrano-Martínez for their valuable comments on an earlier draft of this manuscript and/or assistance with data preparation.

Financial and competing interests disclosure

Data compilation and analysis was supported by the World Bank, Rainforest Foundation Norway, Ford Foundation, Gordon and Betty Moore Foundation and the United States Agency for International Development (USAID). The authors have no other relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript apart from those disclosed. No writing assistance was utilized in the production of this manuscript.

Supplementary data

Supplemental data for this article as well as a Spanish language translation can be accessed at, at http://dx.doi.org/10.1080/17583004.2014.990680.

Executive summary

Background

- More than half of Amazonia (52%; ~4.1 million km^2) is contained within a network of 2954 indigenous territories (ITs) and protected natural areas (PNAs) spanning nine nations.
- These landscapes provide numerous environmental and social benefits of global importance including climate stabilization through forest carbon sequestration.

Carbon storage in ITs and PNAs

- More carbon is stored above ground in Amazonian ITs than is stored in all the forests of the Democratic Republic of Congo (DRC).
- Amazonian ITs and PNAs store more than half (55%) of the region's aboveground carbon, which is more carbon than is stored above ground in all of the DRC and Indonesia combined.

Assessing pressures and threats

- More than half of the Amazonian region (53%; ~4.2 million km^2) is at risk from either current pressures or near-term threats associated with growth in the agriculture, grazing, mining, petroleum, timber and transportation sectors.
- Approximately 43% of this at-risk carbon, an amount equivalent to 90% of the aboveground carbon stock of Indonesia, is contained within the ostensibly secure borders of Amazonian ITs and PNAs.
- The combined area of ITs and PNAs at risk constitutes 18% (~1.4 million km^2) of Amazonia, an area larger than the Colombian, Ecuadorian and Peruvian Amazon combined.

Amazonian protected lands and forest/climate policy

- Nearly 14% of the carbon stored above ground in Amazonian ITs is contained within territories lacking official recognition; obtaining legal recognition for ITs and settling private land claims in PNAs are urgent priorities.
- The costs of creating and consolidating ITs and PNAs and establishing endowments to support administrative operations and monitoring is conservatively estimated at $2–4 billion, a sum well within the scale of present international commitments to reducing deforestation.
- Amazon nations that commit to protect and make social and economic investments in ITs and PNAs should be allowed to count some proportion of their IT and PNA carbon stocks toward post-2020 emissions reductions targets under the UNFCCC.
- The sustainability of ITs and PNAs will depend on the strength and stability of their surrounding economies, necessitating a basin-wide transition to sustainable rural and urban economic development pathways.
- Given the carbon stored in Amazonian ITs and PNAs alone, international recognition of and renewed investment in maintaining the ecological integrity of these landscapes are critical to reducing emissions of CO_2 from land use change.

References

1 Schwartzman S, Nepstad D, Moreira A. Arguing tropical forest conservation: people versus parks. *Conserv. Biol.* 14(5), 1370–1374 (2000).

2 Sutherland W. Parallel extinction risk and global distribution of languages and species. *Nature* 423, 276–279 (2003).

3 Gorenflo L, Romaine S, Mittermeier RA, Walker-Painemilla K. Co-occurrence of linguistic and biological diversity in biodiversity hotspots and high biodiversity wilderness areas. *Proc. Nat. Acad. Sci. USA* 109(21), 8032–8037 (2012).

4 Nepstad D, Schwartzman S, Bamberger B *et al.* Inhibition of Amazon deforestation and fire by parks and indigenous lands. *Conserv. Biol.* 20(1), 65–73 (2006).

5 Joppa L, Loarie S, Pimm S. On the protection of "protected areas." *Proc. Nat. Acad. Sci. USA* 105(18), 6673–6678 (2008).

6 Nelson A, Chomitz KM. Effectiveness of strict vs. multiple use protected areas in reducing tropical forest fires: a global analysis using matching methods. *PLoS One* 6(8), e22722 (2011).

7 Soares-Filho B, Moutinho P, Nepstad D *et al.* Role of Brazilian Amazon protected areas in climate change mitigation. *Proc. Nat. Acad. Sci. USA* 107(24), 10821–10826 (2010).

