EDINBURGH JOURNAL OF BOTANY 72(2): 225–233 (2015)

doi:10.1017/S0960428615000098

CEDRELA NGOBE (MELIACEAE), A NEW SPECIES FROM PANAMA AND COSTA RICA

A. V. Köcke[1,2], A. N. Muellner-Riehl[1,3,4], O. Cáceres[5] & T. D. Pennington[6]

We present a new species of Meliaceae, *Cedrela ngobe* Köcke, T.D.Penn. & Muellner, from Panama and Costa Rica. A detailed description with illustrations and a distribution map are provided. Based on distribution data and climatic niche modelling, the species is classified as Vulnerable according to IUCN Red List categories.

Keywords. Cedrela, Costa Rica, cuticle, IUCN conservation assessment, Meliaceae, morphology, niche model, Panama, species, stomata, taxonomy.

Introduction

Cedrela P.Browne is a genus of economically important hardwood timber trees in the Neotropics. It is distributed from Mexico through Central and South America to northern Argentina. The latest systematic treatment by Pennington & Muellner (2010) comprises 17 species. These occur in seasonally deciduous or evergreen rain forests. *Cedrela* is closely related to the genus *Toona* (Endl.) M.Roem. which occupies similar habitats throughout the Indo-Australian Archipelago and China. *Cedrela* and *Toona* together form the monophyletic group of Cedreleae within Meliaceae subfamily Swietenioideae (Muellner *et al.*, 2003). Although morphologically very similar, *Cedrela* and *Toona* differ in the structure of the androgynophore, the seed wing, and the point of attachment of the seed on the central columella of the fruit (Pennington & Muellner, 2010). Species distinctions in *Cedrela* are based on a combination of six morphological characters, viz.: number of leaflet pairs, amount and type of leaf indumentum, leaflet size, shape and venation, degree of union of sepals, adnation of the petal margins, and size of the capsule (Pennington & Muellner, 2010). We here

[1] Biodiversity and Climate Research Centre (BiK-F) & Senckenberg Research Institute, Department of Botany and Molecular Evolution, Grunelius-Moellgaard Laboratory, Senckenberganlage 25, D-60325 Frankfurt am Main, Germany. Author for correspondence: muellner-riehl@uni-leipzig.de
[2] Department of Biological Sciences, Institute for Ecology, Evolution and Diversity, Goethe University, Max-von-Laue-Str. 13, D-60438 Frankfurt am Main, Germany.
[3] Institute of Biology, Department of Molecular Evolution and Plant Systematics, University of Leipzig, Johannisallee 21–23, D-04103 Leipzig, Germany.
[4] German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, D-04103 Leipzig, Germany.
[5] Herbario UCH, Centro de Investigaciones Micológicas CIMI, Universidad Autónoma de Chiriquí, 0427, David, Chiriquí, Panamá.
[6] Herbarium, Royal Botanic Gardens, Kew, Richmond, Surrey TW9 3AB, UK.

describe a new species of *Cedrela* from Costa Rica and Panama which is distinct in most of these morphological traits. Molecular analyses also confirm that *Cedrela ngobe* represents a new species which is distinct from other species of *Cedrela*, with a close relationship to the Andean *C. nebulosa* T.D.Penn. & A.Daza, *C. saltensis* Zapater & del Castillo and another genetic entity here designated *C.* aff. *odorata* L. from Central and northern South America (Koecke *et al.*, 2013). *Cedrela* aff. *odorata* and *C. ngobe* are sympatrically distributed along the seasonal Pacific side of Central Panama to southern Costa Rica. In order to test for suitable climatic niches and for better estimation of an IUCN criterion, we perform climatic niche modelling of the new species, *Cedrela ngobe*.

Cuticular analyses are sometimes useful for identifying genus or species specific traits in addition to morphological characters. Stomatal architecture and type of indumentum can be taxon specific. Moreover, epidermal and cuticular traits may be preserved in fossil cuticles of carbonised leaves. Identification of fossils thus often depends on the identification of micro-characters. Leaf epidermal characters are therefore presented here together with the formal species description.

