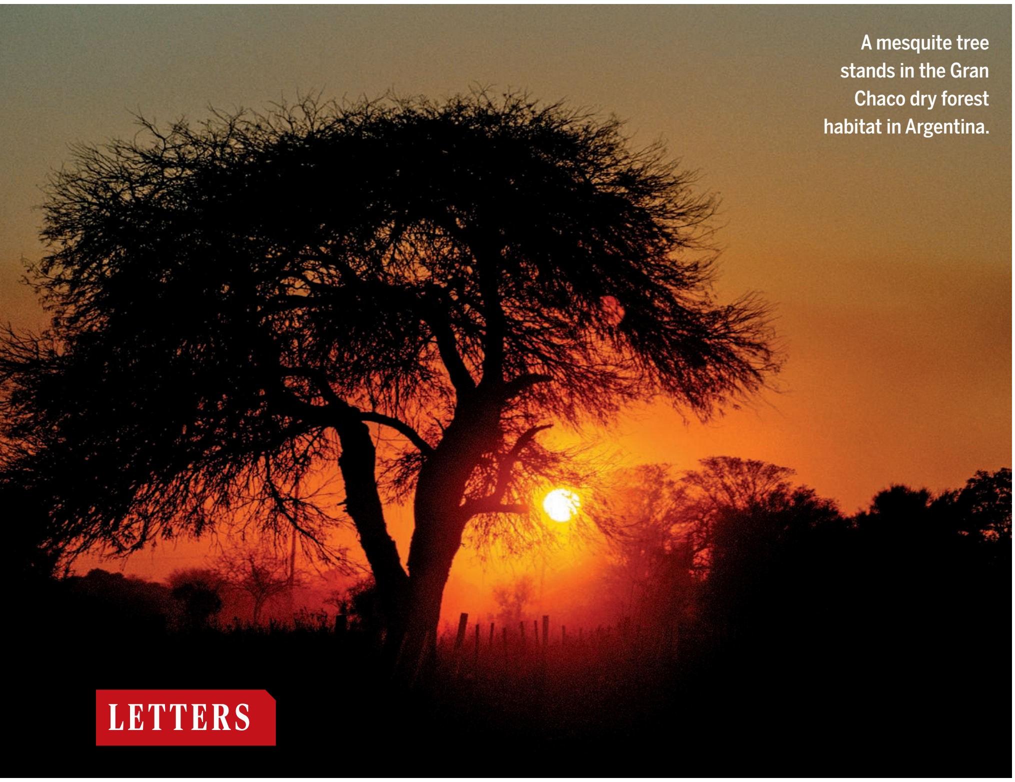

A mesquite tree stands in the Gran Chaco dry forest habitat in Argentina.

PHOTO: DANIEL GOMEZ/MINDEN

Edited by **Jennifer Sills**

Forest conservation: Remember Gran Chaco

TROPICAL AND SUBTROPICAL dry forests around the globe are experiencing rapid clearing and concomitant biodiversity loss (*1*). In their Research Article "Plant diversity patterns in neotropical dry forests and their conservation implications" (23 September 2016, p. 1383), DRYFLOR *et al.* highlight the often underappreciated, yet exceptional floristic richness and uniqueness of these forests, and they provide compelling arguments for ramping up efforts to protect them.

We applaud the DRYFLOR team for their seminal work, but we are also concerned about the exclusion of the Gran Chaco, frequently considered the world's largest continuous tropical dry forest region (*2*–*4*). The Gran Chaco covers more than 1,100,000 km^2 in Northern Argentina, Bolivia, Brazil, and Paraguay. The DRYFLOR team used a restrictive definition of dry forest that excludes the Gran Chaco because of some temperate elements in the Chaco's flora and occasional freezing temperatures there. However, that applies only to parts of the Gran Chaco, and other neotropical dry forests that were included in the analysis also experience such temperatures (*5*).

The Gran Chaco harbors high biodiversity, including many endemic species (*3*, *6*, *7*). This region is also a global deforestation hotspot (*8*) due to the recently accelerated expansion of cattle ranching and soybean cultivation there (*9, 10*). Given the agricultural potential of the region and the growing global demands for agricultural products, the pressure to convert additional natural ecosystems into agricultural land remains very high. Yet, only 9% of the Gran Chaco is currently protected (*6*). For these reasons, the Gran Chaco is one of the most threatened ecoregions worldwide. Various definitions of dry forests exist, but the Gran Chaco should not be neglected when raising awareness to the urgent conservation needs in the often forgotten neotropical dry forests.

