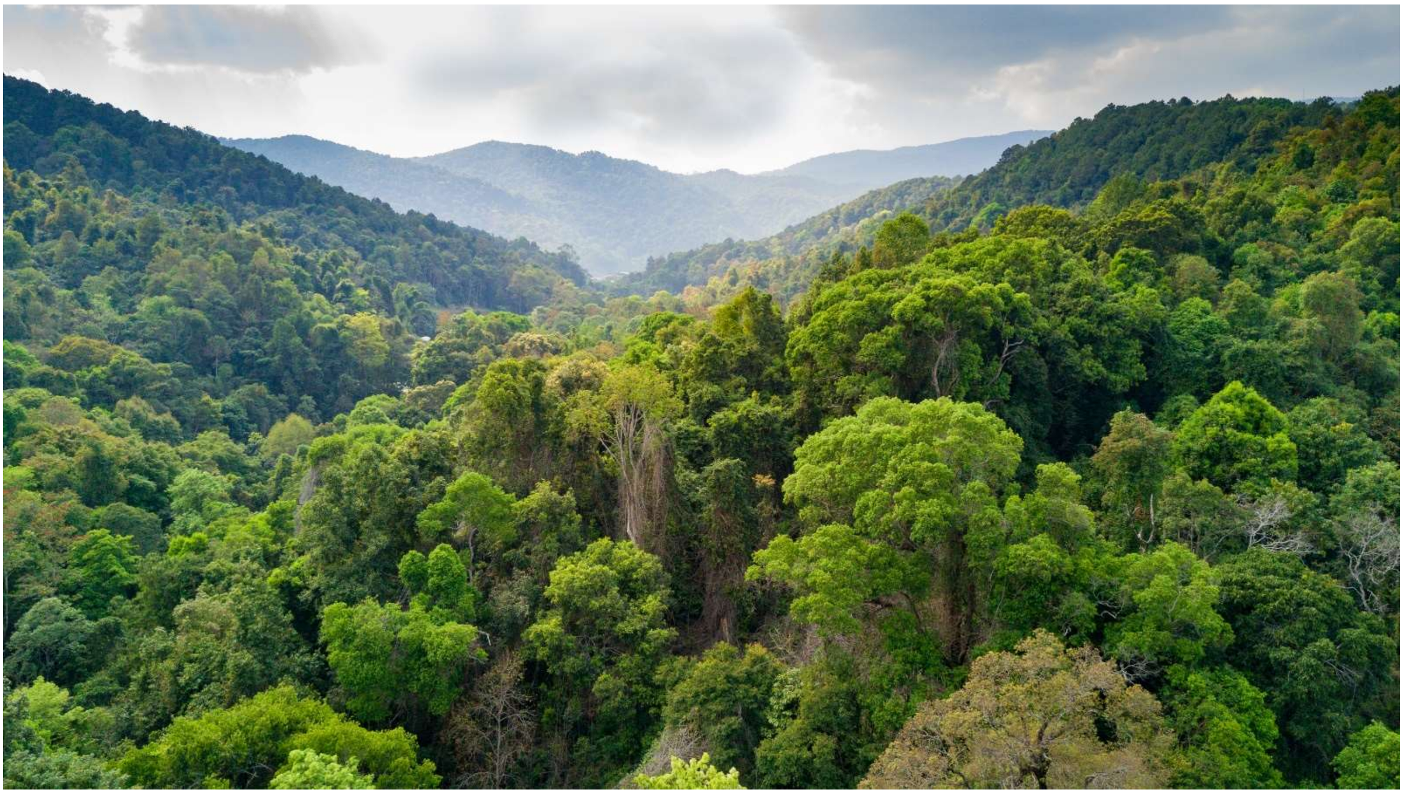


Kohlenstoffspeicherung in 350 Millionen Hektar pantropischem Wald

Pan-tropical forest carbon storage within 350 million hectares of land

Thomas W. Crowther, Johan van den Hoogen & Thomas Lauber

Professur für Globale Ökosystemökologie,
Departement Umweltsystemwissenschaften, ETH Zürich

