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New records of *Tamarix ramosissima* Ledeb. (Tamaricaceae) in basins of Western Chaco dry forest, northwestern Argentina

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Abstract

Different species of the exotic plant *Tamarix* have been registered as colonizing natural and semi-natural environments in many provinces of Argentina. Nevertheless, the genus has not been cited for Tucumán or Santiago del Estero provinces, and not even for the Western Chaco dry forest ecoregion. The present work records the presence of *Tamarix* in riparian zones situated in different basins of Western Chaco ecoregion, namely in Tucumán and Santiago del Estero provinces, as well as the establishment of a *T. ramosissima* population in the Salí River basin in Tucumán.

Key words

Invasive alien plant; new record; Saltcedar; Tamarisk.

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Introduction

The expansion of invasive alien species is considered to be one of the main threats to the biodiversity of the world (Lowe et al. 2004, Nentwig 2007). One case of invasive alien species is the genus *Tamarix*, which corresponds to a group of species native to Africa and Eurasia that was introduced into different continents as ornamentals, windbreaks, and agents of erosion control (Glenn and Nagler 2005). In addition, some members of the *Tamarix* species complex, also known as Tamarisk or Saltcedar, have established and are well expanded in arid and semi-arid regions of the USA, Australia, and Mexico (Baum 1967, De Loach et al. 2000, Chambers and Hall 2001, Australia Weeds Committee 2003, Hart et al. 2005). Furthermore, the rapid expansion of Tamarisk has caused many environmental and economic impacts on the invaded regions (Colorado Department of Natural Resources 2004). For example, Tamarisk consumes higher quantities of water than native vegetation in its naturalized range, which has significant implications in regions marked by water scarcity (Zavaleta 2000). Besides, other implications of Tamarisk invasions have been registered, such as an increase in soil salinity (Cleverly et al. 1997, De Loach et al. 2000, Smith et al. 1998), changes in fire dynamics (Lovich 1996), as well as a decline in biodiversity and some ecological processes (Zavaleta 2000, Glenn and Nagler 2005).

In Argentina, 4 species of the genus were introduced: *T. gallica* L., *T. ramosissima* Ledeb., *T. chinensis* Lour., and *T. parviflora* DC.; the former 3 were recorded colonizing natural and semi-natural habitats (Natale et al. 2008). *Tamarix ramosissima* has been observed to be established in permanent and temporal water courses,

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floodplains, saline areas, and oceanic coasts from 70 to 2700 m above sea level (a.s.l). The presence of *T. ramosissima* was registered in the Argentinean provinces of Buenos Aires, La Pampa, Neuquén, Río Negro, Mendoza, San Luis, Córdoba, San Juan, La Rioja, and Catamarca. The flowering period of the species was recorded from November to the beginning of April, although in La Rioja province this period extends until July (Natale et al. 2008). In the last years several studies about different aspects of the ecology and distribution of *Tamarix* have been done in Argentina (Natale et al. 2010; Bedano et al. 2014; Natale and Reinoso, 2016). For instance, human disturbance, roads, and mainly water courses have been identified as drivers of Tamarisk dispersion (Natale et al. 2012). Natale et al. (2013) modeled a set of potential distribution maps for the genus in Argentina using precipitation, vegetation index, land surface temperature, and digital elevation model as environmental variables; they also predicted a rapid expansion of Tamarisk over arid and semi-arid regions of the country. Therefore, it is important to monitor and report any advance or changes in Tamarisk distribution.

The potential distribution maps modeled by Natale et al. (2013) include almost three-quarters of the arid and semi-arid regions of Argentina. Nevertheless, most of the arid and semi-arid forest of the Western Chaco ecoregion does not appear as a potential area for Tamarisk invasion on the maps. These results are quite remarkable given the arid and semi-arid features of the Western Chaco ecoregion. In the present study, the presence of Tamarisk is reported to occur in riparian zones of 3 sub-basins in Western Chaco ecoregion in Tucumán and Santiago del Estero provinces, Northwestern Argentina. Besides, in 2 locations an establishment of a *T. ramosissima* population was registered.

