DOI: 10.1002/ecy.4135T

All changes in sources to the original version of MADERA published in Ecology previously are highlighted in blue italics throughout this document

Data Paper published in *Ecology*, an Ecological Society of America journal

SUPPLEMENTARY MATERIAL FOR THE DATA PAPER

MADERA *version 2.0:*

A standardized Pan-Amazonian dataset for tropical timber species

Ximena Herrera - Alvarez[1], Juan A. Blanco[1], Oliver Phillips[2], Vicente Guadalupe[3], Leonardo D. Ortega – López[4,5], Hans ter Steege[6,7], Gonzalo Rivas – Torres[8]

Amazonian timber species list DBH ≥ 10 cm

Our taxonomic consensus database reported 1136 accepted name species, 346 genera, and 72 families of trees that can reach DBH ≥10 cm in the Amazon lowland rain forest. According to Cardoso *et al.* (2017) most of the life forms of these species were trees (1008 species, 88.73 %), with a minor presence of shrubs (124 species, 10.92%) and palm trees (4 species, 0.35%).

Species richness, abundance and hyperdominance

More than four-fifths (81.17%) of the species are concentrated in only 20 families:

Fabaceae, Lauraceae, Sapotaceae, Malvaceae, Lecythidaceae, Chrysobalanaceae, Annonaceae, Moraceae, Burseraceae, Vochysiaceae, Myristicaceae, Melastomataceae, Euphorbiaceae, Meliaceae, Myrtaceae, Sapindaceae, Rubiaceae, Apocynaceae, Clusiaceae and Combretaceae (Figure S1). The remaining 18.86% of timber species are distributed across 52 families.

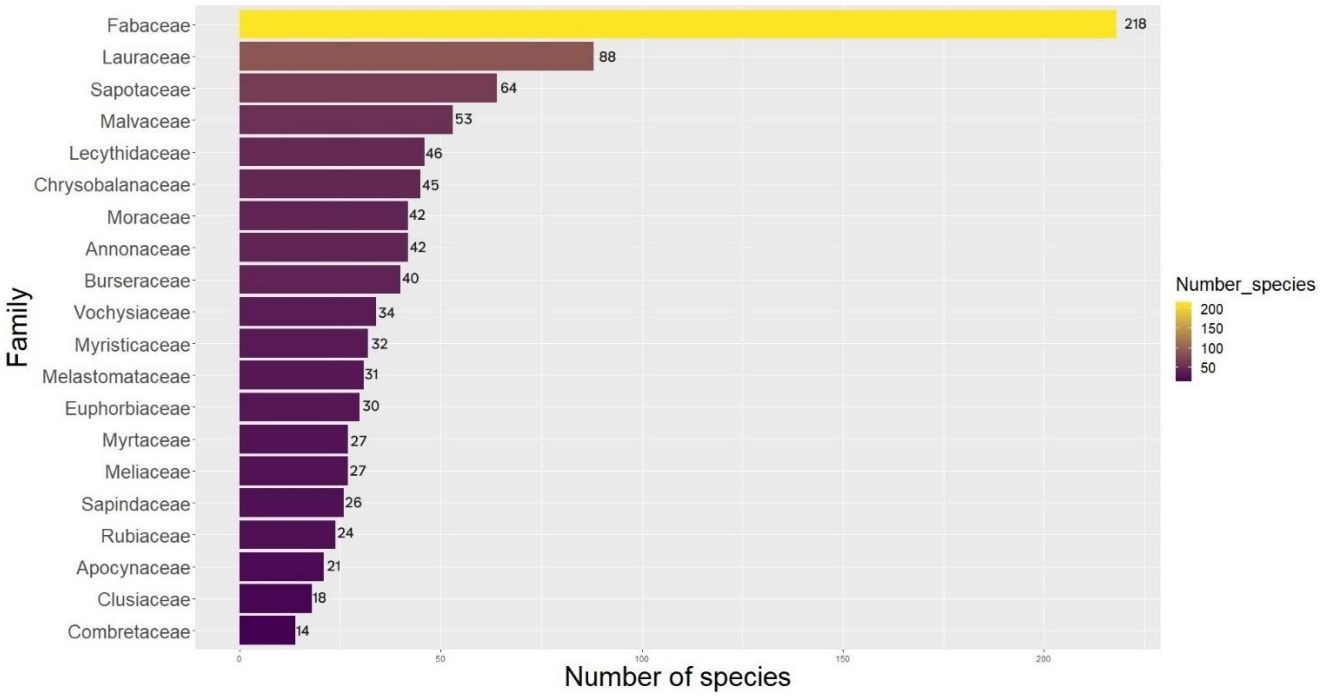

Figure S1. The 20 most species-rich families of timber tree species identified in lowland Amazon rain forests.

