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Conservation priorities in the Southern Central Andes: mismatch between endemism and diversity hotspots in the regional flora

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Abstract North western Argentina, the southernmost portion of the tropical Andes, contains one of the main areas of endemism within the Southern Cone, as well as one of the main diversity hotspots of the country. Historically its reserve area systems have been located in the richest ecoregion of the area; the Southern Andean Yungas. We evaluated the effectiveness of the current protected areas in preserving the endemic flora of the region. The distributions of 505 endemic species were either modeled or included as observed data to determine endemism hotspots in each ecoregion. The endemic species were mainly found in arid ecoregions such as the High Monte and the Central Andean Puna, as well as in the transition zones between these regions and the Southern Andean Yungas. We found that more than 1/3 of the endemic species are unprotected in their entire ranges by the current system, while nearly half of the species are protected in only 5 % of their distribution ranges. New priority areas were chosen to increase the effectiveness based on the irreplaceability concept. We show that adding 251 new cells of 100 km^2 each would improve the protection values and convert the system to effective. The present paper highlights that priorities set on the basis of species richness may not successfully conserve areas of high plant endemism. However, zoologist would have to realize similar assessments in the endemic fauna in order to find the optimal designed of protected areas system to conserve both the endemic flora and fauna in the Southern Central Andes.

Keywords Southern Central Andes · Arid environments · Argentina · Conservation · Endemism · Vascular plants

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Introduction

Systematic conservation planning has been developed in order to identify protected area systems where biodiversity aspects would effectively be represented (Margules and Pressey 2000). In addition, areas with high endemism have been indicated as promising areas for conservation (Myers et al. 2000). Endemic species are restricted to a specific geographical area which means they occur there and nowhere else (Cowling 2001). These species represent the result of complex evolutionary and ecological processes that themselves merit high conservation priority (Young et al. 2002). Furthermore, narrow endemic species are under a higher extinction risk than more widely distributed species as range restricted species are more vulnerable in scenarios of environmental change (Gaston 1994; Mittermeier et al. 1998). Nonetheless, areas of high endemism are still underrepresented in protected area systems around the world (Rodrigues et al. 2004a, 2004b).

With the intention of prioritizing socio-economics resources and time, the spatial congruence between hotspots of richness and endemism has been widely studied (Ricketts 2001; Orme et al. 2005; Lamoreux et al. 2006). If areas with high diversity also tend to present higher levels of endemism, protecting these areas would imply the protection of a high amount of endemic species. However, the spatial congruence between richness and endemism appears to be scale-dependent and vary across taxonomic groups (Ricketts 2001; Orme et al. 2005; Lamoreux et al. 2006; Xu et al. 2008).

The tropical Andes are one of the most important areas of endemism at global scale, but also one of the most threatened and least studied (Myers et al. 2000; Orme et al. 2005). Its endemics taxa are the result of migrations of several lineages from other regions, as well as events of speciation driven by the Andean uplift (Antonelli et al. 2009). The southernmost portion of the tropical Andes lies within north western Argentina (NOA) which was identify by Zuloaga et al. (1999) as one of the most diverse regions of Argentina harboring more than 39 % of its endemics vascular plant species. Recent studies have suggested the existence of several independent areas of endemism within the NOA region (Aagesen et al. 2012), with many endemic species classified as highly threatened and vulnerable by the List of Endemic Vascular Plants Species from Argentina (Villamil et al. 2010). Despite this fact, in terms of systematic conservation planning studies, Argentina's endemic vascular flora is still poorly studied.

Currently, only 7.71 % of the Argentinean territory is protected with most of the reserve area systems historically selected "ad hoc" without considering important aspects of biodiversity such as endemism (Administración de Parques Nacionales 2007). Within NOA most of the protected ecoregions (following Olson et al. 2001) are high diversity sites including humid forest and foggy grasslands (Izquierdo and Grau 2009). A spatial congruence between hotspots of species richness and hotspots of species endemism has been found within the region, but at a very local scale and with specific plant families (Aagesen et al. 2009—Poaceae in the province of Jujuy; Ortega-Baes et al. 2012—Cactaceae in the province of Salta). Ortega-Baes et al. (2012) also found that the actual system of protected areas in the Salta province was effective in protecting most of the Cactaceae species; 81 % of which were endemic to Argentina. If spatial congruence exists at regional level and most protected areas are located in high diversity hotspots, an effective representation of the endemic flora is expected. However, this may not be the case within NOA if the entire region and all endemic vascular plants are considered together since the main areas of endemism were found in semi-arid slopes and valley systems of the Andes with little or no endemism in the species rich humid forest (Aagesen et al. 2012).

The NOA region is being affected by climatic and anthropogenic activities (Grau et al. 2005; Izquierdo and Grau 2009). Land use conversion is causing the loss of large quantities of land in ecoregions such as the Central Andean Dry Puna, the Central Andean Puna, and the Dry forest -termed "Dry Chaco" according to Olson et al. 2001 (Gonzales 2009; Izquierdo and Grau 2009). The presence of cattle (grazing), erosion, industrial activities, mining exploitation, and contamination of water supplies are other important threats in the region (Gonzales 2009). Increased precipitation and temperature, termed "tropicalization of climate" (Gonzales 2009), are manifestations of climatic change that worsen the situation. Thus, urgent conservation strategies need to be implemented if the endemic flora is to be preserved adequately. In order to advance in systematic conservation planning studies of the area, the present study aims to: (1) Determine hotspots of endemism in each of the ecoregions of the study area. (2) Assess the effectiveness of the current protected areas (CPA) in conserving endemic vascular plant species along the NOA region establishing different conservation targets and (3) Identify potential and alternative conservation areas to expand the existing reserve network to improve actual conservation values.