Methods

Study area. The riparian forest of 10 river sites were surveyed in Tucumán and Santiago del Estero provinces (Table 1). Eight of the sampling sites were located in the Salí River sub-basin, which is part of an endorreic basin that ends at the Mar Chiquita Lake in the province of Córdoba in the central part of Argentina. In Tucumán province, the main river of the sub-basin, called the Salí River, flows across the province from northwest to southeast, and it is dammed on the border with Santiago del Estero province, where the sampling area ends (Fig. 1). The other 2 sampling sites were situated in the Urueña River sub-basin, which is part of the Parana River basin. Sampling sites are located in 2 different ecoregions: Yungas subtropical cloud forest and Western Chaco dry forest (Brown and Pacheco 2006). The Yungas subtropical cloud forest, or Yungas forest, is a narrow belt of mountain rainforest, ranging from 400 to over 3000 m a.s.l (Brown 2000). The climate is warm and humid, with annual average temperatures ranging from 14 °C to 26 °C and rainfall from 1000 to 2500 mm (Hueck 1978). Western Chaco ecoregion is mainly a vast sedimentary fluvial plain formed essentially by the streams or rivers that flow through it from northeast to southwest. The headwaters are located in the mountains, outside the region, from where great quantities of sediments are transported. The vegetation is composed of dry forest and segregated grasslands. This ecoregion has been divided into 3 sub-ecoregions: Arid Chaco, Semi-arid Chaco, and Chaco Serrano (Brown and Pacheco 2006). Only the last 2 are represented in the study area. Chaco Serrano is part of the western limit of the ecoregion, characterized by low mountain topography and, depending on the location, this sub-ecoregion is bordered either by the Yungas forest or the Monte ecoregion. Semi-arid Chaco occupies the greatest extension of the ecoregion and a continuous xerophytic and semi-caducifolian forest. Between Western Chaco and the Yungas forest, there is a wide transition zone including species typical of both ecoregions.

Field study. Riparian vegetation was sampled through a longitudinal transect of 50 × 1 m. Three transects randomly distributed (left or right riparian margin) were surveyed in each sampling site. Transects were positioned in perpendicular direction to the river channel. The identity, basal area, and height of each arboreal and bushy individual were registered in each transect. Sampling was carried out during October 2015 and May 2016.

Identification. When *Tamarix* individuals were found in adult form, with flowers and fruits, branches were collected for their identification in laboratory. The samples were analyzed with stereomicroscope and identified according to the identification key proposed by Natale

Table 1. Sampling site locations, with *Tamarix* presence/absence.

River	Locality	Coordinates	Ecoregion	Code	*Tamarix*
Los Sosa	Tafi del Valle, Tucumán	26°59.23′ S, 063°39.82′ W	Yungas forest	Y1	Absent
El Sonador	Monteros, Tucumán	27°09.53′ S, 065°42.58′ W	Yungas forest	Y2	Absent
Pueblo Viejo	Monteros, Tucumán	27°11.48′ S, 065°40.20′ W	Yungas forest	Y3	Absent
Las Conchas	Yerba Buena, Tucumán	26°47.07′ S, 065°20.28′ W	Yungas forest	Y4	Absent
Tala	Trancas, Tucumán	26°13.32′ S, 065°15.25′ W	Western Chaco	C1	Present
Salí	San Vicente, Trancas, Tucumán	26°28.53′ S, 065°12.69′ W	Western Chaco	C2	Present
Urue*ña*	7 de Abril, Burruyacú, Tucumán	26°13.62′ S, 064°32.20′ W	Western Chaco	C3	Present
Urueña	El Remate, Santiago del Estero	26°15.28′ S, 064°29.65′ W	Western Chaco	C4	Present
Marapa	Lamadrid, Tucumán	27°39.43′ S, 065°14.98′ W	Western Chaco	C5	Present
Chico	Monteagudo, Tucumán	27°31.33′ S, 065°16.07′ W	Western Chaco	C6	Absent