Tobias Kuemmerle,[1,2]* Mariana Altrichter,[3] Germán Baldi,[4] Marcel Cabido,[5] Micaela Camino,[6] Erika Cuellar,[7] Rosa Leny Cuellar,[8] Julieta Decarre,[9] Sandra Díaz,[5] Ignacio Gasparri,[10] Gregorio Gavier-Pizarro,[9] Rubén Ginzburg,[11] Anthony J. Giordano,[12] H. Ricardo Grau,[10] Esteban Jobbágy,[4] Gerardo Leynaud,[12] Leandro Macchi,[1] Matias Mastrangelo,[13] Silvia D. Matteucci,[14] Andrew Noss,[15] José Paruelo,[16] Maria Piquer-Rodríguez,[1] Alfredo Romero-Muñoz,[1] Asunción Semper-Pascual,[1] Jeffrey Thompson,[17,18] Sebastián Torrella,[11] Ricardo Torres,[19] José N. Volante,[20] Alberto Yanosky,[17] Marcelo Zak[5]

[1]Geography Department, Humboldt-University Berlin, Germany. [2]Integrative Research Institute on Transformations of Human-Environment Systems (IRI THESys), Humboldt-University Berlin, Germany. [3]Department of Environmental Studies, Prescott College, AZ 86301, USA. [4]Grupo de Estudios Ambientales (IMASL), Universidad Nacional de San Luis & CONICET, San Luis, Argentina. [5]Instituto Multidisciplinario de Biología Vegetal (IMBIV)–CONICET & Facultad de Filosofía y Humanidades, Universidad Nacional de Córdoba, Argentina. [6]Centro de Ecología Aplicada del Litoral (CECOAL)–CONICET, Corrientes, Argentina. [7]Santa Cruz, Bolivia. [8]Fundación Kaa Iya, Santa Cruz, Bolivia. [9]Centro de Investigación en Recursos Naturales (CIRN-IRB), Instituto Nacional de Tecnología Agropecuaria (INTA), Buenos Aires, Argentina. [10]Instituto de Ecología Regional, Universidad Nacional de Tucumán, Yerba Buena, Argentina. [11]Departamento de Ecología, Genética, y Evolución, Universidad de Buenos Aires, Argentina. [12]Society for the Preservation of Endangered Carnivores and their International Ecological Study (SPECIES), Ventura, CA 93003, USA. [13]Grupo de Estudio de Agroecosistemas y Paisajes Rurales (GEAP), Universidad Nacional de Mar del Plata, Balcarce, Argentina. [14]Grupo de Ecología del Paisaje y Medio Ambiente, Universidad de Buenos Aires and CONICET, Argentina. [15]Department of Geography, University of Florida, Gainesville, FL 32611, USA. [16]Departamento de Métodos Cuantitativos y Sistemas de Información (IFEVA), Universidad de Buenos Aires and CONICET, Buenos Aires, Argentina. [17]Guyra Paraguay, Asunción, Paraguay. [18]Consejo Nacional de Ciencia y Tecnología (CONACYT), Asunción, Paraguay. [19]Museo de Zoología, Universidad Nacional de Córdoba, Argentina. [20]Estación Experimental Agropecuaria Salta, INTA, Salta, Argentina.

*Corresponding author.
Email: tobias.kuemmerle@hu-berlin.de

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Response

WE AGREE WITH Kuemmerle *et al.* that the forests in the Gran Chaco region are under massive threat, underprotected, and deserving of greater attention from scientists and conservationists. We could have included the Chaco woodlands in our analyses, and their distinctive flora would have reinforced our conclusions of high floristic turnover among neotropical dry forests. However, level of threat and the label of "dry forest," a term that has been notoriously loosely used across the neotropics (*1*–*3*), were not the criteria used in selecting sites for our study. Rather, we focused on sites in the neotropical dry forest biome as defined based on climatic, soil, hydrologic, physiognomic, and floristic characteristics (*4*, *5*). Based on these criteria, it is more biologically meaningful and relevant for conservation purposes to consider the Chaco woodlands as a distinct biome (*6*, *7*)—essentially a separate evolutionary metacommunity (*4*, *5*, *8*).

We did include sites from within the Gran Chaco region in our analyses, such as the Cerro León in Paraguay, because these are floristically and ecologically dry forests. However, we did not include sites from the Chaco woodlands (*6*, *7*) because these are dominated by a different, temperate-adapted flora. The Chaco woodlands receive regular and severe frost and also suffer the highest summer temperatures recorded in South America (*9*). We suggest that these extreme climatic conditions, added to saline soils and seasonal flooding in many areas (*6*), which contrast with the well-drained, fertile soils of tropical dry forests, have led to the distinctive evolutionary assembly of the temperate-adapted flora of the Chaco woodlands.

