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Preliminary assessment of the conservation status of timber species in the threatened piedmont dry forest of northwestern Argentina

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ABSTRACT

The piedmont dry forest of northwestern Argentina has been under intensive and unplanned forest logging focused on 12 tree species, without any attempts having been made to ensure their regeneration or long-term conservation. In this study, we assessed the conservation status of these timber species in the piedmont dry forest of northwestern Argentina and compared our results with the IUCN assessment. We considered an inadequate conservation status if the species: (1) occurred in less than 50 % of the sampled plots, (2) had a density of large trees (more than 40 cm DBH) lower than one in. ha^{-1}, or (3) had a density of saplings (more than 30 cm in height and less than 9.9 cm in DBH) lower than 30 in. ha^{-1}. Our results showed an inadequate conservation status for eight of the 12 studied timber tree species. Additionally, only seven species were previously assessed and categorized on the IUCN Red List, with our categorization agreeing with only four of them. The data provided in this work can serve as a baseline to monitor the population trends of these species; information can also help to prioritize conservation efforts, which is essential considering the high number of tree species that have potential extinction risk in the short-term.

1. Introduction

Unsustainable forest practices inevitably lead to forest degradation by hindering forest ability to regenerate and producing changes in forest structure and composition (Higman, Judd, Mayers, Bass, & Nussbaum, 2013) and by jeopardizing the maintenance of biodiversity and ecosystem services (Edwards, Tobias, Sheil, Meijaard, & Laurance, 2014; Noble & Dirzo, 1997). One of the most widespread forest practices is timber logging, with more than 400 million ha of tropical forest being actively managed for timber products worldwide (Blaser, Sarre, Poore, & Johnson, 2011). However, neotropical forests have few examples of long-term sustainability and most operations follow a mining strategy (Burivalova, Şekercioğlu, & Koh, 2014; Putz, Dykstra, & Heinrich, 2000). Unsustainable logging is the main global threat to more than a third of the tree species categorized globally as threatened (Oldfield, Lusty, & MacKinven, 1998; ter Steege et al., 2015). Natural forests must be managed for sustainable timber production and adequately protected (Keller et al., 2007). This is particularly relevant, given that demand for timber products is rapidly increasing worldwide, and one third of forest areal extent has already been transformed to other land uses (Damette & Delacote, 2011).

Neotropical dry forests are one of the most threatened forests in the world, with less than 10 % of their original extent being left (Banda et al., 2016). These dry forests have a wide but fragmented distribution from Mexico to Argentina; they are characterized by a marked dry season during which 70 % of the vegetation is deciduous (Banda et al., 2016). The piedmont forest is part of the neotropical dry forests, with a restricted distribution from southern Bolivia to northwestern Argentina (Prado, 2000); this ecosystem has a high conservation value (e.g., 37 endemic mammal, 11 fish, and 17 tree species) and is threatened by land use change (Politi & Rivera, 2019). However, less than 100,000 ha (8 %) of the piedmont forest are within national and provincial protected areas (Humano, 2013). The entire extent of the piedmont forest has historically been under unsustainable and intense forest logging (30,000 m^3/year) focused on 12 tree species, without any attempts having been made to ensure their regeneration or long-term conservation (Balducci, Eliano, Iza, & Sosa, 2012; Minetti, Bessonart, & Balducci, 2009). The most economically valuable tree species of the piedmont forest are *Myroxylon peruiferum*, *Amburana cearensis*, and *Cedrela balansae*; the species of intermediate economic value include *Myracrodruon urundeuva*, *Jacaranda mimosifolia*, *Anadenanthera colubrina*, *Handroanthus ochraceus*, *Handroanthus impetiginosus*, *Calycophyllum multiflorum*, and