Species Description

Cedrela ngobe Köcke, T.D.Penn. & Muellner, **sp. nov.**

A speciebus aliis foliis 6–7-jugis, infra breviter puberulis, petalis 6–6.5 mm longis, capsula 4–6 cm longa differt. – Type: Panama, Comarca Ngöbe-Buglé, foothills of Cerro Guánico, *A.V. Köcke*, *O. Cáceres*, *H. Wessels & M. Piepenbring* 180409/02 (holo K; iso FR, PMA, UCH). **Fig. 1.**

Young branches 4–5 mm diam., smooth, pale buff, with some elongate lenticels, glabrous. *Leaves* (petiole + rhachis) 40–50 cm long, leaflets opposite, 6–7 pairs, 8 × 4 – 13 × 5 cm, ovate (apical pair), oblong-elliptic (middle pairs) or elliptic (basal pair), apex acuminate, base asymmetric, rounded on one side, acute to obtuse on the other, chartaceous, subglabrous above, minutely puberulous on the midrib and secondary veins below, domatia present in the axils of secondary veins below; venation eucamptodromous, midrib not raised or sunken on the upper surface, secondaries (8–)12–14 pairs, ascending, slightly arcuate, parallel or slightly convergent, tertiaries mostly oblique and parallel. *Petiole* c.10 cm long, finely and sparsely puberulous; petiolule c.1 mm long. *Inflorescence* terminal, plant flowering when in leaf, 12–24 cm long, a broadly pyramidal panicle, lowest lateral branches up to 14 cm long, the ultimate branches often cymose, sparsely puberulous; pedicel 0.5–1 mm long. *Calyx* 2–3 mm long, cup-shaped, irregularly and shallowly lobed and split down one side to near the base, sparsely puberulous outside. *Petals* 6–6.5 mm long, 1–1.25 mm broad, narrowly oblong, apex acute to obtuse, adnate to the androgynophore in the lower half, margins adnate for most of their length, pale tomentose outside, indumentum sparser inside. *Staminal filaments* (free portion), male: 1.5–2 mm long, glabrous, anthers c.1 mm long, glabrous; female: filaments shorter, with smaller, shrunken anthers and no