Global Ecosystem Ecology lab,
Department of Earth System Science, ETH Zürich

Aus dem Englischen übersetzt von Sandra H. Lustig

Januar/January 2021

Eine Kurzstudie im Auftrag von/Commissioned by

Stiftung Forum für Verantwortung
Pestelstraße 2
66119 Saarbrücken
www.forum-fuer-verantwortung.de
info@forum-fuer-verantwortung.de

1. Introduction

Forests are a critical component of the global carbon (C) cycle, storing over 400 Gt carbon in plant biomass and over 1000 Gt carbon within the soil (Hengl et al., 2017; Ruesch and Gibbs, 2008). It is estimated that the degradation of tropical ecosystems may have contributed up to 100 Gt carbon of anthropogenic carbon emissions over the last century (Erb et al., 2018). Given the considerable role of these natural ecosystems in governing the global carbon cycle, protecting these ecosystems is the highest priority, with the potential to directly limit greenhouse gas emissions (Griscom et al., 2017), and the recovery of natural forests can also contribute to capturing up to 30% of the excess carbon that exists in the atmosphere as a result of human activity, if the trees can recover to full maturity (Bastin et al., 2020).

Tropical forests are the most productive components of the global forest system, as warm, moist conditions promote the rapid growth of large trees (See Figure 1). As a result, tropical forests are the largest repository of carbon and biodiversity within the terrestrial biosphere. The conservation and protection of tropical ecosystems represents one of the most critical components in the fight against biodiversity loss and rising atmospheric carbon concentrations (Griscom et al., 2017). Given that diverse mixtures of species have consistently been found to capture the largest proportion of carbon (Liang et al., 2016), the protection of existing, healthy forest is a top climate change priority.

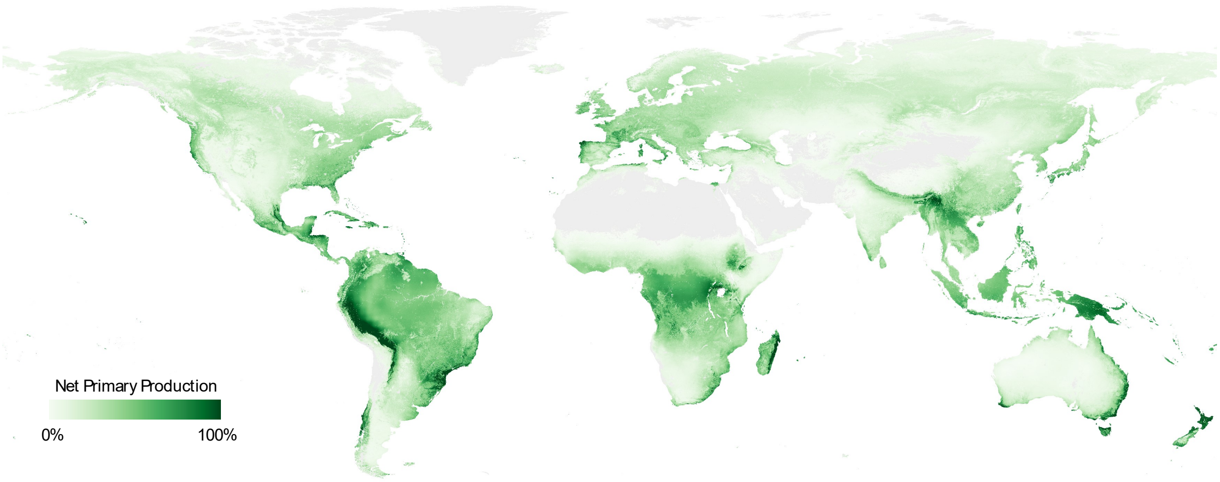


Figure 1. Relativized map of net primary productivity estimated from the MODIS satellite cluster, showing the regions of highest plant productivity in darker green colours, with less productive regions in white.

Given the importance of tropical forests in the fight against, various international initiatives have been established to promote the promote forest conservation within tropical regions. In particular, the Bonn Challenge has set ambitious targets for the conservation of 350 million hectares of tropical forest. However, forest carbon storage varies drastically across tropical ecosystems (Ruesch and Gibbs, 2008), and so the impacts of this effort will vary depending on the areas that are selected for conservation. Evaluating the impacts of forest conservation on terrestrial carbon storage requires information about the carbon that exists in those regions, that would otherwise be vulnerable to degradation.