Regarding the species – richness from each genus, 31.08% of the included timber species were focused in 20 genera: *Pouteria*, *Protium*, *Inga*, *Ocotea*, *Licania*, *Vochysia*, *Virola*, *Eschweilera*, *Nectandra*, *Swartzia*, *Aniba*, *Terminalia*, *Ficus*, *Miconia*, *Mouriri*, *Ormosia*, *Sloanea*, *Talisia*, *Xylopia* and *Cordia*. The 69.32% of species are spread across the 326 remaining genera.

We estimated that 87.28% of all Amazon timber species individuals are represented by just 20 families: Fabaceae, Lecythidaceae, Burseraceae, Moraceae, Sapotaceae, Myristicaceae, Euphorbiaceae, Chrysobalanaceae, Arecaceae, Malvaceae, Lauraceae, Meliaceae, Annonaceae, Urticaceae, Apocynaceae, Anacardiaceae, Vochysiaceae, Clusiaceae, Rubiaceae and Calophyllaceae (Figure S2). The 12.73% of species individuals are spread across the 52 remaining families.

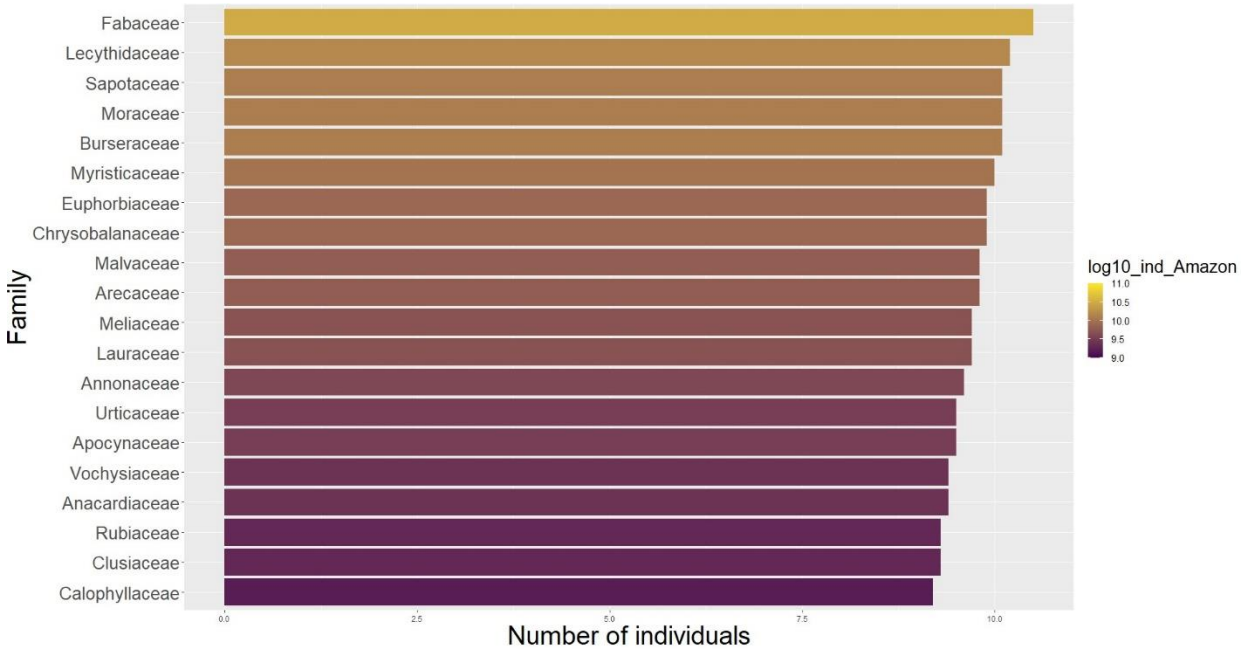

Figure S2. The 20 most abundant families **(**based on number of individuals on a $\log_{10}$ scale) estimated for the Amazon region using data according to ter Steege *et al.*, (2020).

In addition, we identified 156 hyperdominant timber species (13.73% of the total species) that represented 58.90% of the total abundance estimated for the entire Amazon region. Most of these hyperdominant timber species were predominantly *terra firme* species (forest type 4, 66.0%), with an equal quantity in *igapó* and *várzea* (forest types 1 and 5, respectively, 8.9%), podzol was slightly fewer 8.3% (forest type 2) and swamps (forest type 3, 7.7%) (ter Steege *et al.*, 2013).

Commercial timber species and CITES appendices

We identified 37 commercial species distributed across 17 families reported by ITTO that matched with our final timber species list. Most of these species (59.5%) belonged to just five families: Fabaceae, Lecythidaceae, Meliaceae, Moraceae and Vochysiaceae. (Figure S3).