Methods

Study area

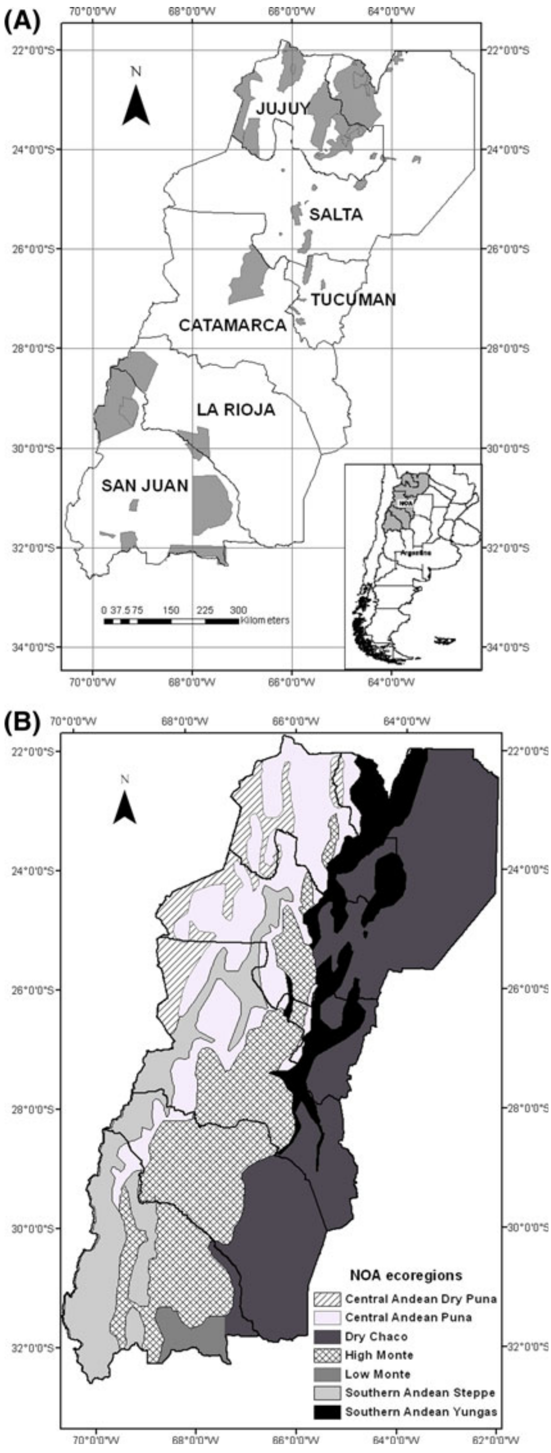
The study area encompasses the provinces of Jujuy, Salta, Tucumán, Catamarca, La Rioja, and San Juan in the north western region of Argentina (NOA, Fig. 1a). It covers an area of about 560,000 km^2, comprising an estimate distance north–south of 1,227 km. and covering an altitudinal range from 180 to above 6,000 m asl (Gonzáles 2005; Fig. 1a, b).

The NOA region is characterized by a climatic heterogeneity that is the product of latitudinal and altitudinal gradients as well as geomorphological variations. Predominantly, there are two kind of climates; warm and humid (subtropical) and cold and dry (arid) associated with the availability of moisture laden masses along different altitudinal limits (Bianchi and Yañez 1992). The precipitation follows a monzonic regime and varies from abundant on the eastern Andes slopes to scarce on the western slopes (Minetti 2005). The temperature also oscillates within the area, with large thermal amplitudes between day and night as well as frosts in some places (Minetti 2005). The climatic conditions allow the presence of seven ecoregions in the area: six arid/semiarid regions (Southern Andean Steppe, Central Andean Dry Puna, Central Andean Puna, Dry Chaco, High Monte, and a small part of Low Monte, Olson et al. 2001, Fig. 1b) and one humid region known as the Southern Andean Yungas (sensu Olson et al. 2001, Fig. 1b) or the Tucumano-Bolivian Yungas sensu Ibisch et al. (2003).

Data

The present study was based on all vascular plants species identified in each of the 16 most important areas of endemism of the NOA region (Aagesen et al. 2012). A total of 505 endemic species from 65 different families of vascular plants were studied (See Table 2 in Appendix). The database was compiled by Aagesen et al. (2012). It was obtained from the Vascular Plants Catalog Project (Zuloaga et al. 2008), the main database of Argentinean vascular flora, available and updated on Documenta Florae Australis Database. The dataset includes information from herbarium specimens, literature, and field collections, all properly georeferenced (according to the point-radius method, Wieczorek et al. 2004). We analyze two sorts

Fig. 1 **a** Geographical location of north western Argentina (NOA). **b** Ecoregions of NOA sensu Olson et al. (2001)



of data; observed data (235 species) and transformed predicted distribution data (270 species). Observed data refers to occurrence data points whereas predicted transformed distribution refers to the adjusted potential distribution of the species using an arbitrary threshold (Carvalho et al. 2010). Although modeled distributions tend to overestimate the area of a species range (Gaston and Fuller 2009), the observed data tend to subestimate it (Solano and Feria 2007). A "mixed" dataset allows for more cost-efficient conservation solutions as it tends to balance omission and commission errors (Carvalho et al. 2010).

The administration of national parks (APN) of Argentina provided the shapefiles of the current system of protected areas in Argentina which includes national parks, provincial parks, natural monuments, biosphere reserves, natural reserves, private reserves, and other categories of protected areas (Administracion de Parques Nacionales 2007, Fig. 1a). We selected the protected areas located within our study area (43 areas, Fig. 1a). The system covers an area of 64, 348 km^2 (11, 5 % of NOA region) with most of the areas concentrated in the Jujuy province and protecting forest and highlands environments (montane areas and foggy grasslands, Izquierdo and Grau 2009, Fig. 1a). All protected areas were used without discrimination of size.

Endemic species hotspots

To identify hotspots of endemism we determined the endemic species richness of each cell of the study area (5,386 cells of 100 km^2 each) and within each of the ecoregions of the NOA. Maxent's ecological niche modeling (Phillips et al. 2006) was selected to model species potential distribution as it outperforms other similar algorithms, particularly, when few records of species occurrence are available (Elith et al. 2006; Hernandez et al. 2006; Pearson 2007; Ortega-Huerta and Peterson 2008; Kumar and Stohlgren 2009). Bioclimatic variables to modeling species distribution were obtained from WorldClim (Hijmans et al. 2005). The accuracy of the resulting models of distribution was tested applying the area under the ROC curve (AUC) criterion. The AUC is an index of habitat suitability ranging between 0.00 (highly unsuitable) and 1.00 (highly suitable) and displays the probability that a randomly chosen presence site will be ranked above a randomly chosen absence site (Phillips et al. 2006). Models with AUC values above 0.7–0.75 are considered potentially useful (Pearce and Ferrier 2000). In this study all species obtained an AUC higher than 0.7 (See Table 2 in Appendix).

From the potential distribution of the species, we calculated a more adjusted distribution to balance commission and omission errors (Carvalho et al. 2010). This procedure also allows obtaining more practical information for conservation proposes (Liu et al. 2005). The step was achieved by converting the maps with a continuous probability of distribution (from 0 to 1) into binary presence/absence maps (0/1). Conversion was reached by setting an arbitrary threshold (0.8) to the distributional range so that only the 20 % most suitable were considered in the analysis (Pearce and Ferrier 2000). Subsequently, all species distribution maps were superposed to a NOA's grid to calculate the corresponding richness values.

Conservation priorities of the regional flora

The study area was divided in 5,386 hexagonal planning units (PU) of 100 km^2 each (*see* Birch et al. 2007; Nhancale and Smith 2011). To analyze the actual system of protected areas we consider a cell protected if more than 52 % of its surface overlapped with a protected area. Following this criterion a total of 461 planning units were considered as protected areas. Marxan's software was used to perform all analyses (Game and Grantham 2008).

Gap analyses were used to evaluate the efficiency versus omissions of the actual reserve network (Jennings 2000). To identify gap species (species unprotected by the current conservation system), a criterion of what is considered protected (or covered) species was set by the establishment of different conservation targets. Conservation/representation targets could refer to a species presence within one or more protected areas or to the representation of a minimal percentage of the species geographic range within the system of reserves. However, Rodrigues et al. (2004a) indicated that 'simple presence' of a species may not be enough to ensure long term persistence of viable populations. Thus, we proposed as targets that at least a 5, 10, 15, 20, 25 or 50 % of the adjusted distribution of each species have to be covered by the current system of protected areas. If a species met the proposed target it was considered a protected (covered) species. Conversely, if a species was not represented in any protected area it was considered a gap species while partial gap species were those that fulfill a lower portion than the one established by a given target (Rodrigues et al. 2004a). The entire protected area system was considered effective when the total percentage of species adequately protected, considering any target, was higher than 60 %.