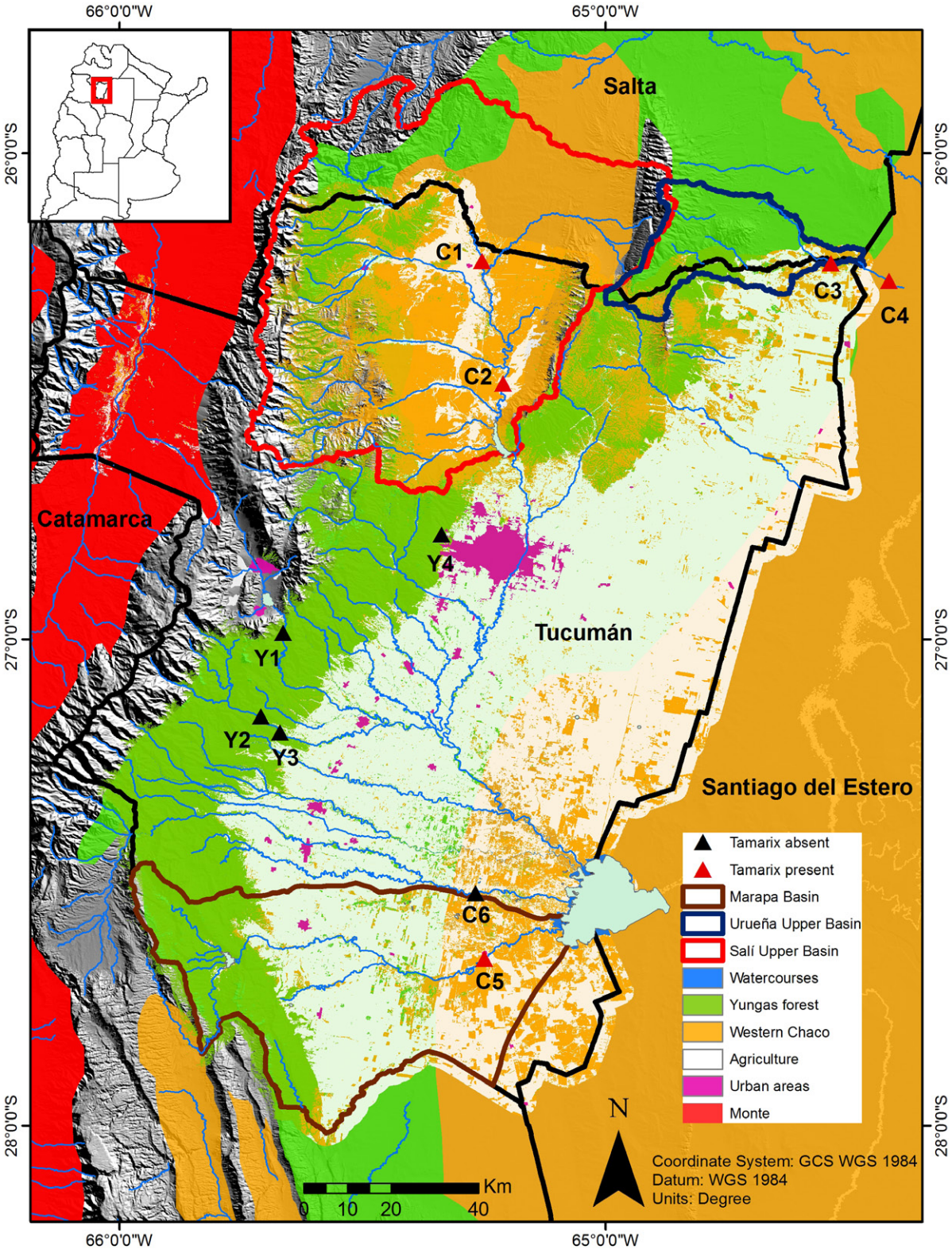

Figure 1. Study area with the location of sampling sites (red triangles=*Tamarix* present, black triangles=*Tamarix* absent) and the delimitation of river basins [Marapa basin, Urueña upper basin and Salí upper basin and ecoregion areas (colored zones)]. Urban and agriculture areas are showed for Tucumán province.

et al. (2008). All samples were identified by the flower features. Following Natale et al. (2008), the filament (F) joined to the nectar disc (D) and the dentate sepal (S) made it possible to identify the species (Fig. 3A). The samples were also sent to Evangelina Natale, an expert in the taxon, for confirmation. The collected material was deposited in the Miguel Lillo herbarium in Tucumán, Argentina (Voucher number: LIL 616.355).