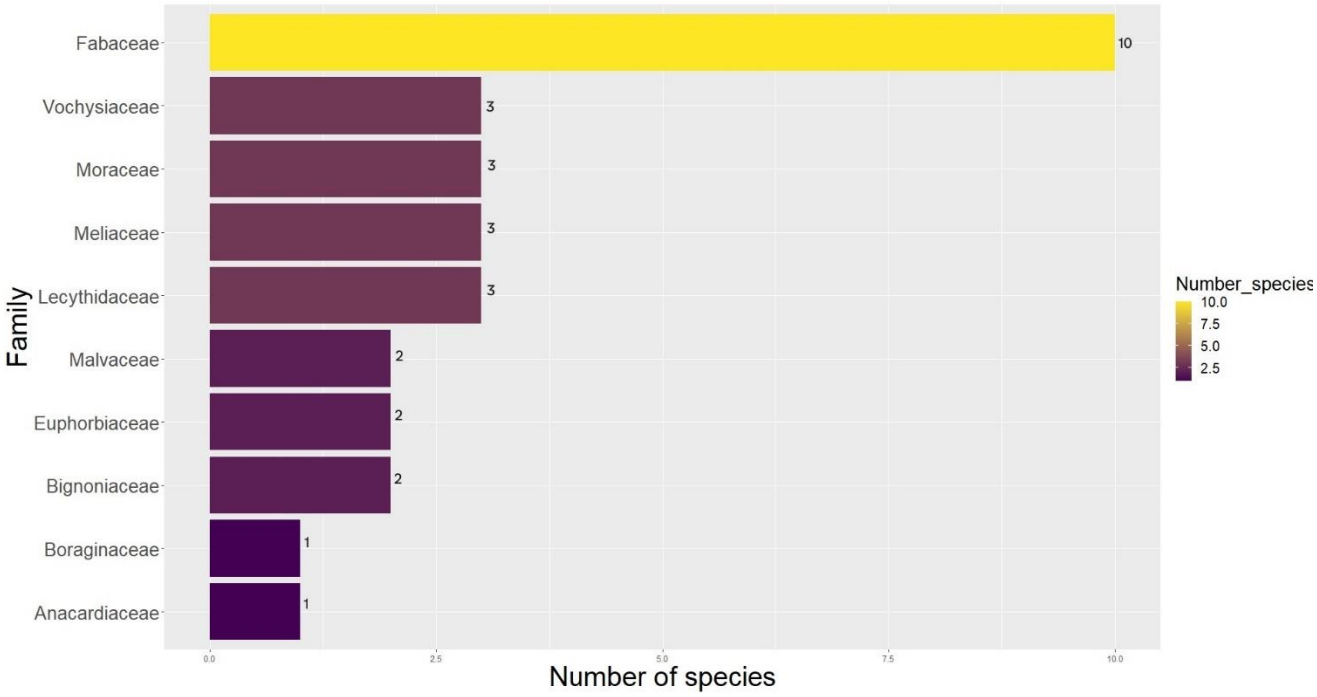

Figure S3. Number of commercial timber species and families of this list according to the International Tropical Timber Organization (2014).

The lesser used species (LUS), also reported by ITTO, and matched with our timber species list, resulting in 136 species distributed in 35 families. The majority (50.73%) of these species are concentrated in five families: Fabaceae, Moraceae, Malvaceae, Lecythidaceae and Lauraceae (Figure S4).