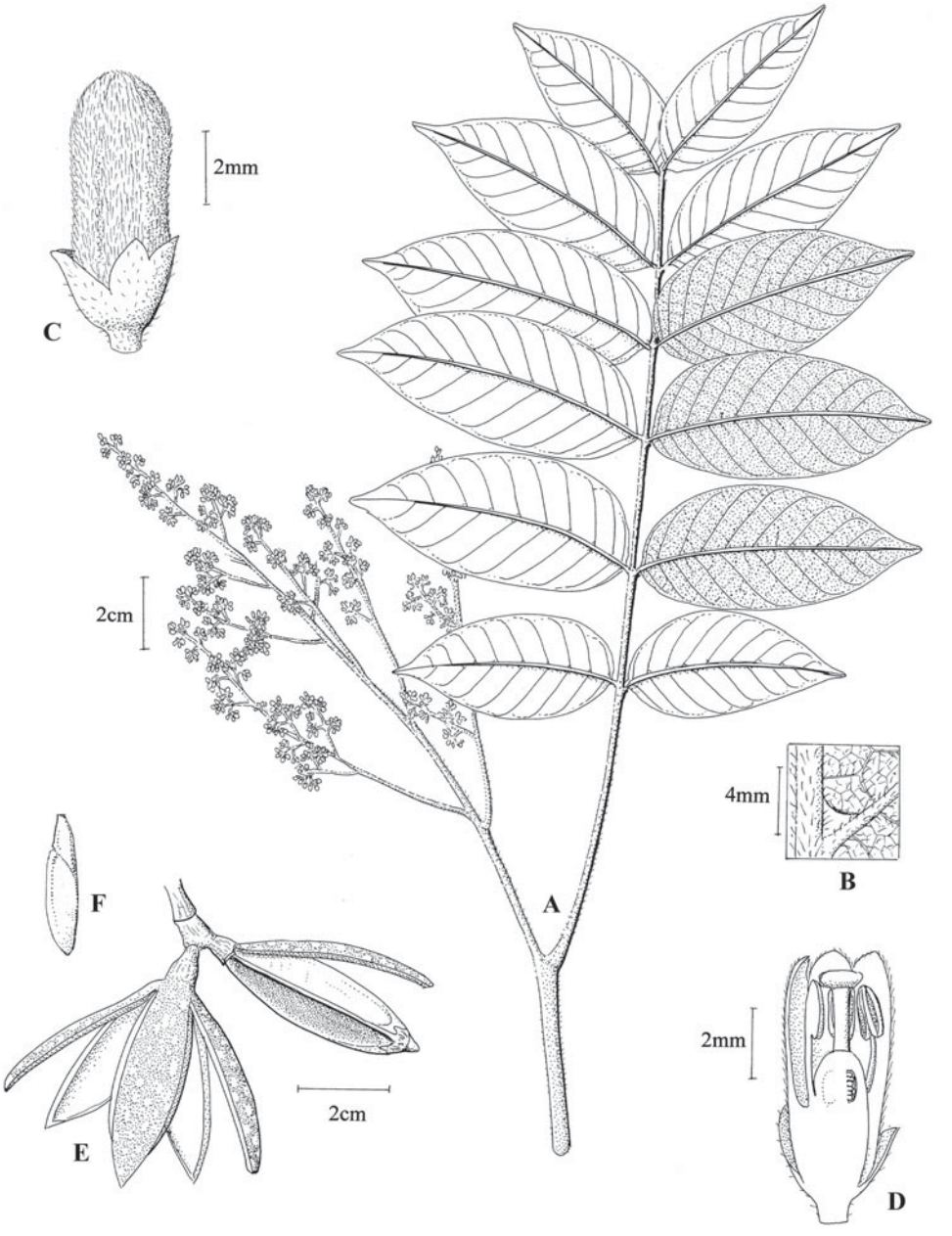

FIG. 1. *Cedrela ngobe* Köcke, T.D.Penn. & Muellner. A, leaf and inflorescence; B, detail of leaf undersurface; C, flower; D, cross section of a male flower; E, capsules; F, seed (A–D, *Köcke et al*. 180409/02; E–F, *Köcke et al*. 180409/01).

pollen, lower part of filaments fused to the androgynophore 1–1.5 mm long. *Ovary* borne at the top of the androgynophore, c.2 mm long, glabrous, female: loculi 5, each with 10–11 ovules in 2 rows, style c.2 mm long, with thick discoid style-head; male: pistillode longer and more slender with 5 small locules and vestigial ovules, style 2–3 mm long. *Capsule* pendulous, 4–6 × c.2.5 cm, ellipsoid, apex and base rounded, dark brown with pale lenticels, valves woody, 2–3 mm thick, columella 5-winged, seed attachment area 5–6 mm long. *Seed* 2.2–3.2 cm long (including the wing), brown.

Leaf epidermal characters (Fig. 2). Epidermal cells of adaxial and abaxial leaf sides polygonal with straight to slightly undulated anticlines. Cuticle striate. Stomata on abaxial leaf sides, agglomerated on and along the leaf veins, oval-shaped, anomocytic, 13–20 μm long. Aperture spindle-shaped with slender I-pieces at the poles. Abaxial leaf surface densely covered with simple multicellular hairs.

Field characters and phenology. Tree to 30 m tall, 50 cm dbh, bole cylindrical, bark whitish grey, regularly longitudinally fissured. Deciduous, leafless at the beginning of the dry season (end of December), in full leaf at the end of the dry/early wet season (in April). The flower colour varies from creamish white to green or yellow. Sterile specimens, especially from sucker shoots, have much larger leaves with more numerous leaflets. Cut surfaces and crushed leaves have a strong onion-like odour (pers. obs. A.V.K.). Annotations on herbarium vouchers describe it as foul, bitter or garlic-like. Flowering at the end of the dry season and early wet season (April to June), leaves present at flowering time; fruit maturing during the dry season.

Vernacular name and uses. Cedro de Sabana. The timber is used for furniture.

Distribution and ecology. Extending from southeastern Costa Rica throughout the southern Pacific (seasonal) side of Panama to the Canal Zone and on the San José Islands of the Perlas Archipelago in the Gulf of Panama (Fig. 3). It is a common species of (primary) semideciduous lowland forest (0–400 m).

Etymology. The new species is named in honour of an indigenous group of people in Panamá, the Ngöbe, who, living in their traditional way within the Panamanian Comarca Ngöbe-Buglé, have contributed to preserving primary forest in Central and Western Panama.