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Phyllostylon rhamnoides; and the tree species of least economic value are *Parapiptadenia excelsa* and *Enterolobium contortisiliquum* (Brown, Grau, Lomascolo, & Gasparri, 2002; Humano, 2013). Logging operations carried out in the piedmont forest are based on minimum cut diameters that vary among species, with a range between 25 and 40 cm in diameter at breast height (DBH), whereas the extraction of *A. cearensis* is banned (Balducci et al., 2012; Politi, Rivera, Lizárraga, Hunter, & Defossé, 2015). Entry cycles in the piedmont forest are approximately of 20 years; this period is not sufficient, since it has been estimated that it takes more than 40 years for the piedmont forest to recover from logging (Balducci et al., 2012; Humano, 2013). Logged piedmont forests depend on natural regeneration. However, in logged forest areas, tree species density of seedlings and saplings is insufficient to maintain viable populations (Politi & Rivera, 2019). The lack of forest management planning in the piedmont forest has led to economic and ecological impoverishment and degradation (Politi & Rivera, 2019). For example, economic impoverishment has been related to the fact that some timber species, such as *A. cearensis*, *C. balansae*, and *M. peruiferum*, have become rare or with depleted timber stocks (Brown, Blendinger, Lomáscolo, & Bes, 2009; Politi & Rivera, 2019), whereas ecological degradation refers to a reduced density of cavity trees and snags, and a lower abundance of cavity-nesting bird species and disturbance-sensitive spider families in logged than in unlogged piedmont forests (Alcalde, Politi, Corronca, & Rivera, 2018; Politi, Hunter, & Rivera, 2010).

Sustainable timber extraction from natural forests is a strategy that generates economic income while ensuring the conservation of forests (Fredericksen & Putz, 2003; Guariguata et al., 2010; Hutton & Leader-Williams, 2003). However, sustainable logging management requires recommendations based on detailed knowledge of the timber species (Newton, 2008; Sist, García-Fernández, & Fredericksen, 2008). Particularly, population density, structure, and regeneration are relevant characteristics to determine the species status and are basic factors of forest management (Herrero-Jáuregui, Sist, & Casado, 2012). Most of the information on the density or population size structure available to support sustainable management in the piedmont forest fails to include the regeneration stratum for most timber species (Brown et al., 2009; Politi & Rivera, 2019). Conservation status of logged timber species must be carefully assessed because they may rapidly become threatened with extinction (Duncan & Young, 2000; Hunter & Gibbs, 2006). In this study, we assessed the conservation status of 12 timber species of the piedmont forest of Jujuy and Salta provinces in northwestern Argentina and compared the results with the International Union for Conservation of Nature (IUCN) assessment. The conservation status of each species was determined by assessing the occurrence of seedlings, saplings, and small and large adult individuals, and the density of large adults and saplings. We included four size categories to better assess the conservation status of each species, since seedlings and saplings are critical stages of the regeneration processes, and small and large adults can provide an insight into the environmental and disturbance conditions that the species was subjected to during its life cycle (Feeley, Davies, Noor, Kassim, & Tan, 2007; Hutchings, 1997). Understanding if natural regeneration is in good status is essential to correctly categorize the species and is the single most important step towards achieving long-term sustainability (Fredericksen, 1999). However, most ecological and forest management studies only focus on species population structure based on diameter distribution of adult trees, which can provide misleading information for sustainable management recommendations.

2. Materials and methods

2.1. Study area

In Argentina, there are two distinct environmental units within the piedmont forest characterized by the dominant tree species: one in the northern sector, in Jujuy and Salta provinces, dominated by *C. multiflorum* and *P. rhamnoides*, and the other in the southernmost distribution area, in Tucumán province, characterized by *Tipuana tipu* and *E. contortisiliquum*. The latter environmental unit has been almost completely transformed into agricultural areas, whereas the former still persists in Argentina. The northern sector has been categorized as a priority conservation area for its outstanding biodiversity, various timber and non-timber forest resources, and its importance in water regulation (Brown et al., 2009).

Study plots were established along a latitudinal gradient in the northern sector of the piedmont forest of Jujuy and Salta provinces, northwestern Argentina (Fig. 1). Plots were located within a continuous forest matrix, between 400 and 900 m asl, and covered the different management conditions in the region (e.g., protected areas, unlogged forest, conventional logging operations). A total of 225 0.05-ha plots were randomly delimited in 16 sites; within sites, plots were at least 100 m away from neighboring plots, and located more than 100 m from other land uses or infrastructure (Schwartz, Falkowski, & Peña-Claros, 2017). Sampling plots followed a nested plot design (Fig. 2) with four 0.001-ha subplots arranged within one 0.05-ha circular plot and one 0.0125-ha subplot within one 0.05-ha circular plot (Robi & Edris, 2017). However, 19 0.0125-ha subplots were not sampled due to logistical problems. The location of each plot was georeferenced with Garmin ETREX-20 GPS.