Results

New records. *Tamarix ramosissima*: Argentina, Tucumán, Trancas, (26°13.32′ S, 065°15.25′ W), Edgardo Javier Ignacio Pero, October 2015, LIL 616.355, number of individuals: 100. Argentina, Tucumán, Lamadrid, (27° 39.43′ S, 065°14.98′ W), Edgardo Javier Ignacio Pero, May 2016, photographed, 2 individuals. *Tamarix sp*.: Argentina, Tucumán, San Vicente, Trancas, (26°28.53′ S, 065°12.69′ W), Edgardo Javier Ignacio Pero, October 2015, photographed, 10 individuals. Argentina, Tucumán, Burruyacú, 7 de Abril, (26°13.62′ S, 064°32.2′ W), Edgardo Javier Ignacio Pero, December 2015, photographed, 5 individuals. Argentina, Santiago del Estero, Nueva Esperanza, El Remate, (26°15.28′ S, 064°29.65′ W), Edgardo Javier Ignacio Pero, December 2015, photographed, 10 individuals.

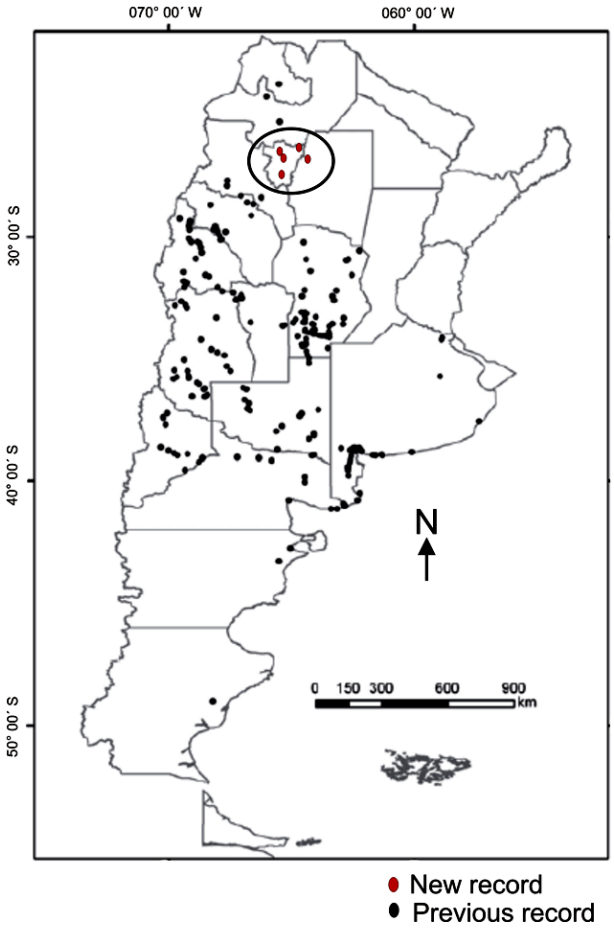

Figure 2. Previous and new records of *Tamarix* in Argentina (modified from Natale et al. 2008).