2. Approach

In this report, we use a combination of modeling products to explore the carbon storage within 350 million hectares of tropical forest in Africa, Asia and America. For estimating aboveground forest biomass, we compiled a range of global biomass products. There have been several efforts to map forest carbon storage – using process-based models (Ruesch and Gibbs, 2008), satellite data (GlobBiomass), and compilations of ground sourced forest inventory data (Pan et al., 2011) – over the last decade (see Table 1 for list of existing global products). Although there are some clear consistencies across these products (e.g. all show the largest carbon storage exists within the tropics), none of them agree entirely on the exact distribution of this carbon storage at the fine scale. As such, we used direct ground-sourced measurements of forest biomass estimates from the Global Forest Biodiversity initiative (Steidinger et al., 2019) to evaluate and validate the existing biomass products. Explaining over 84% of the variation in biomass estimates across 1.2 million forest inventory observations, the GlobBiomass product was by far the best predictor of forest biomass variation across the tropical forest regions (estimated using the RESOLVE biome map (Dinerstein et al., 2017) – see Supplementary information). As such, we use this satellite-derived product to estimate mean aboveground forest biomass across the different tropical biomes in each continent.

For belowground carbon storage, we used the global SoilGrids carbon storage layer, which includes estimates of percentage carbon and bulk density at the 250m spatial resolution, and until a depth of 2m below the soil surface. By scaling the percentage of carbon by the bulk density of the soil at each location (total carbon = proportion carbon * bulk density), it was possible to estimate belowground carbon storage at each location across the Tropics. Using this spatially-explicit map of soil carbon, we calculated the mean soil carbon storage across the tropical forest biomes in each continent.

Band Name	Spatial Resolution	DOI
GlobBiomass - Aboveground Biomass	≈100m	https://doi.org/10.5194/essd-2020-148
IPCC - Global Biomass	≈1km	None
SpawnEtAl - Harmonized Aboveground Biomass	≈300m	https://doi.org/10.1038/s41597-020-0444-4
SpawnEtAl - Harmonized Belowground Biomass	≈300m	https://doi.org/10.1038/s41597-020-0444-4
UNEP WCMC - Global Biomass	300m	https://doi.org/10.1098/rstb.2019.0128
SoilGrids250m - Soil Organic Carbon Stocks	≈250m	https://doi.org/10.1371/journal.pone.0169748
SandermanEtAl - Soil Organic Carbon Stocks	≈10km	https://doi.org/10.1073/pnas.1706103114

Table 1: List of existing global forest biomass products used.

3. Results and implications

There was considerable variation in forest carbon storage across tropical regions. This variation is likely to be driven by a wide range of abiotic factors (including climate, soil and topographic variation), ecological factors (the identity and diversity of tree species) well as considerable variation in human disturbance. According to our harmonized carbon map, America currently stores the largest proportion of aboveground tropical forest carbon, with an average of 58.8 tonnes per hectare (t/ha), with Asian and African forests storing 38.4 t/ha and 29.0 t/ha, respectively. This large proportion of carbon stored within American tropical forests is likely due to the relative proportion of tropical wet forests vs tropical dry forests. A larger proportion of tropical forests in Africa and Asia are dry forests, where annual dry seasons considerably limit the growth and carbon storage of trees, relative to tropical rainforests (see Table 2).

In contrast to the aboveground carbon storage, the density of belowground carbon storage (including soil and root carbon to a depth of 2 meters) was highest in Asian forests, with an average of 233 t/ha, followed by American and African forests, which store 187.1 t/ha and 111 t/ha, respectively. It is likely that this high mean soil carbon storage in Asian forests is due to the large proportion of wetlands and peatlands. For example, large regions of Indonesia are covered by waterlogged soil, where anaerobic conditions can limit decomposition within the soil, driving the vast accumulation of carbon within the soil (see Table 2).

Summing these aboveground and belowground estimates of carbon storage suggests that African forests currently store an average of 140 t/ha. As such, the protection of 350 million hectares of African forest could ensure the protection of 49 Gt carbon. Asian forests store an average of 267.4 t/ha, so 350 million hectares contain 95 Gt carbon. Within the Americas, the average tropical forest stores 245.9 t/ha, and so 350 million hectares currently store 86 Gt carbon. Given that humans have increased the atmospheric carbon burden by almost 300 Gt over the last century, these results clearly highlight that the conservation of 350 million hectares of tropical forest would be a considerable contribution to carbon storage on land (see Table 2).