We selected the 12 economically valuable tree species of the piedmont forest of Jujuy and Salta provinces (Balducci et al., 2012; Minetti et al., 2009). For the selected tree species, we defined four size categories: (1) seedlings: individuals of less than 30 cm in height; (2) saplings: individuals of more than 30 cm in height and less than 9.9 cm in DBH; (3) small adult trees: individuals of a DBH between more than 10 cm and less than 39.9 cm; and (4) large adult trees: individuals of more than 40 cm in DBH. Total sampling effort varied among size categories: (1) seedlings were sampled in 900 0.001-ha circular plots; they were counted and their height was measured with a tape, (2) saplings were sampled in 206 0.0125-ha plots; they were counted and diameter at the base of the stem (DBS) was measured with a digital caliper; and (3) small and large adult trees were counted in 225 0.05-ha circular plots and DBH was measured with a tape (Newton, 2007). Identifying seedlings is a time consuming task that requires smaller plots but a greater sampling effort, which explains the unbalanced sampling effort (Clark et al., 1999). Within the 225 0.05-ha plots, we also recorded all non-timber species with a DBH of more than 10 cm and measured DBH of those species.

We determined mean and standard error ($X \pm SE$) of density, DBH, and basal area, grouping small and large adults of all selected timber and non-timber tree species. Because total sampling effort varied among size categories, for each category we calculated the density of the selected timber species as the number of seedlings, saplings, small, and large adults per hectare (ha^{-1}) and expressed them as $X \pm SE$. In addition, for each timber species we determined $X \pm SE$ of height of seedling, DBS of saplings, DBH of adult trees (grouping both small and large adult timber trees), and basal area of adult trees. For all the variables, $X \pm SE$ were obtained using InfoStat program version 2019p (Di Rienzo et al., 2019).

The occurrence of each timber species was calculated considering the percentage of plots in which the timber species was recorded. Additionally, the conservation status of each species was categorized as inadequate if any of the following criteria was not met: (1) occurrence in more than 50 % of the surveyed plots, (2) density of more than one large adult ha^{-1}, and (3) density of more than 30 saplings ha^{-1} (Villegas et al., 2008). The criteria used to define the species conservation status was assumed to indicate the ability of each species to maintain long-term population viability through natural regeneration and to withstand environmental and disturbance limitations (Esquivel, Harvey, Finegan, Casanoves, & Skarpe, 2008). Finally, we checked the conservation category of each species in the IUCN assessment (IUCN, 2020) and compared it with our findings.

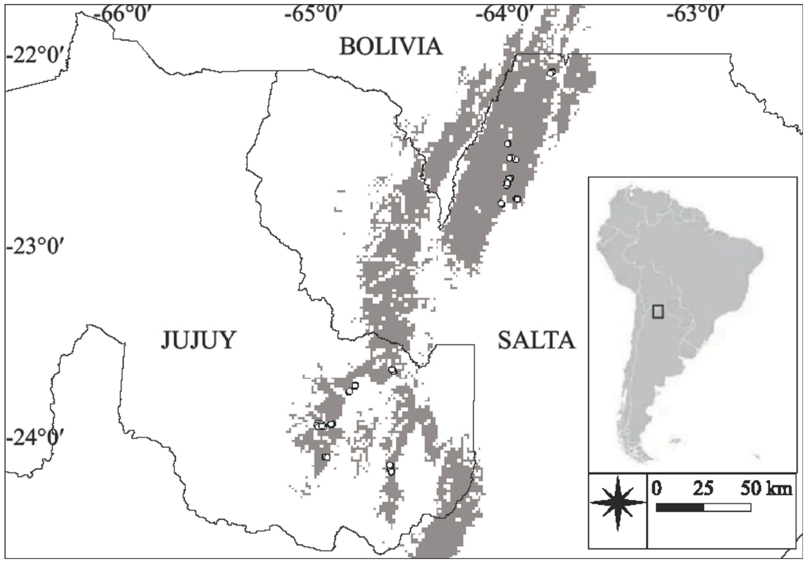

Fig. 1. Location of 225 0.05-ha sampling plots (white circles) in the piedmont forest (400 to 900 m asl; shown in gray) of Jujuy and Salta provinces, northwestern Argentina.