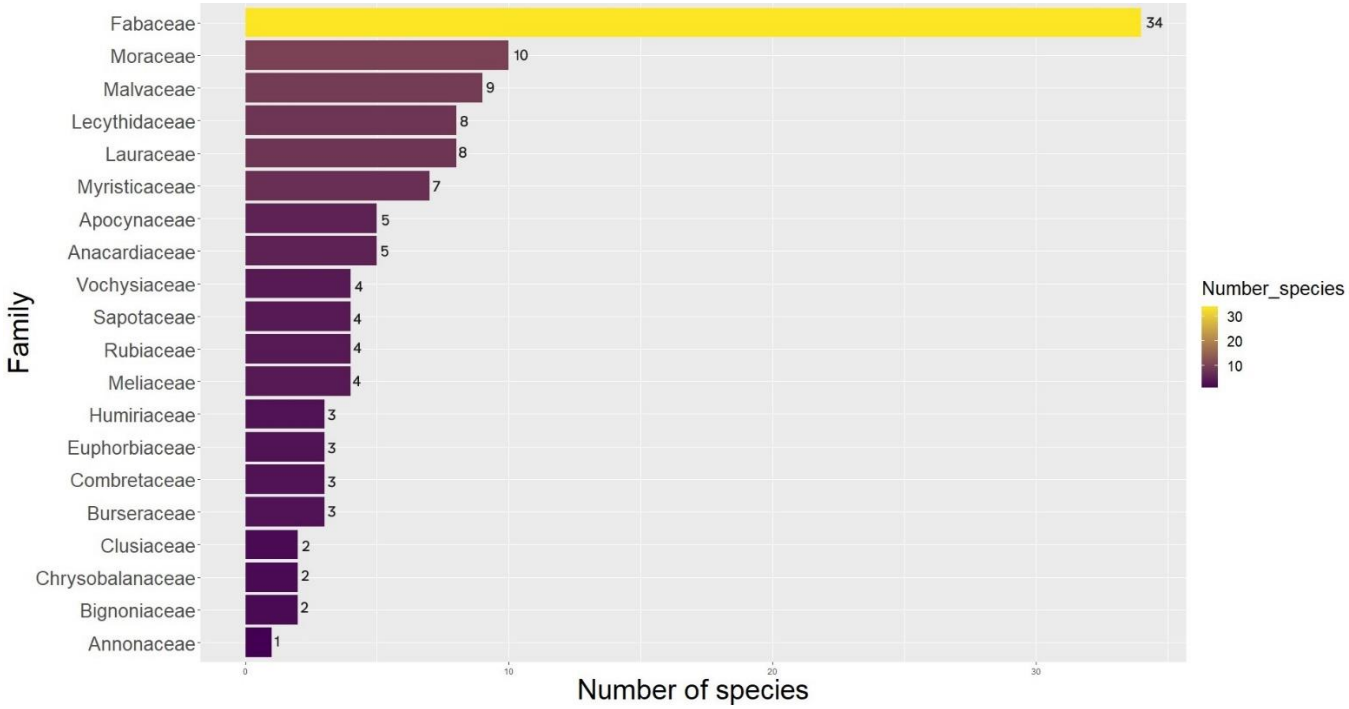

Figure S4. Number of lesser used species (LUS) and families of this timber species list according to the International Tropical Timber Organization (2014).

Finally, we only identified six species in CITES appendices among our 1136 timber species list. Two of these species belonged to appendix II: *Cedrela angustifolia* (Meliaceae), *Cedrela fissilis* (Meliaceae), *Cedrela odorata* (Meliaceae), *Dalbergia spruceana* (Fabaceae), *Swietenia macrophylla* (Meliaceae) and *Handroanthus serratifolius* (Bignoniaceae)

Families and species assessed by *IUCN up to 2023*

We identified 916 species (80.6% of the total list) from 71 families that have been assessed by IUCN Red List Categories among our 1136 timber species list. In addition, 82.55% of these species were distributed across 21 families with ≥10 species each: Fabaceae, Lauraceae, Sapotaceae, Annonaceae, Moraceae, Burseraceae, Malvaceae, Chrysobalanaceae, Lecythidaceae, Euphorbiaceae, Meliaceae, Myristicaceae, Melastomataceae, Vochysiaceae, Myrtaceae, Sapindaceae, Apocynaceae, Clusiaceae,

Rubiaceae, Urticaceae and Bignoniaceae (Figure S5). The 50 families that have been less assessed by IUCN (< 10 spp.) represented the 17.5% remaining.