As the system was classified as ineffective in protecting all endemic plants species of the NOA region, new potential cells that increase conservation values were identify. The selection of cells complementary to the actual system of protected areas was done based on the irreplaceability concept (Game and Grantham 2008). Irreplaceability referrers to the frequency of selection by which a given cell appears among the planning units within a set of possibilities to create an efficient system of reserves (Game and Grantham 2008). It ranges from 0 (an unnecessary site to achieve targets) to 100 % (a necessary site to meets target, without replacement).

If the conservation goals are to be fully achieved, a representation of all species is necessary. This is difficult if not impossible to achieve, not only in terms of amount and availability of priority sites but also for the higher costs that this goal involves. To each of the resultant solutions from the analyses (for each representation target) a selection of the areas with highest values of irreplaceability (>70 %) was made. Finally, to evaluate the effectiveness percentage of the "added cells", the analyses were repeated including the newly selected units as a necessary part of the protected area system.

Results

Endemic species hotspots

Hotspots of plant species endemism at a regional scale were concentrated in the arid ecoregions of NOA. The highest concentrations of endemics were found mostly in the Central Andean Puna and High Monte environments, especially between transition zones from the Southern Andean Yungas to the High Monte, and from the Southern Andean Yungas to the Central Andean Puna (Fig. 2). The most important hotspot is located in the Sierra del Aconquija, between the provinces of Tucuman, Salta and Catamarca and includes 57–73 endemic species (Fig. 2). This hotspot coincides with a transition zone between the High Monte and the Southern Andean Yungas (Fig. 2). Other important areas such as Calchaquies Valleys in Salta and Andalgalá, Santa Maria, Ambato, as well as Sierra de Ancasti and Sierra de Manchao in Catamarca contain between 30 and 56 endemic species (Fig. 2). Several minor areas (including 11–29 endemic species) are scattered unevenly mainly within Jujuy and to a lesser extent in Catamarca, La Rioja and San Juan

(Fig. 2). The cold spots (with less than 3 endemic species) are mainly located in the Dry Chaco, High Monte and the Central Andean Puna ecoregions in the provinces of Salta, La Rioja, and part of Catamarca and San Juan (Fig. 2).

Conservation priorities of the regional flora

Of the 505 endemic species analyzed, we identified 186 gap species (36.8 %, Fig. 3). Depending on the target established, the number of covered and partial gap species varied. In general terms, an increment in the representation target caused a decrease in the number of covered species, and consequently an increase in the number of partial gap species (Fig. 3). However, in none of the cases did fully covered species reach values high enough to consider the protected system effective (Fig. 4). The highest protection value reached was 52.3 % of the endemic species protected with a target representation of 5 %. The lowest protection value was 19 % but with a target representation of 50 % (Fig. 4).

Of the 16 most important areas of endemism defined by Aagesen et al. (2012) only two areas have more than half of their total species covered (Fig. 5); Jujuy (69 %) and Western San Juan (50 %). The Jujuy–Tucuman, Talampaya, NOA, and Southern San Juan areas followed with a considerable number of species under protection if the total of endemic species *per* area is considered (35/84 species, 2/4 species, 19/52 species and 3/10 species respectively; Fig. 5). Jujuy and Tucuman, which are among the best collected areas of the region, contained the major concentration of endemics species (238) but endemism is mainly unprotected in the individual area of Tucuman (14 of 62 endemic species, Fig. 5). When consider endemic species *per* area, Famatina in La Rioja and Ambato in Catamarca are the most deficient areas in conservation terms since none of them have species under protection. The remaining regions have intermediate values of covered species (Fig. 5).

Marxan provides a solution for each of the established targets. The more ambitious the target, the higher was the amount of planning units needed to achieve a maximum representation of the species. For example, when the target was to protect at least the 5 % of the geographic range of all species, it was necessary to add 898 new planning units to the current system of protected areas. Higher targets such as protecting 50 % of the distribution of all endemic species requires adding 1,915 planning units to the system (See Table 1). Since the implementation of the most ambitious targets would be difficult and very costly, intermediate targets such as protecting a 15, 20 or 25 % of all species ranges seems to be the most pragmatic solution (Table 1). As a result, a large percentage of species could be protected while covering a relatively small surface (Table 1; Fig. 6), bearing in mind that bigger targets (25 %) imply a major protection of each species range ensuring its long term conservation and viability.

By applying the irreplaceability concept, we selected a minimum number of planning units to be considered priority for endemic plants conservation. A total of 251 new planning units are proposed to be included in the current system of protected areas (cells with irreplaceability >70 %). When these areas were added to the actual system of protected areas and the analyses were repeated, an increment in the percentage of protected species was observed (Fig. 4; Table 1). This increment ranged from 61 % to 86 % depending on the target representation considered (Fig. 4; Table 1).

In nearly all cases the system of protected areas was shown to be effective in protecting the diversity of endemic plants with exception of the most ambitious target (50 %), in which case effectiveness only reach 45 % (Fig. 4; Table 1).

New priority cells for species conservation were, independent of the target, located in the same areas. However, as expected, the number of cells needed *per* area raises with the

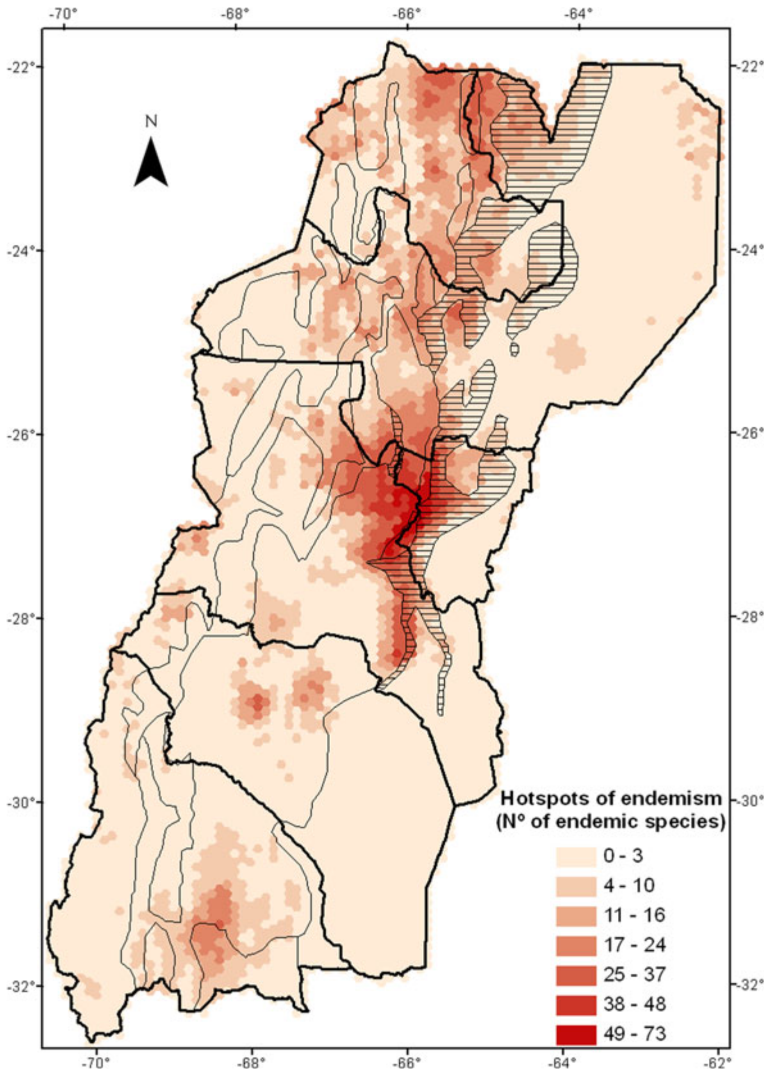
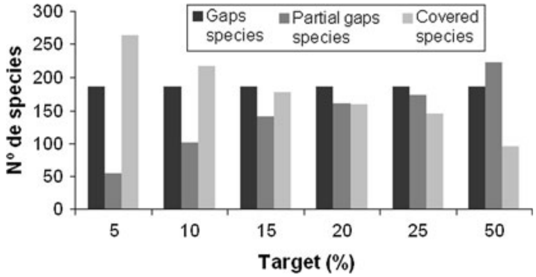