8 Baccini A, Goetz SJ, Walker W *et al.* Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps. *Nat. Clim. Change* 2, 182–185 (2012).

9 Hansen M, Potapov P, Moore R *et al.* High-Resolution global maps of 21st-century forest cover change. *Science* 342, 850–853 (2013).

10 Laurance W, Cochrane M, Bergen S *et al.* The future of the Brazilian Amazon. *Science* 291, 438–439 (2001).

11 Nobre AD. *The future climate of Amazonia scientific assessment report.* São José dos Campos SP, Brazil.

12 Schmink M, Wood C. *Contested frontiers in Amazonia.* Colombia University Press, New York, USA (1992).

13 Van der Werf GR, Morton DC, DeFries RS et al. CO_2 emissions from forest loss. *Nat. Geosci.* 2, 737–738 (2009).

14 Clay J. Freeze the footprint of food. *Nature* 475, 287–289 (2011).

15 Nepstad D, Irawan S, Bezerra T *et al.* More food, more forests, fewer emissions, better livelihoods: linking REDD plus, sustainable supply chains and domestic policy in Brazil, Indonesia and Colombia. *Carbon Management* 4(6), 639–658 (2013).

16 Agrawal A, Chhatre A, Hardin R. Changing governance of the world's forests. *Science* 320(5882), 1460–1462 (2008).

17 Balée WL. The culture of Amazonian forests. In: *Resource management in Amazonia: indigenous and folk strategies (advances in economic botany 7).* New York Botanical Garden Press, Bronx, NY, USA.

18 Heckenberger MJ, Kuikuro A, Kuikuro U *et al.* Amazonia 1492: pristine forest or cultural parkland. *Science* 1710–1713 (2003).

19 Schwartzman S, Boas AV, Ono KY *et al.* The natural and social history of the indigenous lands and protected areas corridor of the Xingu River basin. *Philos. Trans. R. Soc. B Biol. Sci.* 368 (2013).

20 Fu R, Yin L, Li W *et al.* Increased dry-season length over southern Amazonia in recent decades and its implication for future climate projection. *Proc. Nat. Acad. Sci. USA* 110(45), 18110–18115 (2013).

Websites

101 RAISG. *Amazonia under pressure.* Red Amazónica de Información Socioambiental Georreferenciada (RAISG), São Paulo, Brazil (2012). http://raisg.socioambiental.org/mapa

102 Vaughan A. Ecuador signs permits for oil drilling in Amazon's Yasuni national park. *The Guardian* (2014). http://www.theguardian.com/environment/2014/may/23/ecuador-amazon-yasuni-national-park-oil-drill

103 Warren R, Price J, Strassburg B, Lowe J, Raper S. *Modeling the role of remaining tropical forests in climate change mitigation.* (2013). www.metoffice.gov.uk/media/pdf/7/3/AVOID_WS2_D1_36_Avoided_Deforestation.pdf

104 Eliasch J. *Climate change: financing global forests.* (2008). https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/228833/9780108507632.pdf

105 UNFCCC. *Dec.1/CP.16.* United Nations Framework Convention on Climate Change (2011). http://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf

106 CCBA. *Climate, community & biodiversity standards*, 3rd ed. Climate, Community, & Biodiversity Alliance, Arlington, VA (2013). https://s3.amazonaws.com/CCBA/Third_Edition/CCB_Standards_Third_Edition_December_2013.pdf

107 ROW. *California, Acre, and Chiapas: partnering to reduce emissions from tropical deforestation.* Red Offset Working Group (ROW) (2013). http://greentechleadership.org/documents/2013/07/row-final-recommendations-2.pdf

108 Vergara W, Scholz S. Assessment of the risk of Amazon dieback. Washington DC (2011). http://documents.worldbank.org/curated/en/2010/01/13155273/assessment-risk-amazondieback

109 IFF. *Stimulating interim demand for REDD +emission reductions: the need for a strategic intervention from 2015 to 2020.* Interim Forest Finance (IFF) Project (2014). www.globalcanopy.org/sites/default/files/IFF reportJan 2014-Stimulating Interim Demand for REDD+_single pages.pdf