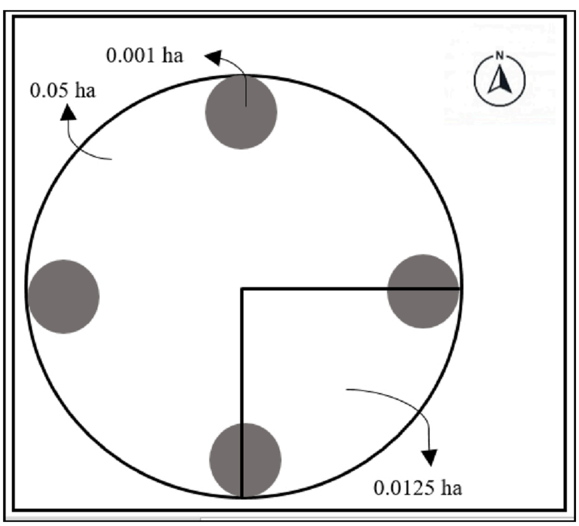

Fig. 2. Schematic representation of a 0.05-ha plot delimited for the survey of adults (i.e., individuals of more than 10 cm diameter at breast height (DBH)), a 0.0125-ha nested subplot for the survey of saplings (i.e., individuals of more than 30 cm in height and less than 9.9 cm in DBH), and 4 0.001-ha nested subplots for the survey of seedlings (i.e., individuals of less than 30 cm in height).

3. Results

The total accumulated sampling area was 0.9 ha for seedlings, 2.57 ha for saplings and 11.25 ha for adults. Seedling height was less than 10 cm in four tree species, between 10–19.99 cm in five species, and between 20−30 cm in two species (Table 1). Sapling DBS ranged between 20 and 50 mm in five species, being less than 20 mm in the remaining species (Table 1). Two species (*H. ochraceus* and *A. cearensis*) had a DBH of more than 40 cm, and three species (*A. colubrina*, *C. multiflorum* and *P. rhamnoides*) had a basal area of more than 1 m^2 ha^{-1} (Table 1). Four species (*M. urundeuva*, *M. peruiferum*, *A. cearensis*, and *C. multiflorum*) had a bell-shaped size class distribution and less than 100 seedlings ha^{-1}, whereas six species (*H. impetiginosus*, *A. colubrina*, *P. excelsa*, *E. contortisiliquum*, *C. balansae*, and *P. rhamnoides*) showed a reverse J shape and more than 100 seedlings ha^{-1}, and *H. ochraceus* showed a reverse J shape and fewer than 100 seedlings $ha{-}^{1}$ (Fig. 3). Species with fewer than 30 saplings ha^{-1} included *M. urundeuva*, *J. mimosifolia*, *H. ochraceus*, *E. contortisiliquum, A. cearensis*, and *C. balansae* (Fig. 3). Two species (*A. colubrina* and *P. rhamnoides*) had more than 40 small adults ha^{-1} and more than 5 large adults ha^{-1} (Fig. 3). No seedlings or adults (small or large) were recorded for *J. mimosifolia* and no large adults were recorded for *E. contortisiliquum* (Fig. 3).

Of the 12 selected timber species, three occurred in less than 5 % of the sampled plots, four occurred in 30–50 %, and five occurred in more than 50 % (Table 2). The conservation status was inadequate for eight of

Table 1
Height of seedling (Sdl H), diameter at the base of sapling (DBS), diameter at breast height (DBH) and basal area (BA) of small and large adults of 12 timber species and DBH and BA of timber and non-timber species in the piedmont forest of Jujuy and Salta provinces, Argentina. Values are shown as mean and standard error; the family of each tree species is indicated.