Climatic niche modelling. To estimate the accuracy of the distribution map and detect potential areas of occurrence, we performed maximum entropy modelling of the geographic distribution using the program Maxent (v.3.3.3k; Phillips & Dudík, 2008) based on the collection sites of 17 individuals of the new species and 19 climatic variables (Bioclim; Hijmans *et al.*, 2005). We used climatic layers with a resolution of 30s (c.1 km^2). The Maxent analyses were performed using 10 replicates. The average test AUC (Area Under the receiver operating Curve) values of the models were above 0.9. Results from the maximum entropy modelling (as indicated by the colour gradient in Fig. 3) show that climatically suitable habitats of *Cedrela ngobe* are only located in

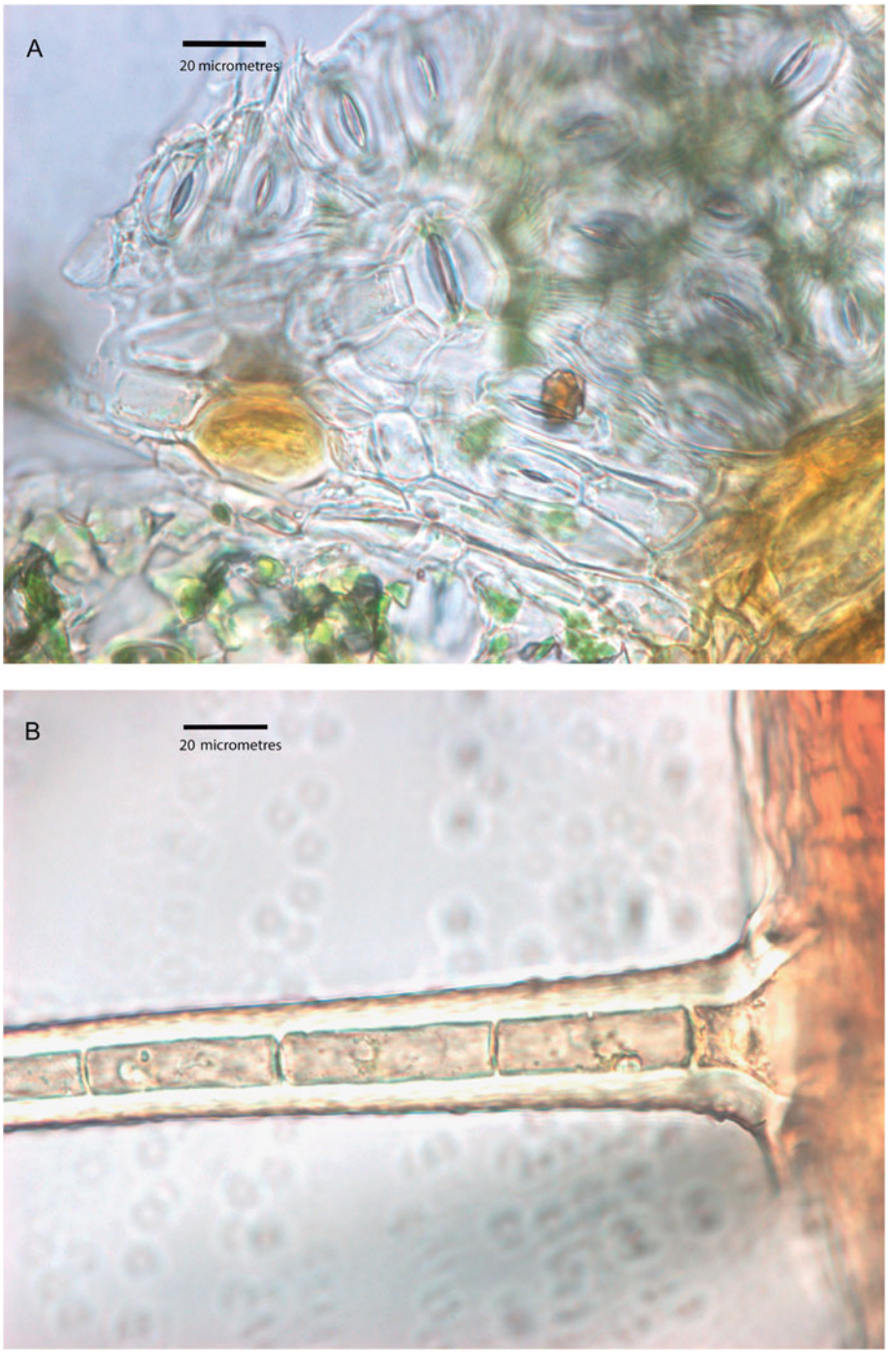

FIG. 2. Leaf epidermal characters of *Cedrela ngobe*. A. Stomata along vein on lower leaf side. B. Base of a multicellular trichome.