Fig. 2 Hotspots of endemism within NOA (the striped region corresponds to the Southern Andes Yungas; the richest plants ecoregion of the NOA)

Fig. 3 Number of gap species, partial gap species and covered species *under* different conservation targets



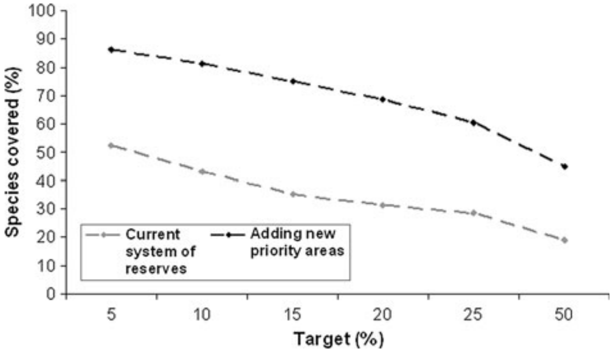


Fig. 4 Percentage of covered species in the actual system of protected areas versus the same system when adding new priority areas

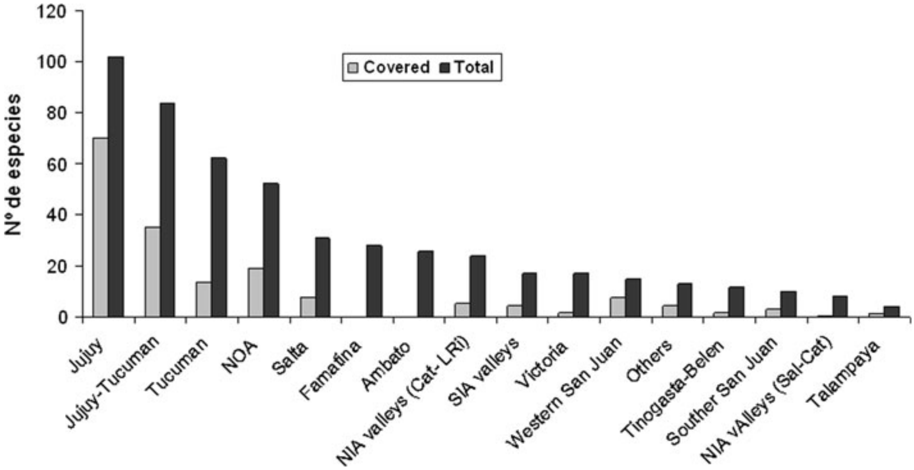


Fig. 5 Total number of endemic species versus number of covered species in the 16 areas of endemism defined by Aagesen et al. (2012)

increment of species representation targets (from 5 to 50 % of all species ranges). Taking into account the representation targets from 5 to 25 %, eight priority areas were defined (Fig. 6): (1) Sierra del Centinela in Jujuy, (2) Victoria area in Jujuy-Salta (Sierra de Santa Victoria and Yavi), (3) Sierra del Aconquija, Sierra del Cajon, and others in Salta-Catamarca, (4) Cumbres Calchaquies and Cumbres de Tafi in Tucuman, (5) The Tinogasta-Belen area in Catamarca (Chaschuil Valley, Sierra de Fiambalá, and others), (6) Andalgalá area in Catamarca (Cuesta de Capillitas and Sierra del Manchao), (7) Sierra de Ancasti and Sierra de Ambato in Catamarca, and (8) Sierra de Famatina in La Rioja. The San Juan province does not present new priority areas at least when the targets are between 5 and 25 %. For the highest target (50 % of all species ranges) six new areas are shown in the analysis (Fig. 6b), while extra cells were added to the above mentioned areas. The six new areas were: (9) Calchaquies Valleys in Salta (Abra del Acay, Nevado del Acay, and others), (10) Sierra de Chañi and surroundings in Salta, (11) Sierra and Cuesta de Zapata in Catamarca, (12) The Aimogasta area (Sierra de Velasco and part of the Sierra de Ambato)

Table 1 Total PU's needed to achieve a 100 % representation of the 505 endemic species in the NOA region and how many of that PU's have irreplaceability values higher than 70 %

Target representation (%)	Total of new PU's	Protection adding total PU's (%)	New PU's (irreplaceability >70 %)	Protection adding 251 PU's (%)
5	898	100	251	86
10	1,223	100	261	81
15	1,548	100	252	75
20	1,732	100	253	69
25	1,757	100	257	61
50	1,915	100	389	45

Adding the minimum number of planning units with an irreplaceability >70 % (251 PU's) would reach the protection values exposed in the last column of the table

in La Rioja, (13) Sierra de la Punilla and part of the Colanguil Cordon in San Juan, and (14) San Juan area (Sierra del Tontal and Sierra Pie de Palo among others).

Discussion

As a consequence of their restricted ranges, endemic species are potentially more sensible to environmental perturbations than widely distributed species, and thereby, more vulnerable to extinction. For this reason endemic species need special conservation efforts (Peterson and Watson 1998). Lamoreux et al. (2006) pointed out that reserve systems based on endemism protect a high diversity of species due to the species turnover between high endemism areas. Our results highlight that the actual system of reserves in the NOA does not appropriately represent its endemic vascular flora, and is, consequently, considered as ineffective. The main reason for this is that most of the protected areas of the NOA followed an 'ad hoc' reservation and are concentrated in the highest diversity ecoregion; the Southern Andean Yungas (humid forest and foggy grassland, Izquierdo and Grau 2009). This ecoregion, excluding its grasslands, was recently indicated by Aagesen et al. (2012) to be a low or poor endemic region at the scale of the present study.