	African tropics	Asian tropics	American tropics
Average aboveground C	29.0 t/ha	38.4 t/ha	58.8 t/ha
(CO_2 equivalent)*	(106.33 t/ha)	(140.8 t/ha)	(215.6 t/ha)
Average belowground C	111.0 t/ha	233 t/ha	187.1 t/ha
(CO_2 equivalent)	(407 t/ha)	(854.33 t/ha)	(686.03 t/ha)
Average ecosystem C	140.0 t/ha	271.4 t/ha	245.9 t/ha
(CO_2 equivalent)	(513.33 t/ha)	(995.13 t/ha)	(901.63 t/ha)
Total C within 350 mha	49 Gt	94.9 Gt	86 Gt
(CO_2 equivalent)	(179.67 t/ha)	(347.97 t/ha)	(315.33 t/ha)

*Note: one tonne of carbon equals 44/12 (3.67) tonnes of CO_2.

Table 2: Estimated mean carbon storage within tropical forests of different continents.

Of course, the implications of this work depend directly on the duration of conservation efforts. Globally, forests are getting younger over time, as increasing human disturbance continues to limit the capacity of these ecosystems to reach maturity (McDowell et al., 2020). These young trees capture carbon at a faster rate than old trees relative to their size, but they are limited in their carbon storage potential relative to old trees old trees. One mature tree will store tens of thousands of times more carbon than saplings of the same species. As such, mature forests store vastly more carbon both in the soil and vegetation, and they support vastly more biodiversity than young, developing forests (McDowell et al., 2020). Protecting these ecosystems in the long term (70-100 years) is absolutely critical if we are going to achieve the carbon storage potential.

4. Limitations and Considerations

As mentioned above, there are a wide variety of factors influencing the spatial patterns of carbon storage across tropical forests. As such, coarse continent-scale average values cannot highlight specific regions to focus on. In addition, they cannot reflect the range of carbon storage values across the region, so they do not necessarily reflect the full potential for carbon storage in the respective areas. For example, tropical moist and dry forests store substantially different amounts of carbon both aboveground and belowground. Splitting out these two distinct ecosystem types might be necessary to identify where the highest potential for carbon storage truly exists within tropical regions. However, these broad average values can provide robust insights into the full global potential of forest conservation.

It is important to consider that these values simply represent the total estimated amount of carbon in these forests at the present day. Degrading these ecosystems would not necessarily remove all of the carbon from the system, as converted land can still store a considerable amount of carbon, depending on the resulting land use. However, the degradation of ecosystems generally causes considerable declines in forest carbon, and so the values we present highlight the amount of carbon that would be vulnerable to degradation. As such, conserving these areas effectively would be likely to guarantee the protection of this much carbon in the long term.

5. Conclusions

Tropical forests are essential repositories of biodiversity and carbon. The scale of carbon storage in these regions highlights that protecting 350 million hectares of tropical would directly limit a considerable proportion (up to 30%) of anthropogenic greenhouse gas emissions in the long term. In addition, restoring additional land may have the potential to act as an additional carbon drawdown mechanism. Our estimates were generated from average carbon stocks of existing mature forests, so it is reasonable to assume that restored forests might ultimately reach this level of carbon capture if they are allowed to reach full maturity, with the natural diversity of native species. It remains unclear how long this would take for restored ecosystems to capture their maximum carbon sequestration potential, especially in the soil, but none of those ecosystems would be likely to reach maturity unless they could be protected for over 70-100 years. As such, it is absolutely critical that investment in conservation or restoration are long-term commitments, as the full carbon storage potential of these ecosystems is only reached by the next century. The selection of the optimal 350 million hectares of land should not only be optimized for carbon, but it is essential that restoration efforts are also for the biodiversity and human livelihoods that depend on these healthy forests. Given many of the synergies between carbon storage, diverse ecosystems and human livelihoods, this may not be a challenge, but the trade-offs between these attributes require careful consideration at local scales. Yet, our analysis provides some initial insights to help establishing meaningful carbon targets that may be achievable if massive-scale conservation efforts were achieved.