The presence of *Tamarix* was registered in 5 of the 10 sampled sites (Fig. 1) and for the first time in Tucumán and Santiago del Estero provinces (Fig. 2). All the sites where Tamarisk was found are located in Western Chaco ecoregion. Individuals in adult form with flowers and fruits were found only in 2 sites, and in both cases the specimens were identified as *T. ramosissima*. In site C1, a population of *T. ramosissima* was found, and it was composed of more than 100 individuals of around 19.6 cm^2 of basal area and 2 m in height, covering an area of approximately 6,000 m^2 (Fig. 3B. This population was found in a flowering period both in October to December 2015 and in May 2016. The other site where adults of *T. ramosissima* were found was C5, which is located in riparian zones of the Marapa River in the locality of Lamadrid, Tucumán. In this site, 2 specimens were registered in a flowering stage. These specimens were the biggest of all the specimens recorded in the sampling, reaching 103.2 cm^2 of basal area and approximately 4 m in height. On the other hand, in the other sites where *Tamarix* individuals were found there were less than 10 individuals and only small specimens of less than 50 cm in height. These sites were C2, located in riparian zones of the Salí River, which continue from the Tala River, and C3 and C4, which are situated in riparian zones of the Urueña River, separated

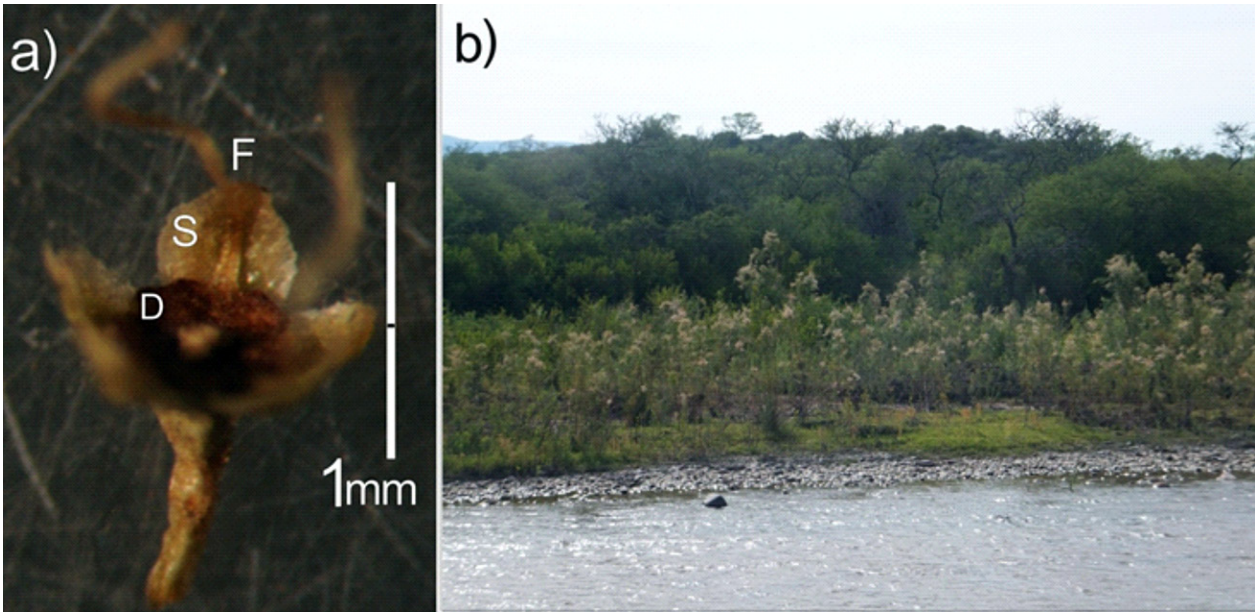

Figure 3. *Tamarix ramosissima*: **a)** flower; see the detail of the filament (F) joined to the nectar disc (D) and the dentate sepal (S), features that make it possible to identify the species (Natale et al. 2008); **b)** population of *T. ramosissima* in flower in the riparian zone of site C1.

by 8 km, the former in Tucumán province and the latter in Santiago del Estero province (Table 1).