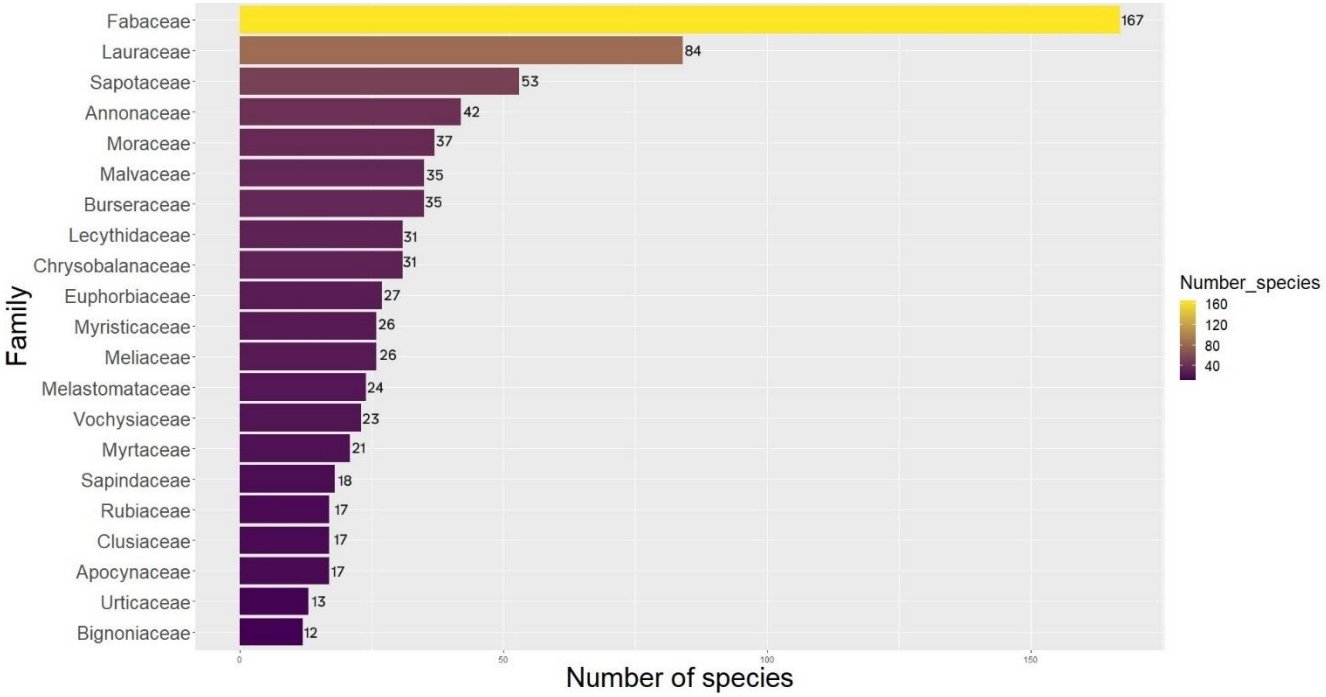

Figure S5. Number of timber species (≥10 spp.) and families according to the present study that are assessed by *IUCN Red List Categories up to 2023.*

Current IUCN Red List Categories for this timber species list

Regarding the 916 timber species (80.65%) from our list that have been assessed by IUCN, most of these species were in the Least Concern category (837 spp., 73.7%), and the 79 remaining species were spread across other Red List Categories (7 %). In addition, there were a total of 220 timber species (19.4%) that have not been evaluated by IUCN, and therefore their conservation status remains unknown (Table S1).

Table S1. Summary of this Amazon timber species list in each *Red List Category up to 2023.*

IUCN_Red_List_Category_2023	Number_Amazon_timber_species	Percentage (%)
Least Concern	837	73.68
Not evaluated	220	19.37
Vulnerable	31	2.73
Data Deficient	17	1.50
Endangered	12	1.06
Near Threatened	9	0.79
Lower Risk/least concern	5	0.44
Critically Endangered	2	0.18
Lower Risk/near threatened	2	0.18
Lower Risk/conservation dependent	1	0.09
Total	1,136	100.00

Amazon timber species threatened by climate change and deforestation scenarios in 2050 (Gomes *et al.*, 2019)

To evaluate the conservation status of Amazonian timber species by 2050 under different climate change scenarios, we used the Representative Concentration Pathways (RCP) from the Intergovernmental Panel on Climate Change (IPCC). RCP categories were established at the IPCC Fifth Assessment Report) and are defined as climate change categories depending on greenhouse concentration trajectories in the atmosphere (IPCC, 2014). Here, we used a low greenhouse gas concentration scenario (RCP 2.6) and the worst-case scenario of high greenhouse gas concentration (RCP 8.5) with different global climate consequences, according to the IPCC categories. We identified a clear increasing tendency of the number of Critically endangered (CR) and Endangered (EN) species in

the higher RCP 8.5 compared to the RCP 2.6 scenario. However, the number of Vulnerable (VU) species was almost similar in both scenarios (Figure S6).