Family	Species	Sdl H (cm)	DBS (mm)	DBH (cm)	BA (m^2 ha^{-1})
Timber and non-timber				22.78 ± 0.20	19.41 ± 0.60
Anacardiaceae	*Myracrodruon urundeuva*	18.00 ± 5.39	23.22 ± 5.85	26.92 ± 1.68	0.99 ± 0.20
Bignoniaceae	*Jacaranda mimosifolia*	00.00 ± 0.00	18.10 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
	Handroanthus ochraceus	25.83 ± 0.83	10.68 ± 1.66	50.53 ± 11.88	0.05 ± 0.04
	Handroanthus impetiginosus	14.14 ± 0.71	13.37 ± 1.09	23.12 ± 1.61	0.36 ± 0.09
Fabaceae	*Anadenanthera colubrina*	6.36 ± 0.04	21.77 ± 2.67	25.36 ± 0.44	4.57 ± 0.32
	Parapiptadenia excelsa	5.20 ± 0.05	30.64 ± 2.48	20.09 ± 0.87	0.34 ± 0.06
	Enterolobium contortisiliquum	8.74 ± 0.41	12.81 ± 1.81	25.47 ± 4.01	0.01 ± 0.01
	Myroxylon peruiferum	18.43 ± 0.79	12.69 ± 0.54	26.55 ± 1.88	0.38 ± 0.08
	Amburana cearensis	25.00 ± 0.00	5.54 ± 1.66	43.68 ± 5.30	0.08 ± 0.04
Meliaceae	*Cedrela balansae*	6.20 ± 0.27	47.75 ± 4.88	27.70 ± 1.28	0.48 ± 0.08
Rubiaceae	*Calycophyllum multiflorum*	11.77 ± 1.34	38.16 ± 2.07	27.72 ± 1.01	1.39 ± 0.19
Ulmaceae	*Phyllostylon rhamnoides*	12.45 ± 0.22	18.91 ± 0.54	23.53 ± 0.46	2.64 ± 0.27