We found that the hotspots of endemic vascular plants were mainly concentrated in arid ecoregions of NOA such as the High Monte and the Central Andean Puna, as well as in the transition zones between these two ecoregions and the Southern Andean Yungas (Fig. 2). Ecological transition zones are already known to harbor higher concentrations of species as a result of a mixture between floras of different ecoregions (Gaston et al. 2001). Higher endemism found in High Monte and in the Central Andean Puna ecoregions could be a consequence of the Andean Mountains uplift (Antonelli et al. 2009; Roig et al. 2009; Young et al. 2002). This uplift caused a decrease in the precipitation of the western regions of South America generating semi-arid and arid conditions, together with Inter Andean valleys isolated from each other, that promote differentiations (Antonelli et al. 2009; Roig et al. 2009; Young et al. 2002). Indeed the High Monte ecoregion was considered an area of independent evolution because of the complexity of its biota, (a mixture between Brazilian and Patagonian biota's, Roig et al. 2009) while in the Central Andean Puna high endemism may be explained for the species radiation from other biogeographical regions

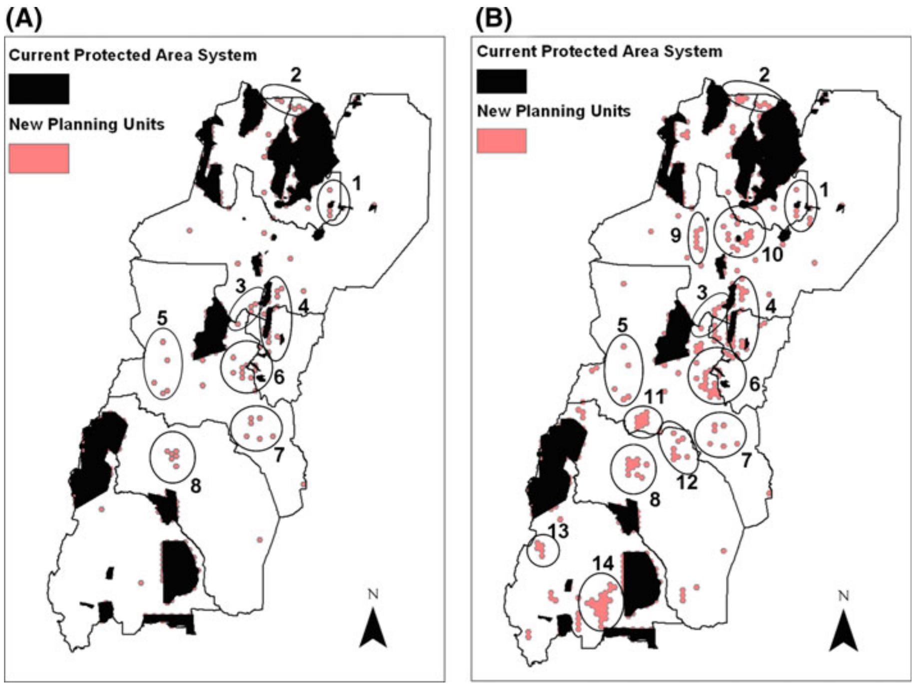


Fig. 6 Solutions obtained by Marxan applying the irreplaceability concept: **a** Target: Cover the 5 % of the distributional range of all endemic species. **b** Target: Cover the 50 % of the distributional range of all endemic species. New priority areas: (*1*) Sierra del Centinela, (*2*) Victoria area, (*3*) Sierra del Aconquija, Sierra del Cajon and others, (*4*) Cumbres Calchaquíes and Cumbres de Tafí, (*5*) Tinogasta-Belen area (*6*) Andalgalá area (*7*) Sierras de Ancasti and Sierra de Ambato (*8*) Sierra de Famatina (*9*) Calchaquíes Valleys, (*10*) Sierra de Chañi and surroundings, (*11*) Sierra and Cuesta de Zapata (*12*) Aimogasta area, (*13*) Sierra de la Punilla and part Colanguil Cordon and, (*14*) San Juan area

and for the extreme isolation and habitat conditions generated after the final phase of the uplift (Donato et al. 2003).

Lack of spatial congruence between species hotspots and areas of endemism, combined with the bias towards protecting diversity hotspots in humid habitats, have resulted in a system in which 37 % of the endemics species are not even touched by any protected area (Fig. 3). Presently only 19 % of the endemic species have half of their geographic range or more covered by the CPA, while 48 % of the endemic species have less than 5 % of their geographic range covered by the same system (Fig. 3). The present study stand out that priorities set on the basis of species richness may not successfully conserve areas of high endemism, at least not within the southern most portions of the Central Andes. Lack of congruence between species richness and areas of endemism was also found in the neighboring Bolivian region of the Southern Central Andes (Ibisch et al. 2003). As in our study high endemism in the Bolivian portion of the southern Andes were mainly found in the Dry Inter Andean Forest and in the Prepuna rather than in the Southern Andean Yungas (referred as Tucumano–Bolivian Yungas in Ibisch et al. 2003). Areas of endemism may therefore seem to be unrelated to species hotspots in the entire Southern Central Andes as far north as 19° S which is the northern limit of the Tucumano–Bolivian Yungas. While it is not the scope of the present paper to evaluate the system of protected areas in Bolivia it should be mentioned that, as in Argentina, most of the protected areas in Bolivia are found in the species rich humid ecoregions and not in the arid slope and valley system of the Andes where the majority of vascular plant endemism is found (López and Zambrana-Torrelio 2006; Larrea-Alcázar et al. 2010). Similar results where found also in Chile (Benoit 1996) and in Peru (Swenson et al. 2012), which may suggest that areas of endemism are unprotected all along the Andes.

The only other analysis related to systematic conservation studies carried out in the NOA (Ortega-Baes et al. 2012) included the Cactaceae family only, and showed results different to those exposed here. These authors evaluated the effectiveness of protected areas in conserving the Cactaceae species in the Calchaquies Valleys (province of Salta) and qualified the system as effective. The divergence of the result seems to be related to the spatial congruence between hotspots of species richness and endemism found in the family Cactaceae, which occurs also at country level (Mourelle and Ezcurra 1996). As is known, the Cactaceae is a highly specialized family with very specific habitat requirements (Mourelle and Ezcurra 1996, 1997). In Salta (and NOA in general) Cactaceae species belong mainly to two clades—the Cactoideae and the Opuntioideae (Hernández-Hernández et al. 2011). According to Reid (1998), the likelihood of finding species from the same taxonomic category that share narrower habitat requirement at small geographic scales is higher, while at larger scales it is lower. Therefore, when expanding systematic conservation studies to include several families of vascular plants there is no congruence between main areas of endemism of the different families and the Southern Andean Yungas ecoregion, which is the most diverse plants unit of the NOA region (Cabrera 1976; Zuloaga et al. 1999).

In order to address the present threats detected in the NOA region (Izquierdo and Grau 2009) it is necessary to strategically set up new priority areas for endemic species conservation. Based on endemism new priority sites must be located mainly in arid and semiarid lands. Several studies, including the present paper, have shown that these environments tend to accumulate endemism within the Southern Central Andes (Ezcurra 2006; Navone and Abraham 2006; Roig et al. 2009; Aagesen et al. 2012). Our study highlight as priorities 251 cells of 100 km^2 each that would increase, if included, the effectiveness of the current conservation system (Fig. 4; Table 1). If these priority cells are added to the present system the percentage of protected endemic plant species would increase to 61 or 86 %, depending on the preferred conservation target, but in any cases qualifying the reserve system as effective (Fig. 4; Table 1). Moreover, it is important to notice that previous analyses indicated that choosing centers of endemism for conservation may result representative for other taxa such as vertebrates (Rodrigues et al. 2004a). In the NOA region few other studies have identified areas of endemism (but see Diaz-Gomez 2007) and it is premature to determine whether areas of endemism are congruent among taxa.