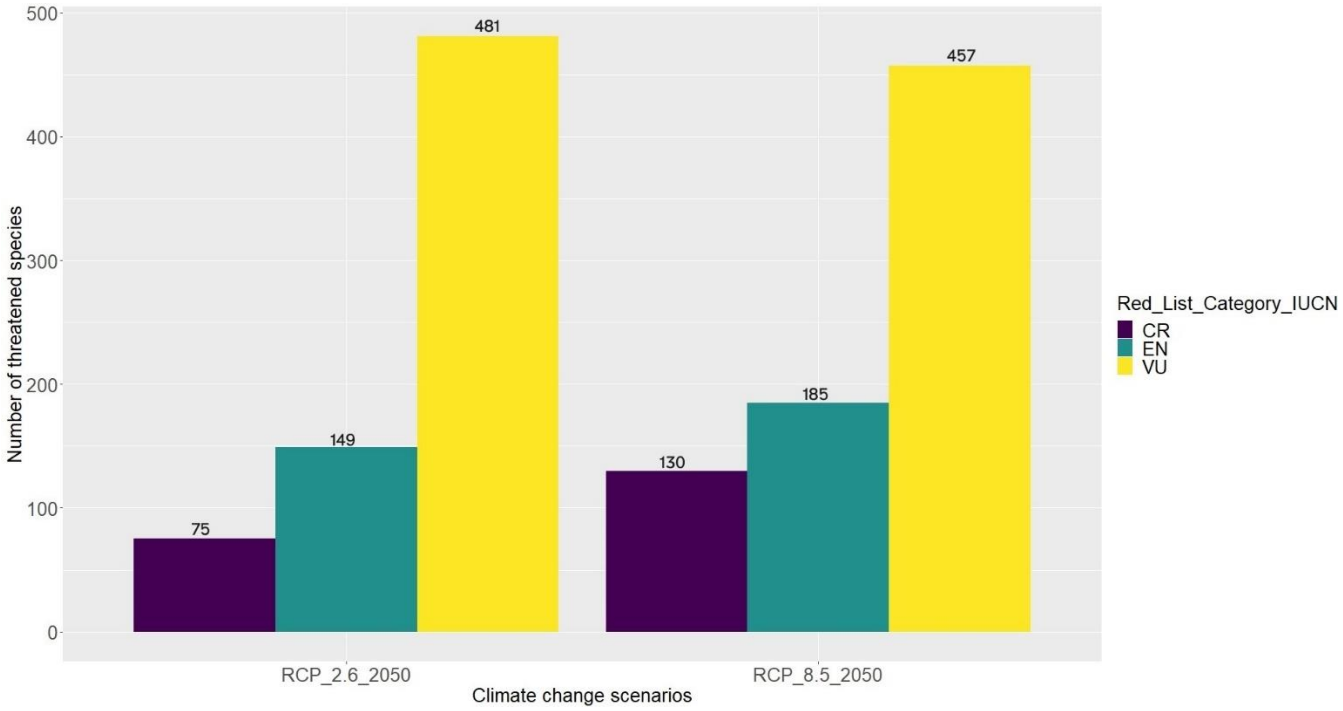

Figure S6. Number of Amazon timber species threatened by 2050 under two different climate change scenarios (RCP 2.6 and RCP 8.5) (Gomes *et al.*, 2019). RCP: representative concentration pathways from the IPCC Fifth Assessment Report (AR5) (IPCC, 2014). Red List Categories IUCN: CR: Critically Endangered, EN: Endangered, VU: Vulnerable.

In addition, the combined scenarios of climate change (RCP 2.6 and RCP 8.5) and Improved Governance Deforestation (IGS) by 2050 also increased the number of CR and EN species more than climate change scenarios alone. Nevertheless, the IGS conditions reduced in less proportion the impact of climate change scenarios themselves for VU species (Figure S7).