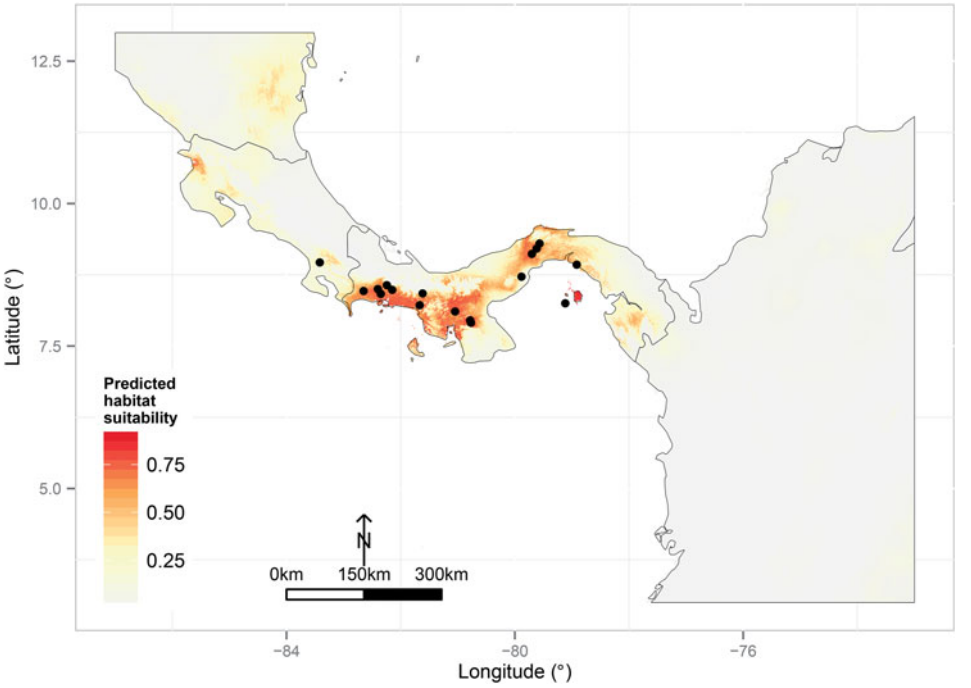

FIG. 3. Map of distribution and climatic niche suitability of *Cedrela ngobe*. The value of each grid cell represents the mean (average value) of the 10 models. The colour scale indicates the predicted suitability: low = 0 (light yellow), high = 1 (dark red).

southern Costa Rica and throughout Panama within comparatively small scattered areas.

Specimens examined. COSTA RICA. **Puntarenas**, Rio Grande de Terraba, vicinity of La Presa, about 3 miles above Palmar, *Allen* 5280 (A). Around **Alhajuela**, *Pittier* 3729 (NY-01239674).