Our study represents a starting point for systematic conservation planning studies in NOA. The cells here indicated as potential for conservation were unevenly distributed within the region but spatially congruent with the areas of endemism defined by Aagesen et al. (2012) and coincident with areas where a lack of reserves was observed (Fig. 6). The provinces which need to increment substantially their protection areas are Salta and Catamarca both with lesser reserves systems in relation to the remaining NOA provinces (Fig. 6). New priority sites locations appear to follow two patterns. Some cells are adjacent or approximate to the CPA system while other cells seem to constitute new independent protected sites. Areas adjacent to already established reserves may facilitate expanding the actual system thought land acquisition or trough the implementation of biological corridors. This would be the case of Victoria area (Area 2, Fig. 6) that would be covered if adding neighbor cells to the Biosphere reserve in Jujuy. Expanding the same reserve towards the east and to the south would preserve more endemic species next to Quebrada de Humahuaca in Jujuy (Fig. 6). Other priority cells that are neighbors to already established reserves include Sierra del Centinela (Area 1) adjacent to the Provincial Reserve Las Lancitas in Jujuy, cells of Cumbres Calchaquies and Cumbres de Tafi (Area 4) near to the Natural Reserve Quebrada del Portugues in Tucuman, and cells from Sierra del Aconquija, Sierra del Cajon and others (Area 3) that could be included in the present system by expanding the Provincial Reserve Quebrada de las Conchas in Salta (Fig. 6). High priority cells that would constitute new independent protected areas include cells in the areas of the Sierra de Ancasti and Sierra de Ambato (Area 7), Sierra de Famatina area (Area 8), Tinogasta-Belen area (Area 5), and an assemblage of cells concentrated in the area of Andalgalá (Area 6, Fig. 6). Some of the new and independent protected areas appear to protect rare and sparsely collected species. Potential distributions were not produced for these species due to lack of sufficient collection data. Further collection within these remote areas could potentially provide new collection information that would allow for modeling the potential distribution of these species and adjust the number and placement of the priority cells.

Our aim with the present paper is to present a first estimate on how to protect endemic plant species in one of the mayor areas of vascular plant endemism within the Southern Cone. We do not suggest that adding our new priority areas are the only or the final solution but, we do suggest endemism as a fundamental criterion to identify conservation areas. We urge our zoologist colleagues to conduct the necessary complementary analyses, in order to obtain an integrated solution for protecting both the flora and fauna in the region. As in the case for vascular plants, the Southern Yungas are hotspots for a wide range of vertebrates and insects (Szumik et al. 2012) however, knowledge on endemism for the same taxa is very sparse. In a period were information and time is scarce, we need quality information obtained in relatively short time. Obtaining the necessary distribution data for gap analyses, like the present one, is admittedly problematic as compiling and georeferencing the relevant specimens is prohibitive time consuming, yet crucial for the quality of the data set. Databasing museum and herbarium collections as well as making these public significantly ease the task of compiling distribution data and should be prioritized by both institutions and national networks. This information together with actual technologies should allow finding more efficient conservation solutions. Modeling the potential distribution of relevant species is presently the best, and in some cases the only available approach for obtaining suitable data sets when species distribution data is scarce (Phillips et al. 2006). However, the reliability of the modeled distribution also depends on the quality of the input data. When priority areas are obtained from modeled distributions, as in the present case, the final step ideally would include additional fieldwork to confirm the presence of the target species within the selected priority areas for conservation.

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Appendix

See Appendix Table 2.

Table 2 Endemic species included in the present analyses (505 species) with their corresponding endemism area in the NOA region

Family	Endemic species	AUC	Area of endemism
Acanthaceae	*Aphelandra lilacina*		Jujuy
Acanthaceae	*Dicliptera cabrerae*	0.985	Jujuy–Tucuman
Acanthaceae	*Justicia hunzikeri*	0.976	Talampaya
Acanthaceae	*Justicia riojana*	0.987	NIA valleys-Cat_LRi
Alstroemeriaceae	*Alstroemeria bakeri*	0.932	Ambato
Alstroemeriaceae	*Bomarea macrocephala*	0.909	Jujuy–Tucuman
Alliaceae	*Schickendantziella trichosepala*	0.942	Jujuy–Tucuman
Amaranthaceae	*Alternanthera cana*		Southern San Juan
Amaranthaceae	*Alternanthera cinerella*		Tucuman
Amaranthaceae	*Gomphrena cladotrichoides*	0.993	Southern San Juan
Amaranthaceae	*Gomphrena radiata*	0.975	Jujuy–Tucuman
Amarillidaceae	*Chlidanthus yaviensis*		Victoria
Amarillidaceae	*Habranthus andalgalensis*	0.937	NIA valleys-Cat_LRi
Amarillidaceae	*Habranthus pictus*		Ambato
Amarillidaceae	*Habranthus riojanus*		Famatina
Amarillidaceae	*Habranthus ruizlealii*		Others
Amarillidaceae	*Hieronymiella aurea*	0.974	Salta
Amarillidaceae	*Hieronymiella marginata*	0.978	NOA
Amarillidaceae	*Hieronymiella speciosa*	0.940	Jujuy–Tucuman
Amarillidaceae	*Hippeastrum aglaiae*	0.986	Jujuy–Tucuman
Amarillidaceae	*Zephyranthes andina*	0.885	Jujuy
Amarillidaceae	*Zephyranthes diluta*	0.983	SIA valleys
Anacardiaceae	*Schinus gracilipes*	0.926	Jujuy–Tucuman
Anthericaceae	*Anthericum argentinense*	0.825	Jujuy–Tucuman
Anthericaceae	*Anthericum hickenianum*	0.951	Jujuy–Tucuman
Apiaceae	*Austropeucedanum oreopansil*	0.952	Jujuy–Tucuman
Apiaceae	*Bowlesia hieronymusii*		Jujuy–Tucuman
Apiaceae	*Bowlesia venturii*		Tucuman
Apiaceae	*Eringyum lorentzii*	0.997	Tucuman
Apiaceae	*Mulinum axilliflorum*	0.946	Jujuy
Apiaceae	*Mulinum famatinense*	0.954	NOA
Apocynaceae	*Cynanchum samuelssonii*		Tucuman
Apocynaceae	*Jobinia glossostelma*		Tucuman
Apocynaceae	*Macropharynx meyeri*	0.992	Jujuy
Apocynaceae	*Matelea schreiteri*	0.962	Jujuy
Apocynaceae	*Metastelma microgynostegia*	0.986	Jujuy
Apocynaceae	*Petalostelma sarcostemma*	0.933	Tucuman
Apocynaceae	*Philibertia affinis*		Jujuy
Apocynaceae	*Philibertia barbata*	0.965	Jujuy–Tucuman
Apocynaceae	*Philibertia castillonii*		Jujuy
Apocynaceae	*Philibertia cionophora*	0.971	Jujuy–Tucuman
Apocynaceae	*Philibertia coalita*		Ambato
Apocynaceae	*Philibertia nivea*	0.931	Jujuy–Tucuman