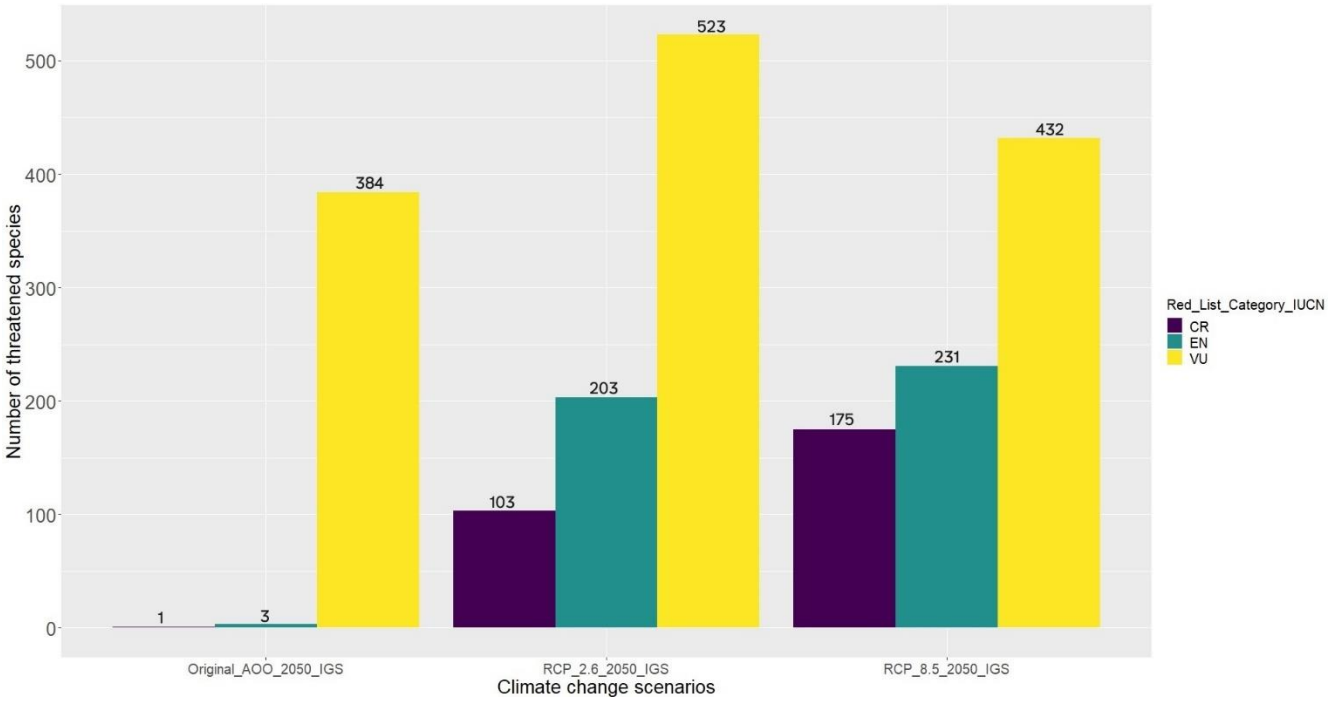

Figure S7. Number of Amazon timber species threatened in the combined scenarios of climate change (RCP 2.6 and RCP 8.5) and improved governance deforestation (IGS) by 2050 (Gomes *et al.*, 2019). RCP: representative concentration pathways from the IPCC Fifth Assessment Report (AR5) (IPCC, 2014). Red List Categories IUCN: CR: Critically Endangered, EN: Endangered, VU: Vulnerable.

On the other hand, the combined scenarios of climate change (RCP 2.6 and RCP 8.5) and Business- as-usual scenario (BAU) by 2050 is the worst-case scenario for CR and EN species. The number of species under these two categories will increase more than under the other scenarios of climate change only and climate change with IGS. However, the number of VU species under this scenario will decrease compared to the other two, just because of the species increase the CR and EN categories (Figure S8).

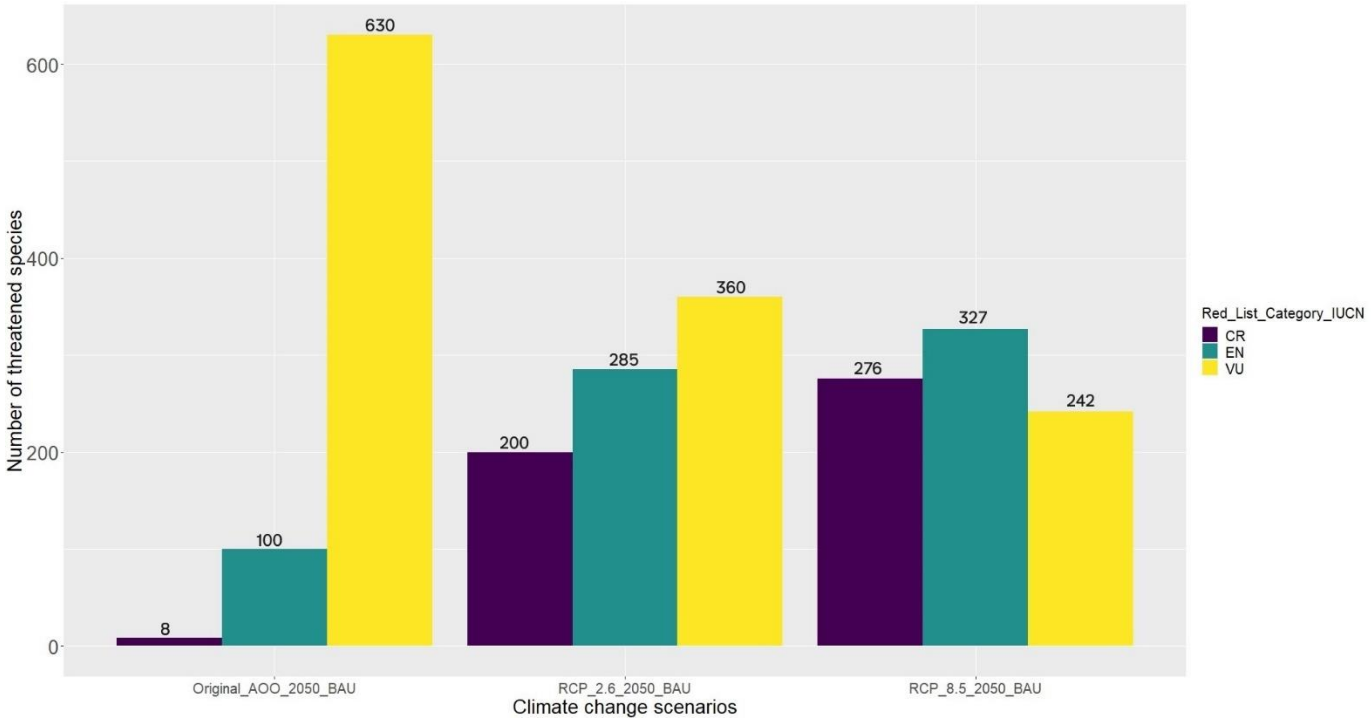

Figure S8. Number of Amazon timber species threatened in the combined scenarios of climate change (RCP 2.6 and RCP 8.5) and business- as-usual scenario (BAU) by 2050 (Gomes *et al.*, 2019). RCP: representative concentration pathways from the IPCC Fifth Assessment Report (AR5) (IPCC, 2014). Red List Categories IUCN: CR: Critically Endangered, EN: Endangered, VU: Vulnerable.