6. References

Bastin, J., Finegold, Y., Garcia, C., Mollicone, D., 2020. The global tree restoration potential 79, 76–79.

Dinerstein, E., Olson, D., Joshi, A., Vynne, C., Burgess, N.D., Wikramanayake, E., Hahn, N., Palminteri, S., Hedao, P., Noss, R., Hansen, M., Locke, H., Ellis, E.C., Jones, B., Barber, C.V., Hayes, R., Kormos, C., Martin, V., Crist, E., Sechrest, W., Price, L., Baillie, J.E.M., Weeden, D., Suckling, K., Davis, C., Sizer, N., Moore, R., Thau, D., Birch, T., Potapov, P., Turubanova, S., Tyukavina, A., De Souza, N., Pintea, L., Brito, J.C., Llewellyn, O.A., Miller, A.G., Patzelt, A., Ghazanfar, S.A., Timberlake, J., Klöser, H., Shennan-Farpón, Y., Kindt, R., Lillesø, J.P.B., Van Breugel, P., Graudal, L., Voge, M., Al-Shammari, K.F., Saleem, M., 2017. An Ecoregion-Based Approach to Protecting Half the Terrestrial Realm. Bioscience 67, 534–545. doi:10.1093/biosci/bix014

Erb, K., Kastner, T., Plutzar, C., Bais, A.L.S., Carvalhais, N., Fetzel, T., Gingrich, S., Haberl, H., Lauk, C., Niedertscheider, M., Pongratz, J., Thurner, M., 2018. Unexpectedly large impact of forest management and grazing on global vegetation biomass. Nat. Publ. Gr. 553, 73–76. doi:10.1038/nature25138

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., 2017. Natural climate solutions 114, 11645–11650. doi:10.1073/pnas.1710465114

Hengl, T., De Jesus, J.M., Heuvelink, G.B.M., Gonzalez, M.R., Kilibarda, M., Blagotić, A., Shangguan, W., Wright, M.N., Geng, X., Bauer-Marschallinger, B., Guevara, M.A., Vargas, R., MacMillan, R.A., Batjes, N.H., Leenaars, J.G.B., Ribeiro, E., Wheeler, I., Mantel, S., Kempen, B., 2017. SoilGrids250m: Global gridded soil information based on machine learning. PLoS One 12, 1–40. doi:10.1371/journal.pone.0169748

Liang, J., Crowther, T.W., Picard, N., Wiser, S., Zhou, M., Alberti, G., Schulze, E.-D., McGuire, A.D., Bozzato, F., Pretzsch, H., De-Miguel, S., Paquette, A., Hérault, B., Scherer-Lorenzen, M., Barrett, C.B., Glick, H.B., Hengeveld, G.M., Nabuurs, G.-J., Pfautsch, S., Viana, H., Vibrans, A.C., Ammer, C., Schall, P., Verbyla, D., Tchebakova, N., Fischer, M., Watson, J.V., Chen, H.Y.H., Lei, X., Schelhaas, M.-J., Lu, H., Gianelle, D., Parfenova, E.I., Salas, C., Lee, E., Lee, B., Kim, H.S., Bruelheide, H., Coomes, D.A., Piotto, D., Sunderland, T., Schmid, B., Gourlet-Fleury, S., Sonké, B., Tavani, R., Zhu, J., Brandl, S., Vayreda, J., Kitahara, F., Searle, E.B., Neldner, V.J., Ngugi, M.R., Baraloto, C., Frizzera, L., Bałazy, R., Oleksyn, J., Zawiła-Niedźwiecki, T., Bouriaud, O., Bussotti, F., Finér, L., Jaroszewicz, B., Jucker, T., Valladares, F., Jagodzinski, A.M., Peri, P.L., Gonmadje, C., Marthy, W., O'Brien, T., Martin, E.H., Marshall, A.R., Rovero, F., Bitariho, R., Niklaus, P.A., Alvarez-Loayza, P., Chamuya, N., Valencia, R., Mortier, F., Wortel, V., Engone-Obiang, N.L., Ferreira, L.V., Odeke, D.E., Vasquez, R.M., Lewis, S.L., Reich, P.B., 2016. Positive biodiversity-productivity relationship predominant in global forests. Science (80-.). 354, aaf8957. doi:10.1126/science.aaf8957