Table 2 continued

Family	Endemic species	AUC	Area of endemism
Apocynaceae	*Philibertia subnivea*		Salta
Apocynaceae	*Schistogyne tucumanensis*		Jujuy–Tucuman
Aristolochiaceae	*Aristolochia melanoglossa*	0.946	Tucuman
Aristolochiaceae	*Aristolochia oranensis*		Jujuy
Asteraceae	*Antennaria sleumeri*		Victoria
Asteraceae	*Aphyllocladus decussatus*		Famatina
Asteraceae	*Aphyllocladus ephedroides*	0.970	Western San Juan
Asteraceae	*Baccharis cabrerae*	0.951	Tucuman
Asteraceae	*Baccharis famatinensis*		Famatina
Asteraceae	*Baccharis kurtziana*	0.953	SIA valleys
Asteraceae	*Baccharis niederleinii*		SIA valleys
Asteraceae	*Baccharis petrophila*		Salta
Asteraceae	*Baccharis polygama*	0.978	Tucuman
Asteraceae	*Baccharis rodriguezii*		Tucuman
Asteraceae	*Baccharis rupestris*	0.977	NOA
Asteraceae	*Cabreraea andina*	0.980	SIA valleys
Asteraceae	*Conyza cordata*	0.918	NOA
Asteraceae	*Chersodoma argentina*	0.974	NOA
Asteraceae	*Chersodoma glabriuscula*	0.940	NOA
Asteraceae	*Chiliotrichiopsis ledifolia*	0.978	NIA valleys-Cat_LRi
Asteraceae	*Chuquiraga calchaquina*	0.928	NOA
Asteraceae	*Chuquiraga echegaray*	0.993	Southern San Juan
Asteraceae	*Erigeron tucumanensis*	0.996	Tucuman
Asteraceae	*Eupatorium arachnoideum*		Jujuy
Asteraceae	*Eupatorium hickenii*	0.996	Jujuy
Asteraceae	*Flourensia blakeana*	0.944	NIA valleys-Cat_LRi
Asteraceae	*Flourensia hirta*	0.935	SIA valleys
Asteraceae	*Flourensia leptopoda*	0.855	Others
Asteraceae	*Flourensia macroligulata*	0.979	Jujuy–Tucuman
Asteraceae	*Flourensia niederleinii*	0.985	Famatina
Asteraceae	*Flourensia riparia*	0.969	Jujuy–Tucuman
Asteraceae	*Flourensia suffrutescens*	0.975	Jujuy
Asteraceae	*Flourensia tortuosa*	0.902	NIA valleys-Cat_LRi
Asteraceae	*Gamochaeta longipedicellata*		Jujuy
Asteraceae	*Gnaphalium yalaense*	0.882	Jujuy–Tucuman
Asteraceae	*Gutierrezia repens*	0.977	Jujuy–Tucuman
Asteraceae	*Hieracium cienegae*	0.999	Tucuman
Asteraceae	*Hieracium kieslingii*		Jujuy
Asteraceae	*Hieracium lorentzianum*	0.998	Ambato
Asteraceae	*Hieracium luteomontanum*	0.931	Jujuy
Asteraceae	*Hieracium neofurcatum*		Victoria
Asteraceae	*Hieracium niederleinii*	0.959	Jujuy–Tucuman
Asteraceae	*Hieracium sordidum*	0.979	Ambato

Table 2 continued

Family	Endemic species	AUC	Area of endemism
Asteraceae	*Hieracium streptochaetum*		NOA
Asteraceae	*Hieracium tucumanicum*	0.954	Jujuy–Tucuman
Asteraceae	*Hieracium vervoorstii*		Ambato
Asteraceae	*Holocheilus fabrisii*	0.902	Jujuy–Tucuman
Asteraceae	*Huerpea andina*		Western San Juan
Asteraceae	*Hyaloseris rubicunda*	0.968	NOA
Asteraceae	*Hysterionica aberrans*	0.918	Jujuy–Tucuman
Asteraceae	*Hysterionica pulchella*	0.994	NIA valleys-Cat_LRi
Asteraceae	*Isostigma molfinianum*		Famatina
Asteraceae	*Laennecia altoandina*		Jujuy
Asteraceae	*Luciliocline catamarcense*		Ambato
Asteraceae	*Microliabum eremophilum*		Tucuman
Asteraceae	*Microliabum humile*		Jujuy
Asteraceae	*Mikania jujuyensis*	0.993	Jujuy
Asteraceae	*Mikania minima*	0.952	Tucuman
Asteraceae	*Mikania siambonensis*		Tucuman
Asteraceae	*Mutisia saltensis*		Jujuy
Asteraceae	*Mutizia kurtzii*	0.989	NOA
Asteraceae	*Perezia volcanensis*		Jujuy
Asteraceae	*Porophyllum cabrerae*		Salta
Asteraceae	*Senecio ambatensis*		Ambato
Asteraceae	*Stevia centinelae*		Jujuy
Asteraceae	*Stevia crassicephala*	0.978	Jujuy
Asteraceae	*Stevia jujuyensis*	0.994	Jujuy
Asteraceae	*Stevia okadae*		Victoria
Asteraceae	*Stevia yalae*		Jujuy
Asteraceae	*Tagetes riojana*	0.998	SIA valleys
Asteraceae	*Tagetes rupestris*	0.997	Tucuman
Asteraceae	*Trichocline macrorhiza*	0.953	Jujuy
Asteraceae	*Verbesina saltensis*		Salta
Asteraceae	*Vernonia lipeoensis*	0.992	Jujuy
Asteraceae	*Vernonia novarae*		Jujuy
Asteraceas	*Senecio altoandinus*		Jujuy
Asteraceas	*Senecio argophylloides*	0.958	NOA
Asteraceas	*Senecio asplenifolius*		Tucuman
Asteraceas	*Senecio belenensis*		Tinogasta-Belen
Asteraceas	*Senecio cajoensis*		Tucuman
Asteraceas	*Senecio calchaquinus*		Tucuman
Asteraceas	*Senecio calingastensis*		Southern San Juan
Asteraceas	*Senecio catamarcensis*	0.936	Jujuy–Tucuman
Asteraceas	*Senecio cremeiflorus*	0.963	Jujuy–Tucuman
Asteraceas	*Senecio cremnicola*		Famatina
Asteraceas	*Senecio cremnophilus*	0.901	Western San Juan