RECOMMENDATIONS

Based on our findings, we suggest the following actions:

1) All threatened timber species according to IUCN Red List Categories deserve to be assessed by each country.

2) All timber species that have not been evaluated by IUCN, and their conservation status is unknown should also be assessed.

3) The species that are commercial (ITTO) and are threatened according to IUCN Red List Categories but are not listed in CITES appendices deserve also consideration for assessment.

4) The species that are more vulnerable under climate change and deforestation scenarios according to Gomes et al., (2019) must also be cautiously assessed.

Based on the important list of species presented in this work, it is imperative to consider the role of the Amazon Forest as a key element in the Earth system. A proper management should ensure that biophysical tipping points are not crossed that impede the Amazon Forest to maintain its ecosystem functions, or it could have devastating effects both locally and globally (Bastos Lima et al., 2021).

ACKNOWLEDGMENTS

We highly appreciate the willingness of the forest services of each Amazon country to share their information about timber species, facilitated by the generous support of the Amazon Cooperation Treaty Organization (ACTO) - Amazon Regional Observatory (ARO). We also acknowledge the official information provided by The International Tropical Timber Organization (ITTO). In addition, we recognized the support of the University of Leeds, the Government of Navarre and the Public University of Navarre for financially supporting Ximena Herrera-Alvarez.

LITERATURE CITATIONS

Bastos Lima, M. G., Harring, N., Jagers, S. C., Löfgren, Å., Persson, U. M., Sjöstedt, M., Brülde, B., Langlet, D., Steffen, W., & Alpízar, F. (2021). Large-scale collective action to avoid an Amazon tipping point - key actors and interventions. Current Research in Environmental Sustainability, 3(October 2020). https://doi.org/10.1016/j.crsust.2021.100048.

Cardoso, D., Särkinen, T., Alexander, S., Amorim, A. M., Bittrich, V., Celis, M., Daly, D. C., Fiaschi, P., Funk, V. A., Giacomin, L. L., Goldenberg, R., Heiden, G., Iganci, J., Kelloff, C. L., Knapp, S., De Lima, H. C., Machado, A. F. P., Dos Santos, R. M., Mello-Silva, R., … Forzza, R. C. (2017). Amazon plant diversity revealed by a taxonomically verified species list. Proceedings of the National Academy of Sciences of the United States of America, 114(40), 10695–10700. https://doi.org/10.1073/pnas.1706756114.

Gomes, V. H. F., Vieira, I. C. G., Salomão, R. P., & ter Steege, H. (2019). Amazonian tree species threatened by deforestation and climate change. Nature Climate Change, 9(7), 547–553. https://doi.org/10.1038/s41558-019-0500-2

IPCC. (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri, and L.A. Meyer (eds.)]. In Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change (IPCC, Vol. 9781107025). https://doi.org/10.1017/CBO9781139177245.003.

Ter Steege, H., Pitman, N. C. A., Sabatier, D., Baraloto, C., Salomão, R. P., Guevara, J. E., Phillips, O. L., Castilho, C. V., Magnusson, W. E., Molino, J. F., Monteagudo, A., Vargas, P. N., Montero, J. C., Feldpausch, T. R., Coronado, E. N. H., Killeen, T. J., Mostacedo, B., Vasquez, R., Assis, R. L., … Silman, M. R. (2013). Hyperdominance in the Amazonian tree flora. Science, 342(6156). https://doi.org/10.1126/science.1243092

Ter Steege, H., Prado, P. I., Lima, R. A. F. d., Pos, E., de Souza Coelho, L., de Andrade Lima Filho, D., Salomão, R. P., Amaral, I. L., de Almeida Matos, F. D., Castilho, C. V., Phillips, O. L., Guevara, J. E., de Jesus Veiga Carim, M., Cárdenas López, D., Magnusson, W. E., Wittmann, F., Martins, M. P., Sabatier, D., Irume, M. V., … Pickavance, G. (2020). Biased-corrected richness estimates for the Amazonian tree flora. Scientific Reports, 10(1), 1–13. https://doi.org/10.1038/s41598-020-66686-3

The International Tropical Timber Organization (ITTO) (2014a). Commercial species. Unpublished database provided by Ramón Carrillo (ITTO Communications Manager), Yokohama, Japan.

The International Tropical Timber Organization (ITTO) (2014b). Lesser Used Species (LUS). Unpublished databaseprovided by Ramón Carrillo (ITTO Communications Manager), Yokohama, Japan.

UNEP-WCMC (2021). Full CITES Trade Database Download. Version 2021.1. CITES Secretariat, Geneva, Switzerland. Compiled by UNEP-WCMC, Cambridge, UK. https://trade.cites.org/