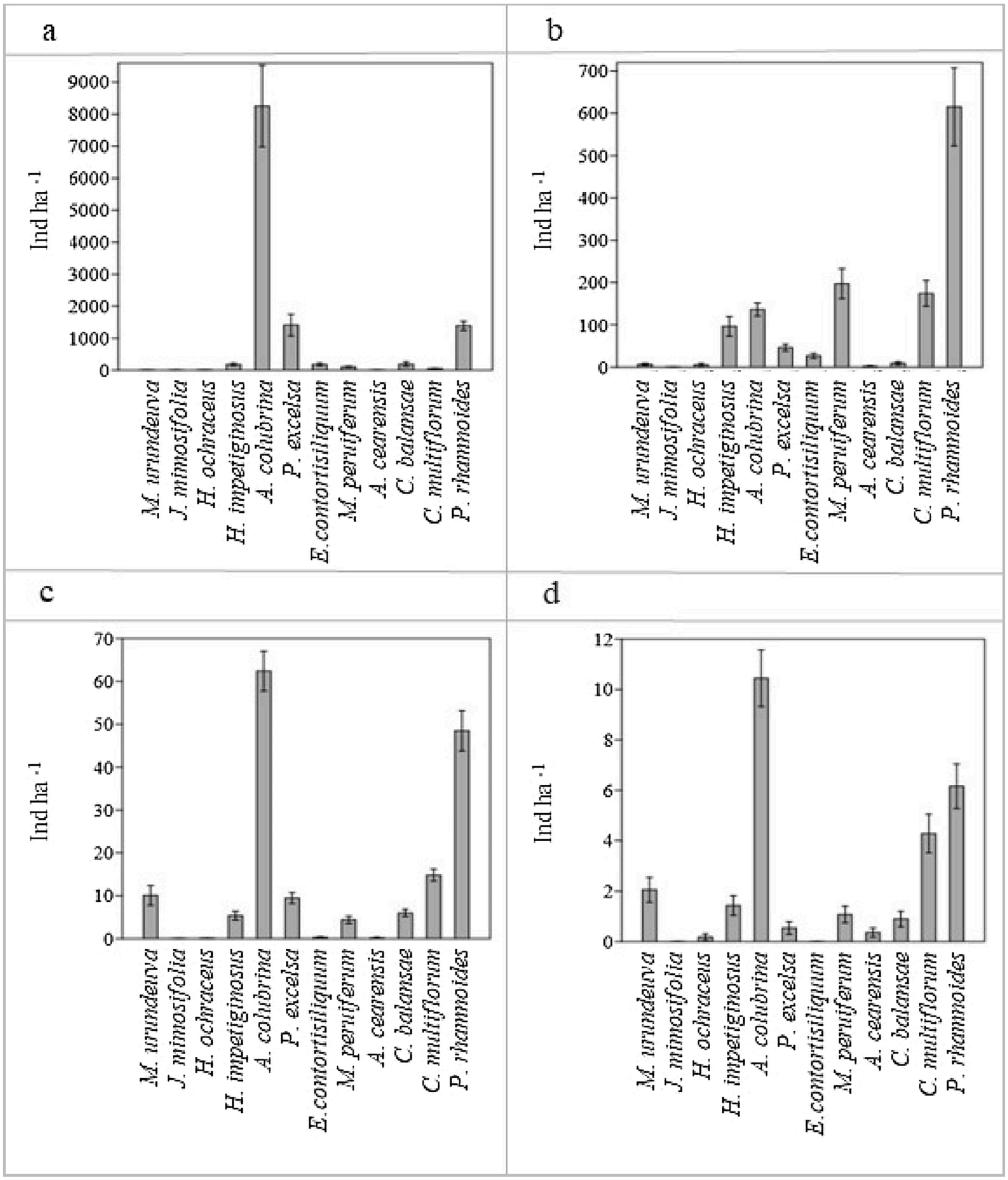

Fig. 3. Density of 12 timber species according to four size categories: (a) seedlings, (b) saplings, (c) small trees and (d) large trees in the piedmont forest of Jujuy and Salta provinces, Argentina. Values are shown as the mean and standard error of the number of individuals per hectare (ind ha^{-1}).

the 12 species (Table 2). Seven tree species were in some IUCN category and five have still not been assessed (Table 2).

4. Discussion

Here, we provide the first assessment of the conservation status of timber species in the piedmont forest of Jujuy and Salta provinces, Argentina, including the regeneration stratum, and a complete overview of the size structure of these species. Unfortunately, our results indicate that eight of the 12 studied species have an inadequate conservation status. The low occurrence of adult trees in the plots and their low density may increase the probability of extinction of these species (Sambuichi et al., 2008). The low density of large adults for the 12 species is of concern, since seed production increases with increasing tree diameter (Mostacedo et al., 2009). The decrease in seed production could affect the regeneration and therefore the stock of these species in the future (Politi & Rivera, 2019). Regeneration seems already compromised in half the studied timber species (*M. urundeuva*, *J. mimosifolia*, *H. ochraceus*, *E. contortisiliquum*, *A. cearensis,* and *C. balansae*), since it has been suggested that a density lower than 30 in. ha^{-1} in the regeneration stratum would be inadequate for tropical tree species (Villegas et al., 2008). Seven species exhibited a reverse J shaped size class distribution (i.e., a gradual decrease in the number of individuals in higher diameter classes), which suggests a good reproduction and potential recruitment of species (Dhaulkhandi, Dobhal, Bhatt, & Kumar, 2008). However, of those species, *E. contortisiliquum* showed an absence of individuals with DBH of more than 40 cm and *H. ochraceus, P. excelsa,* and *C. balansae* showed a very low density of that size category, which could result in a lack of recruitment in the future (Robi & Edris, 2017).

Table 2
Conservation status of 12 timber species from the piedmont forest of Jujuy and Salta provinces in northwestern Argentina and their category (LC: Least Concern; VU: Vulnerable; EN: Endangered; DD: data deficient; N: not evaluated) according to the International Union for Conservation of Nature (IUCN) assessment. The conservation status of each species was determined by multiplying the occurrence (1: if the species occurred in > 50 % of the sampled plots, or 0: if the species occurred in < 50 % of the sampled plots); the density of large trees (1: if the species had a density of > 1 large tree ha^{-1}, or 0: if it had a density < 1 large tree ha^{-1}); and the density of saplings (1: if the species had a density of > 30 saplings ha^{-1}, or 0: if the species had a density of < 30 saplings ha^{-1}). The conservation status of the species was considered adequate when all values were 1.