PANAMA. **Chiriquí**, Ngöbe-Buglé: Nole Duime, Comunidad, de Llano Nopo, *Cáceres* 4003 (FR); along the interamerican highway between Chiriquí village and David, next to the bridge crossing Río Chiriquí, *Köcke et al.* 180409/01 (FR, K), *M. Piepenbring & O. Cáceres* 5195 (UCH). Ngöbe-Buglé, foothills of Cerro Guánico, *Köcke et al.* 180409/02 (FR, K, PMA, UCH); road to Gualaca, close to Bella Vista, *Köcke et al.* 220409/01 (FR, K); Los Algarrobos, *Munoz* 22 (MO-2901926); SE of La Tranca in pasture beside cliffs near Rio Caldera, *Schmalzel* 1560 (MO-5755198), (MO-5755199); pasture along road between David and El Hato, *Stern & Chambers* 103 (NY-01239675); **Herrera**, 10 mi S of Ocu, *Tyson et al.* 2827 (MO-1817269); vicinity of Ocu, *Allen* 4082 (MO-1600383); **Panama**, Canal Zone, *Blum* 680 (MO-1817743); between Santa Cruz and entrance to pipeline road, near Gamboa, near Canal zone, *Croat* 38307 (MO-2388650); Canal Zone, Madden forest, *Gentry* 2068 (MO-2692676); mouth of Rio Pasiga, *Gentry* 2205B (MO-2301774); Old Panama, *Getek* 3588 (MO-1138432); Arraiján, near the city, *Lao* 104 (FHO-00004467); on road to Cerro Campana, *Lazor* 5799 (MO-2593115); **Perlas Archipelago**, Gulf of Panama, San Jose Isl., *Johnston* 323 (MO-1590779); **Veraguas**, El Embalsadero, 8 miles west of Santiago, *Tyson* 6077 (MO-1973862); S of Santa Fe, *Nee* 8056 (FHO-00004477).

COLOMBIA. **La Guajira**, Via La Paz a Manaure, *Cuadros & Gentry* 3432 (MO-4007754).

Phylogenetic relationships. Molecular phylogenetics as well as network analyses based on the nuclear internal transcribed spacer (ITS) region and the plastid *psb*A-*trn*H region also confirm that *Cedrela ngobe* represents a new species which is genetically distinct from other species of *Cedrela* (Cavers *et al.*, 2013; Koecke *et al.*, 2013). Phylogenetic relationships show a close affinity to the Andean *Cedrela nebulosa*, *C. saltensis* and another genetic entity of *Cedrela* which is designated as *C.* aff. *odorata* from Central and northern South America (Koecke *et al.*, 2013). This corroborates previous phylogenetic and phylogeographic analyses, which uncovered the distinctness of some genetic entities within the broad species complex of *Cedrela odorata* sensu lato (Muellner *et al.*, 2009; Cavers *et al.*, 2013; Koecke *et al.*, 2013). From the current perspective, these entities comprise the newly described *Cedrela ngobe*, *C. cubensis* Bisse (from Cuba and the Cayman Islands), *C. odorata* sensu stricto (basically from northern Central America with some occurrences in South America), and *C.* aff. *odorata* (from southern Central and South America).

Notes. Sterile specimens of *Cedrela ngobe* were formerly associated with *C. fissilis* Vell. on account of the leaf indumentum, but the recent collection of flowering and fruiting specimens from Panama shows that it is morphologically distinct from this and all other species. The combination of characters that defines *Cedrela ngobe* is 6–7 pairs of subsessile leaflets, the lower surface of the leaflets puberulous on the midrib and secondary veins, petals 6–6.5 mm long, and capsule 4–6 cm long. *Cedrela fissilis*, which is not native in Central America, is clearly separable by its more numerous leaflets (10–17 pairs), longer petals (8–10.5 mm long), and much larger fruit (7–11 cm long). The sympatric *Cedrela* aff. *odorata* differs in the subglabrous lower leaflet surface, generally longer petals and distinct phenology (*C. ngobe* flowers at the end of the dry season and early wet season, *C.* aff. *odorata* at the end of the wet season and early dry season). Another species occurring in Panama is *Cedrela tonduzii* C.DC., but this is clearly distinct in its more numerous, larger leaflets (mostly 8–12 pairs, 14–20.5 cm long), longer petals (8.5–10 mm long) and distinct ecology (wet montane forest at 1000–2500 m elevation).

Conservation assessment. *Cedrela ngobe* is threatened by deforestation throughout southwestern and central Panama. Chiriquí and Veraguas provinces are among the most productive areas of crops and livestock farming and have thus undergone more extensive deforestation than other regions in Panama since the second half of the 20th century (Kaimowitz, 1996). Comarca Ngöbe-Buglé has experienced the greatest decline in forest cover since 1992 (ANAM, 2003; Parker *et al.*, 2004), and we predict that *Cedrela ngobe* will suffer further decline. Its distribution is fragmented; single trees sometimes occur as remnants of previously forested areas along streets and pastures. The largest extent of predicted climatic niche suitability covers the lowland areas of Chiriquí province, Veraguas province, and southern regions of Comarca Ngöbe-Buglé. To the east, potentially suitable habitats for *Cedrela ngobe* are found in the province of Panamá and on the Las Perlas Archipelago. Its occurrence further

east could not be confirmed, except for one questionable herbarium specimen from Colombia. The total area of occupancy of *Cedrela ngobe* is therefore estimated to be less than 2000 km^2 and has probably undergone a population size reduction of $\geq 30\%$ within the last decades, thereby meeting the IUCN criteria listed under A and B for Vulnerable (VU).