Discussion

The report of *Tamarix* in Western Chaco ecoregion must raise an alert for monitoring a possible advance of this alien taxon in the area, mainly because of the invasive history of its species in other regions of the world. In addition, the records of Tamarisk presence included the discovery of an established population in a reproductive stage, as well as the presence of juvenile specimens in closer sites. These results could indicate that the taxon is effectively dispersing in the region. However, there is 1 site where only 2 specimens were found. These specimens were the biggest recorded in the study area, which could indicate that this population is older than those of the other sites. Remarkably, these specimens were surrounded by a high number of individuals of another species, *Tessaria integrifolia* L., which is indigenous and very common in riparian zones of Western Chaco. *Tessaria integrifolia* was also observed in site C1, occupying similar habitats to those where *T. ramosissima* was established, with both species apparently competing with each other. The situation of the *T. ramosissima* population found in site C5 poses the question of whether it could be similar to a future condition of the population of site C1. It would therefore be interesting to monitor the state of the *T. ramosissima* populations and their possible competition with *T. integrifolia*.

In the sampling sites located in the Yungas subtropical cloud forest, no specimens of Tamarisk were registered. Although the absence of Tamarisk in Yungas forest sites was expectable because of the humid conditions of Yungas environments, these data are useful for developing potential distribution maps. Conversely, Western Chaco ecoregion is characterized by arid and semi-arid habitats with dry forest and grasslands, similar to those where Tamarisk is native and to those where other invasions have been recorded. Therefore, it is feasible to expect that Tamarisk could expand in Western Chaco environments, mainly because most of the registered specimens were in a juvenile stage and others were established and effectively reproducing. Nevertheless, Western Chaco areas were not recorded as potential areas for the advance of Tamarisk in the proposal of Natale et al. (2013).

There could be several reasons why the Western Chaco areas were not considered potential distribution areas in the models. The use of absence data could generate false negatives because of the restriction of the model to identify some areas as potential locations for the establishment of a species. In some cases the use of this absence data could mislead the results because the species absence could be related to historical factors, local extinctions, or biological interactions, and not to environmental restrictions (Kadoya et al. 2009). In any case, Natale et al. (2013) acknowledged these limitations of their models. In addition, differences in the invasive behavior of Tamarisk species were observed in other continents, such as Australia and North America (De Loach et al. 2000, Chambers and Hall 2001, Australia Weeds Committee 2003, Hart et al. 2005). Thus, it would be important to have more species-level data, because potential distribution maps were developed from generic-level data. Furthermore, environmental variables used for the development of potential distribution maps were mainly climatic. Considering that *T. ramosissima* has an ecological relation with hydrological cycles (Zavaleta 2000, Natale and Reinoso 2016), it would be important to consider hydrological variables for future studies. Consequently, these methodological issues should be taken into account in the process of modeling potential distribution maps for alien species.

The presence of Tamarisk in other ecoregions of northwestern Argentina, such as the Monte ecoregion, is well registered (Natale et al. 2008). The Monte ecoregion forms an ecotone, or transition zone, with Western Chaco in some areas. Hence, Tamarisk may have dispersed through these areas by wind or water courses, reaching Western Chaco zones. Nevertheless, in some of the sites where Tamarisk was registered, such as the Salí River basin, the mentioned ecotone does not occur. On the contrary, in this basin, Yungas cloud forest is located between Monte and Western Chaco (Fig. 1). Therefore, it is remarkable the possibility that Tamarisk specimens were able to disperse from Monte areas, across the humid Yungas forest, and reach the lowland zones of Western Chaco. It is also possible that Tamarisk specimens were dispersed by human interactions. Nevertheless, the presence of *Tamarix* has not been documented in urban or rural areas of Western Chaco before. It would be important to study other similar South American ecoregions, such as the Brazilian Cerrado, as potential ecosystems for the establishment of *T. ramosissima*, because of these 2 ecoregions have comparable environmental features.

To conclude, Western Chaco could be considered a potential area for the advance of Tamarisk, mainly because of its environmental features and the establishment of the *T. ramosissima* populations registered in the present study. The early detection of alien species, while their populations are still in a primary stage of establishment, is favorable for their future control (Inglis et al. 2006). Therefore, it is important to consider these new records of Tamarisk presence in Western Chaco to raise the alert, promote more extensive samplings, and evaluate the probable advance of this alien plant in the region.

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