Family	Species	IUCN	Occurrence (%)	Conservation status (occurrence × large tree density × sapling density)
Anacardiaceae	*Myracrodruon urundeuva*	DD	28	$(0 \times 1 \times 0) = 0$
Bignoniaceae	*Jacaranda mimosifolia*	VU	0.04	$(0 \times 0 \times 0) = 0$
	Handroanthus ochraceus	N	3	$(0 \times 0 \times 0) = 0$
	Handroanthus impetiginosus	LC	44	$(0 \times 1 \times 1) = 0$
Fabaceae	*Anadenanthera colubrina*	LC	96	$(1 \times 1 \times 1) = 1$
	Parapiptadenia excelsa	LC	53	$(1 \times 0 \times 1) = 0$
	Enterolobium contortisiliquum	LC	31	$(0 \times 0 \times 0) = 0$
	Myroxylon peruiferum	LC	68	$(1 \times 1 \times 1) = 1$
	Amburana cearensis	EN	4	$(0 \times 0 \times 0) = 0$
Meliaceae	*Cedrela balansae*	N	31	$(0 \times 0 \times 0) = 0$
Rubiaceae	*Calycophyllum multiflorum*	N	67	$(1 \times 1 \times 1) = 1$
Ulmaceae	*Phyllostylon rhamnoides*	N	88	$(1 \times 1 \times 1) = 1$

Our results agree with the IUCN for four species; i.e., *J. mimosifolia* and *A. cearencis* are categorized as Vulnerable and Endangered, respectively, by the IUCN, and we categorized those species with an inadequate conservation status; and *A. colubrina* and *M. peruiferum* are categorized as Least concern by the IUCN and according to our results they have an adequate conservation status. For three other species, *H. impetiginosus*, *P. excelsa*, and *E. contortisiliquum*, our results differ from the IUCN assessment; i.e., they are categorized as Least Concern, but our results suggest that they have an inadequate conservation status. The IUCN assessment of most tree species has been made with little information or based on expert opinion (ter Steege et al., 2015), which could explain the differences from our assessment. Importantly, we also provide information on a Data Deficient species (*M. urundeuva*) and of four species still not categorized by the IUCN (*H. ochraceus, C. balansae, C. multiflorum,* and *P. rhamnoides*). We found that, of these five species the former three species have an inadequate conservation status, and the latter two have an adequate conservation status. Our results highlight the need for actions to ensure the long-term conservation of those species categorized with an inadequate conservation status, particularly because some species are naturally rare, while others might have undergone reductions in their population densities due to inadequate management or habitat loss, such as land use change (Hubbell et al., 2008; Peres et al., 2010; Sodhi et al., 2008). Furthermore, the information provided in this study may help to conduct a nationwide assessment –which currently is not available– to delineate management recommendations at the country level.

4.1. Species with an inadequate conservation status

The following eight species were found to have an inadequate conservation status:

(1) *H.impetiginosus.* The density of individuals with a DBH greater than 10 cm found in this study is higher than previously reported for the piedmont forest of Argentina (Malizia, Pacheco, & Loiselle, 2009), and higher than the density recorded in Bolivian forests (2.5 in. ha^{-1}) (Justiniano & Fredericksen, 2000). The density of the regeneration stratum was also higher in our study than in the Amazon forests (5.7 ± 3.8 in. ha^{-1}) (Schulze, Grogan, Uhl, Lentini, & Vidal, 2008). *H. impetiginosus* is widely distributed throughout tropical and subtropical forests of South America (Schulze et al., 2008).

(2) *P. excelsa.* This tree species has a wide distribution in the tropical and subtropical forests of South America. The density of individuals with more than 10 cm of DBH found in this work was higher than that previously reported in the study area (between 1.77 and 3.63 in. ha^{-1}) (Minetti et al., 2009).

(3) *E. contortisiliquum*. This is a typical species of the neotropical seasonally dry forest, although its distribution has been severely reduced due to land use change (primarily brought on by agriculture and urbanization) (Brown et al., 2009). We found a low density of trees of more than 10 cm DBH, as already reported (Lozano et al., 2016; Minetti et al., 2009).

(4) *C. balansae*. Previous density records of trees with more than 10 cm DBH of 5.4 in. ha^{-1} (Malizia et al., 2009) are higher than the value we obtained in this study. *C. balansae* is distributed throughout Central and South America, but occurs naturally at low densities and presents an aggregate spatial pattern (Koecke, Muellner-Riehl, Pennington, Schorr, & Schnitzler, 2013; Soldati, Fornes, Van Zonneveld, Thomas, & Zelener, 2013). Previous studies have indicated the need for additional conservation measures to safeguard the current genetic diversity of the species (Soldati, Fornes, Van Zonneveld, Thomas, & Zelener, 2013).