Acknowledgements

We thank the directors, curators and staff of A, FHO, FR, JE, K, MNHN, MO, NY, OXF, PMA and UCH for loan of specimens, or allowing the revision of herbarium material during our visits. The ANAM (Panama) kindly provided collection and export permits to Valerie Köcke. We are much indebted to Hauke Wessels (Hanau) and Meike Piepenbring (Universidad Autónoma de Chiriquí, Panama and Goethe University, Frankfurt M., Germany) and Daniel Cáceres (UCH) for help in the field and to Rosemary Wise, Department of Plant Sciences, Oxford, for producing the beautiful drawings. We thank Gaelle Bocksberger and Meike Piepenbring for helpful comments, and Caroline Pannell and an anonymous reviewer for comments and suggestions on an earlier version of this manuscript. Financial support was provided by the German Science Foundation (DFG) to A. N. Muellner-Riehl and T. D. Pennington (grant no. MU 2934/1-1), and the Research funding programme 'LOEWE − Landes-Offensive zur Entwicklung Wissenschaftlich-ökonomischer Exzellenz' of Hesse's Ministry of Higher Education, Research, and the Arts.

References

ANAM (2003). *Informe Final de Resultados de la Cobertura Boscosa y uso del Suelo de la Republica de Panamá: 1992–2000*. In: La Autoridad Nacional para el Ambiente (ANAM) y The International Tropical Timber Organization Panamá.

Cavers, S., Telford, A., Arenal Cruz, F., Pérez Castañeda, A. J., Valencia, R., Navarro, C., Buonamici, A., Lowe, A. J. & Vendramin, G. G. (2013). Cryptic species and phylogeographical structure in the tree *Cedrela odorata* L. throughout the Neotropics. *J. Biogeogr.* 40(4): 732–746.

Hijmans, R. J., Cameron, S. E., Parra, J. L., Jones, P. G. & Jarvis, A. (2005). Very high resolution interpolated climate surfaces for global land areas. *Int. J. Climatol.* 25(15): 1965–1978.

Kaimowitz, D. (1996). *Livestock and Deforestation in Central America in the 1980s and 1990s: A Policy Perspective*. Cifor.

Koecke, A. V., Muellner-Riehl, A. N., Pennington, T. D., Schorr, G. & Schnitzler, J. (2013). Niche evolution through time and across continents: The story of Neotropical *Cedrela* (Meliaceae). *Amer. J. Bot.* 100(9): 1800–1810.

Muellner, A. N., Samuel, R., Johnson, S. A., Cheek, M., Pennington, T. D. & Chase, M. W. (2003). Molecular phylogenetics of Meliaceae (Sapindales) based on nuclear and plastid DNA sequences. *Amer. J. Bot.* 90(3): 471–480.

Muellner, A. N., Pennington, T. D. & Chase, M. W. (2009). Molecular phylogenetics of Neotropical Cedreleae (mahogany family, Meliaceae) based on nuclear and plastid

DNA sequences reveal multiple origins of "Cedrela odorata". *Molec. Phylogen. Evol.* 52(2): 461–469.

PARKER, T., CARRIÓN, J. & SASMUDIO, R. (2004). *Tropical Forest Conservation, Protection, and Management in Panama: Assessment and Recommendations*. Section 118/119 Biodiversity and Tropical Forestry Assessment of the USAID/Panama Program Submitted to USAID/Panama by Chemonics International Inc.

PENNINGTON, T. D. & MUELLNER, A. N. (2010). *A Monograph of* Cedrela *(Meliaceae)*. Sherborne, UK: dh books.

PHILLIPS, S. J. & DUDÍK, M. (2008). Modelling of species distributions with Maxent: New extensions and a comprehensive evaluation. *Ecography* 31(2): 161–175.

Received 25 August 2014; accepted for publication 14 January 2015