McDowell, N.G., Allen, C.D., Anderson-Teixeira, K., Aukema, B.H., Bond-Lamberty, B., Chini, L., Clark, J.S., Dietze, M., Grossiord, C., Hanbury-Brown, A., Hurtt, G.C., Jackson, R.B., Johnson, D.J., Kueppers, L., Lichstein, J.W., Ogle, K., Poulter, B., Pugh, T.A.M., Seidl, R., Turner, M.G., Uriarte, M., Walker, A.P., Xu, C., 2020. Pervasive shifts in forest dynamics in a changing world. Science (80-.). 368. doi:10.1126/science.aaz9463

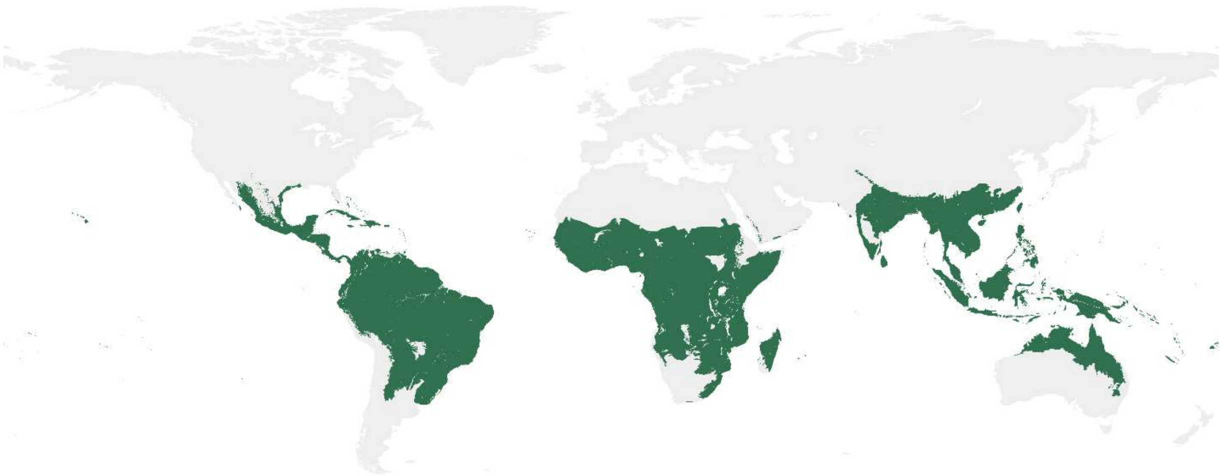
Pan, Y., Birdsey, R. a, Fang, J., Houghton, R., Kauppi, P.E., Kurz, W. a, Phillips, O.L., Shvidenko, A., Lewis, S.L., Canadell, J.G., Ciais, P., Jackson, R.B., Pacala, S.W., McGuire, a D., Piao, S., Rautiainen, A., Sitch, S., Hayes, D., 2011. A large and persistent carbon sink in the world's forests. Science 333, 988–93. doi:10.1126/science.1201609

Ruesch, A., Gibbs, H.K., 2008. New IPCC Tier-1 Global Biomass Carbon Map For the Year 2000., in: New IPCC Tier-1 Global Biomass Carbon Map For the Year 2000. Environmental System Science Data Infrastructure for a Virtual Ecosystem.

Steidinger, B., Crowther, T., Liang, J., Van Nuland, M., Werner, GD Reich, P., Nabuurs, G., De-Miguel, S., Zhou, M., Picard, N., Herault, B., Zhao, X., Zhang, C., Routh, D., List], [GFBi Author, Peay, K., 2019. Climatic controls of decomposition drive the global biogeography of forest tree symbioses. Nature in press.

7. Supplementary Information

To select Tropical forest regions, we used the RESOLVE biomes map (Dinerstein et al., 2017). This map is presented below, highlighting only the tropical forest regions.



ETH Zürich
Departement Umweltsystemwissenschaften
Rämistrasse 101
CH - 8092 Zürich