We agree with others (*5*) that there is a need to arrive at better, universally agreed-upon definitions of neotropical biomes, especially in seasonally dry areas and including the Gran Chaco region. For this reason, there are 50 inventories of Chaco woodland in the openly available DRYFLOR database (*10*). Exploring biome definitions at this continental scale will require quantitative analysis of how floristic composition and ecosystem function is influenced by environmental conditions and geographic distance across all major neotropical biomes, including rain forests, dry forests, and savannas. We predict that if the Chaco woodlands are included in such a broad-scale analysis, their highly distinctive flora would separate them as a biome at a continental scale, underlining the importance of conserving their unique plant diversity.

DRYFLOR[1]: R. Toby Pennington,[2]* Karina Banda-R,[2,3] Alfonso Delgado-Salinas,[4] Kyle G. Dexter,[2,5] Luciano Galetti,[6] Reynaldo Linares-Palomino,[7,8] Hernán M. Maturo,[6] Virginia Mogni,[6] Luis Oakley,[6] Ary Olivera-Filho,[9] Darién Prado,[6] Catalina Quintana,[10] Ricarda Riina,[11] Tiina Särkinen[2]

[1]Latin American and Caribbean Seasonally Dry Tropical Forest Floristic Network, Royal Botanic Garden Edinburgh, Edinburgh, EH3 5LR, UK. [2]Royal Botanic Garden Edinburgh, EH3 5LR, Edinburgh, UK. [3]Fundación Ecosistemas Secos de Colombia, Bogotá, Colombia. [4]Departamento de Botánica, Universidad Nacional Autónoma de México, México D.F., México. [5]School of GeoSciences, University of Edinburgh, Edinburgh, UK. [6]Cátedra de Botánica, IICAR-CONICET, Facultad de Ciencias Agrarias, Universidad Nacional de Rosario, S2125ZAA Zavalla, Argentina. [7]Universidad Nacional Agraria La Molina, Avenida La Molina, Lima, Perú. [8]Smithsonian Conservation Biology Institute, San Isidro, Lima, Perú. [9]Universidade Federal de Minas Gerais (UFMG), Instituto de Ciências Biológicas (ICB), Departamento de Botânica, Belo Horizonte, Minas Gerais, Brazil. [10]Pontificia Universidad Católica del Ecuador, Facultad de Ciencias Exactas, Escuela de Biología, Quito, Ecuador. [11]Real Jardín Botánico, RJB-CSIC, 28014 Madrid, Spain.

*Corresponding author.
Email: t.pennington@rbge.ac.uk

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Forest conservation: Humans' handprints

NEOTROPICAL FORESTS HAVE been home to humans since the end of the Pleistocene, and large pre-Columbian societies emerged in tropical dry forests in Central and South America and in wetter forests of the Amazon basin during the past several millennia. The role of humans in shaping species distributions, however, tends to be overlooked in ecological studies. For example, in their Research Article analyzing the largest data set of floristic inventories in neotropical dry forests ("Plant diversity patterns in neotropical dry forests and their conservation implications," 23 September 2016, p. 1383), DRYFLOR *et al.* mentioned humans occasionally, but not as a potential driver of the patterns observed.

Although DRYFLOR *et al.* showed neotropical dry forests to be dominated by woody plant species with geographically restricted distributions, 17 of the 4660 species recorded were widespread across dry forests, occurring in at least 9 of 12 floristic groups. Interestingly, 8 of these 17 widespread species are known to be cultivated today (*1*), and two of those have populations that were cultivated and probably domesticated by pre-Columbian societies (*Sapindus saponaria* and *Trema micrantha*) (*1*). Surprisingly, all eight widespread species of the dry biome that were cultivated by past or modern Amerindians also occur in Amazonian forests (*2*). Amazonian forests are partly dominated by useful species, a pattern that might result from past management activities (*2*). The widespread distribution of cultivated and/or domesticated species across wet and dry biomes suggests that human-plant interactions transcend ecological boundaries and supports the hypothesis of a substantial effect of past human societies in shaping plant distributions across the neotropics. Accordingly, it is important that ecological studies take into account the potential role of prehistorical and historical human dispersal as a driver of plant distributions within and among neotropical biomes.

Carolina Levis,[1,2]* Charles R. Clement,[3] Hans ter Steege,[4,5] Frans Bongers,[2] André Braga Junqueira,[6] Nigel Pitman,[7] Marielos Peña-Claros,[2] Flavia R. C. Costa[8]

[1]Programa de Pós-Graduação em Ecologia, Instituto Nacional de Pesquisas da Amazônia, Manaus, Amazonas, 69067-375, Brazil. [2]Forest Ecology and Forest Management Group, Wageningen University & Research, Wageningen, 6700 AA, The Netherlands. [3]Coordenação de Tecnologia e Inovação, Instituto Nacional de Pesquisas da Amazônia, Manaus, Amazonas, 69067-375, Brazil. [4]Biodiversity Dynamics, Naturalis Biodiversity Center, Leiden, The Netherlands. [5]Systems Ecology,

Trema micrantha has been cultivated in both tropical dry forests and Amazonian forests.