(5) *H. ochraceus*. This species has a wide distribution in the neotropical dry forests. Its occurrence in the plots was very low and coincides with the low probability of occurrence predicted by potential distribution models for the species (Vitorino, Lima-Ribeiro, Terribile, & Collevatti, 2018). The density of individuals of more than 10 cm of DBH recorded in this work is similar to that found in Bolivian forests (0.92 in. ha^{-1}) (Justiniano & Fredericksen, 2000).

(6) *M. urundeuva*. Previous records of density of individuals of more than 10 cm of DBH are variable (between 4.62 in. ha^{-1} and 24.6 in. ha^{-1}) (Malizia et al., 2009; Minetti et al., 2009). The species has a wide distribution throughout the seasonally dry forests of Brazil, Bolivia, Paraguay, and northwestern Argentina (Leite, 2002). The species has already been mentioned as requiring priority conservation actions and was considered one of the most threatened species in the Neotropics due to overexploitation (Leite, 2002). If unsustainable logging operations continue, the remaining populations may well approach critical extinction levels.

(7) *J. mimosifolia*. This species has a restricted distribution range in South America (Martínez, 2016). According to our results, it has the most inadequate conservation status of all the species evaluated in this study and deserves priority in conservation actions. Although logging of this species in northwestern Argentina is allowed with a minimum cut diameter of 30 cm DBH, it is not currently used by the wood industry, probably due to its low density (Eliano, Badinier, & Malizia, 2009). We found no previous records of the species density in the literature.

(8) *A. cearensis*. This species is widely distributed throughout the seasonally dry forests of South America (Leite, 2005), but has very low population densities (less than 1 in. ha^{-1}) (Malizia et al., 2009); therefore, it is necessary to implement the conservation actions already proposed for the species (Politi, Rivera, Lizárraga, Hunter, & Defossé, 2015).

4.2. Species with an adequate conservation status

According to our results, four species have an adequate conservation status:

(1) *C. multiflorum*. This species has a restricted distribution range through Bolivia, southwestern Brazil, Paraguay and northern Argentina along the narrow belt of neotropical dry forests (Santos Biloni, 1990). Previous studies reported densities of 25.9 in. ha^{-1} of individuals of more than 10 cm DBH (Malizia et al., 2009), which is slightly higher than the values we found.

(2) *P. rhamnoides*. This species is distributed from Mexico to northern Argentina (Killeen, García, & Beck, 1993), especially in xerophytic and seasonally dry forests. In the piedmont forest, previous records indicate a high density of trees of more than 10 cm DBH (51.7 in. ha^{-1}) (Malizia et al., 2009), which is similar to our results.

(3) *A. colubrina*. The density of trees of this species with more than 10 cm DBH recorded in this study was higher than previous findings for the piedmont forest of northwestern Argentina (65.2 in. ha^{-1}) (Malizia et al., 2009) and the forests of Bolivia (47.20 in. ha^{-1}) (Justiniano & Fredericksen, 1998). Its distribution is very wide in tropical and subtropical forests of the neotropics, where it is one of the most common tree species (Brown et al., 2009). The species started to be used in the forest industry in the mid-1990s (Justiniano & Fredericksen, 1998); sustainable management is recommended to ensure an adequate conservation status.

(4) *M. peruiferum*. The species has a wide distribution in South America. Our density records of trees with DBH of more than 40 cm was lower than previous findings (5 in. ha^{-1}) (Malizia et al., 2009). Although, our results show that the species stills maintains an adequate conservation status, in the Atlantic forest of Brazil it has been reported that unsustainable logging has increased the species vulnerability to extinction, producing a significant reduction in its population size (Silvestre et al., 2018). Therefore, it is recommended that sustainable forest management guidelines are implemented to ensure the species conservation.

5. Conclusion

Our results show the need for updating the IUCN assessment, which was conducted more than 20 years ago (Oldfield et al., 1998) as well as to make a national assessment in Argentina, which is currently lacking. We provide detailed information of the timber species, with an analysis of population structure including the regeneration stratum. This critical stage is usually omitted in most assessment studies, although it provides essential information to understand the long-term viability of species. Furthermore, the data provided in this work may serve as a baseline to monitor the population status in the piedmont forest and will allow us to prioritize conservation efforts, which is essential considering the high number of tree species that are potentially at risk of extinction (Newton et al., 2015).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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