PHOTO: ALEX POPOVKIN/FLICKR

Free University Amsterdam, The Netherlands. [6]Department of Soil Quality, Wageningen University & Research, Wageningen, 6700 AA, The Netherlands. [7]The Field Museum, Chicago, IL 60605, USA. [8]Coordenação de Biodiversidade, Instituto Nacional de Pesquisas da Amazônia, Manaus, Amazonas, 69067-375, Brazil.

*Corresponding author.
Email: carollevis@gmail.com

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Response

WE AGREE WITH Levis *et al.* that humans have influenced dry forests since their first arrival in the neotropics. This long interaction has had major effects, not least in leading to widespread destruction of this now highly threatened vegetation (*1*). It is also possible, as pointed out by Levis *et al.*, that humans modified the distributions of useful woody plant species in dry forests and that this human influence could be partly responsible for their wide geographic distribution. However, the number of such species that are or were cultivated as a proportion of the overall flora of neotropical dry forests is small (8 out of the 4660 species in our data set, according to Levis *et al.*). We found high floristic turnover among major geographic areas of dry forest. This pattern is driven by the large numbers of range-restricted species in our data set: 3115 species are restricted to only one of the 12 regional floristic groups we identified. Therefore, the effect of geographically widespread species on our conclusions is negligible, whatever the reasons underlying their broad ranges.

Levis *et al.* suggest that the presence in the Amazonian rain forest biome of the same widespread, ecologically generalist, human-cultivated species found in the dry biome is surprising and may indicate that human-plant interactions transcend ecological boundaries. We find it more likely that the preferences of these species for disturbed areas underlie their wide distribution, given the high level of degradation of many dry forest sites. This would ultimately be a human effect, but one operating indirectly through the pioneer nature and wide ecological tolerances intrinsic to these species.

We agree that ecological studies should take into account the potential role of human dispersal as a driver of plant distributions in the neotropics (*2*), but we do not believe that the pattern of high floristic turnover that we described for dry forests, and its clear implication that many more protected areas are urgently required, is affected by previous human influence on the species' ranges.

DRYFLOR[1]: R. Toby Pennington,[2]* Karina Banda-R,[2,3] Alfonso Delgado-Salinas,[4] Kyle G. Dexter,[2,5] Reynaldo Linares-Palomino,[6,7] Ary Olivera-Filho,[8] Darién Prado,[9] Catalina Quintana,[10] Ricarda Riina[11]

[1]Latin American and Caribbean Seasonally Dry Tropical Forest Floristic Network, Royal Botanic Garden Edinburgh, Edinburgh, EH3 5LR, UK. [2]Royal Botanic Garden Edinburgh, EH3 5LR, Edinburgh, UK. [3]Fundación Ecosistemas Secos de Colombia, Bogotá, Colombia. [4]Departamento de Botánica, Universidad Nacional Autónoma de México, México D.F., México. [5]School of GeoSciences, University of Edinburgh, Edinburgh, UK. [6]Universidad Nacional Agraria La Molina, Avenida La Molina, Lima, Perú. [7]Smithsonian Conservation Biology Institute, San Isidro, Lima, Perú. [8]Universidade Federal de Minas Gerais (UFMG), Instituto de Ciências Biológicas (ICB), Departamento de Botânica, Belo Horizonte, Minas Gerais, Brazil. [9]Cátedra de Botánica, IICAR-CONICET, Facultad de Ciencias Agrarias, Universidad Nacional de Rosario, S2125ZAA Zavalla, Argentina. [10]Pontificia Universidad Católica del Ecuador, Facultad de Ciencias Exactas, Escuela de Biología, Quito, Ecuador. [11]Real Jardín Botánico, RJB-CSIC, 28014 Madrid, Spain.

*Corresponding author.
Email: t.pennington@rbge.ac.uk

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Forest conservation: Remember Gran Chaco

Tobias Kuemmerle, Mariana Altrichter, Germán Baldi, Marcel Cabido, Micaela Camino, Erika Cuellar, Rosa Leny Cuellar, Julieta Decarre, Sandra Díaz, Ignacio Gasparri, Gregorio Gavier-Pizarro, Rubén Ginzburg, Anthony J. Giordano, H. Ricardo Grau, Esteban Jobbágy, Gerardo Leynaud, Leandro Macchi, Matias Mastrangelo, Silvia D. Matteucci, Andrew Noss, José Paruelo, Maria Piquer-Rodríguez, Alfredo Romero-Muñoz, Asunción Semper-Pascual, Jeffrey Thompson, Sebastián Torrella, Ricardo Torres, José N. Volante, Alberto Yanosky and Marcelo Zak

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