Table 2 continued

Family	Endemic species	AUC	Area of endemism
Asteraceas	*Senecio cylindrocephalus*	0.837	NOA
Asteraceas	*Senecio delicatulus*		Tinogasta-Belen
Asteraceas	*Senecio diaguita*	0.924	SIA valleys
Asteraceas	*Senecio fabrisii*		NIA valleys-Sal_Cat
Asteraceas	*Senecio famatinensis*		Famatina
Asteraceas	*Senecio flagellifolius*	0.789	Jujuy–Tucuman
Asteraceas	*Senecio friesii*		NOA
Asteraceas	*Senecio infimus*	0.977	Jujuy
Asteraceas	*Senecio keshua*	0.888	Jujuy
Asteraceas	*Senecio krapovickasii*		Famatina
Asteraceas	*Senecio kunturinus*		Tucuman
Asteraceas	*Senecio lanosissimus*		Famatina
Asteraceas	*Senecio lilloi*		Tinogasta–Belen
Asteraceas	*Senecio maculatus*		Tucuman
Asteraceas	*Senecio niederleinii*		Famatina
Asteraceas	*Senecio octolepis*	0.982	NOA
Asteraceas	*Senecio pseudotites*		NOA
Asteraceas	*Senecio punae*	0.992	Jujuy
Asteraceas	*Senecio roripifolius*		Tucuman
Asteraceas	*Senecio sanagastae*		SIA valleys
Asteraceas	*Senecio saucensis*		NIA valleys-Cat_LRi
Asteraceas	*Senecio schreiteri*	0.900	NOA
Asteraceas	*Senecio tilcarensis*	0.983	Jujuy
Asteraceas	*Senecio tocomarensis*		Jujuy
Asteraceas	*Senecio tucumanensis*		Tucuman
Asteraceas	*Senecio vervoorstii*	0.987	NIA valleys-Sal_Cat
Asteraceas	*Senecio yalae*	0.989	Jujuy
Begoniaceae	*Begonia sleumeri*		Jujuy
Begoniaceae	*Begonia tafiensis*	0.998	Tucuman
Berberidaceae	*Berberis lilloana*	0.864	Jujuy–Tucuman
Boraginaceae	*Cryptantha latefissa*		Western San Juan
Boraginaceae	*Heliotropium ruizlealii*	0.943	Southern San Juan
Boraginaceae	*Ixorhea tschudiana*	0.999	Salta
Brassicaceae	*Descurainia adpressa*	0.976	Others
Brassicaceae	*Descurainia brevifructa*		Southern San Juan
Brassicaceae	*Dictyophragmus punensis*	0.981	Jujuy
Brassicaceae	*Draba burkartiana*	0.986	Jujuy–Tucuman
Brassicaceae	*Draba tucumanensis*	0.804	NOA
Brassicaceae	*Exhalimolobos burkartii*		Jujuy
Brassicaceae	*Lepidium jujuyense*		Jujuy
Brassicaceae	*Lepidium argentinum*	0.821	NOA
Brassicaceae	*Mancoa venturii*	0.940	Jujuy
Brassicaceae	*Menonvillea famatinensis*		Famatina

Table 2 continued

Family	Endemic species	AUC	Area of endemism
Brassicaceae	*Parodiodoxa chionophila*	0.995	Jujuy–Tucuman
Brassicaceae	*Petroravenia eseptata*		Jujuy
Brassicaceae	*Polypsecadium tucumanense*		Jujuy–Tucuman
Brassicaceae	*Sarcodraba andina*		Western San Juan
Bromeliaceae	*Deuterocohnia haumanii*	0.928	NOA
Bromeliaceae	*Pitcairnia saltensis*		Jujuy
Bromeliaceae	*Puya assurgens*		Jujuy
Bromeliaceae	*Puya castellanosii*	0.988	Salta
Bromeliaceae	*Puya harmsii*	0.979	Ambato
Bromeliaceae	*Puya lilloi*	0.903	Jujuy–Tucuman
Bromeliaceae	*Puya micrantha*		Jujuy
Bromeliaceae	*Puya smithii*	0.892	Jujuy–Tucuman
Bromeliaceae	*Puya volcanensis*		Jujuy-Tucuman
Bromeliaceae	*Puya weberiana*	0.977	Salta
Bromeliaceae	*Puya yakespala*		Victoria
Bromeliaceae	*Tillandsia albertiana*		Salta
Bromeliaceae	*Tillandsia brealitoensis*		Salta
Bromeliaceae	*Tillandsia friesii*	0.925	Jujuy–Tucuman
Bromeliaceae	*Tillandsia tenebra*	0.937	NIA valleys-Cat_LRi
Bromeliaceae	*Tillandsia zecheri*		Jujuy–Tucuman
Cactaceae	*Acanthocalycium ferrarii*	0.960	Tucuman
Cactaceae	*Acanthocalycium glaucum*		Ambato
Cactaceae	*Acanthocalycium thionanthum*	0.990	Salta
Cactaceae	*Echinopsis silvestrii*	0.993	Salta
Cactaceae	*Gymnocalycium albiaerolatum*	1.000	Famatina
Cactaceae	*Gymnocalycium baldianum*	0.996	NIA valleys-Cat_LRi
Cactaceae	*Gymnocalycium bayrianum*	0.978	Tucuman
Cactaceae	*Gymnocalycium castellanosii*	0.986	Talampaya
Cactaceae	*Gymnocalycium hybopleurum*	0.972	Ambato
Cactaceae	*Gymnocalycium kieslingii*		Famatina
Cactaceae	*Gymnocalycium marsoneri*		Salta
Cactaceae	*Gymnocalycium mazanense*	0.997	Famatina
Cactaceae	*Gymnocalycium mucidum*		Famatina
Cactaceae	*Gymnocalycium pugionacanthum*	0.924	NIA valleys-Cat_LRi
Cactaceae	*Gymnocalycium ragonesei*		Others
Cactaceae	*Gymnocalycium ritterianum*		Famatina
Cactaceae	*Gymnocalycium saglionis*	0.972	NOA
Cactaceae	*Gymnocalycium spegazzinii*	0.995	Jujuy–Tucuman
Cactaceae	*Gymnocalycium uebelmannianum*		Famatina
Cactaceae	*Lobivia bruchii*		Tucuman
Cactaceae	*Lobivia crassicaulis*		Ambato
Cactaceae	*Lobivia chrysantha*		Salta
Cactaceae	*Lobivia chrysochete*		Victoria

Table 2 continued

Family	Endemic species	AUC	Area of endemism
Cactaceae	*Lobivia densispina*		Jujuy
Cactaceae	*Lobivia einsteinii*	0.959	Jujuy
Cactaceae	*Lobivia famatimensis*	0.883	SIA valleys
Cactaceae	*Lobivia gonjianii*		Jujuy
Cactaceae	*Lobivia haematantha*	0.969	NIA valleys-Sal_Cat
Cactaceae	*Lobivia jajoiana*		Jujuy
Cactaceae	*Lobivia korethroides*		Salta
Cactaceae	*Lobivia marsoneri*		Jujuy
Cactaceae	*Lobivia nigricans*		Jujuy
Cactaceae	*Lobivia sanguiniflora*		Victoria
Cactaceae	*Lobivia schreiteri*		Tucuman
Cactaceae	*Lobivia walteri*		Salta
Cactaceae	*Maihuenipsis minuta*	0.914	Jujuy
Cactaceae	*Parodia aureicentra*	0.992	Salta
Cactaceae	*Parodia chrysacanthion*		Jujuy
Cactaceae	*Parodia nivosa*		Jujuy
Cactaceae	*Parodia penicillata*		Salta
Cactaceae	*Parodia stuemeri*	0.947	Jujuy
Cactaceae	*Pterocactus megliolli*		Southern San Juan
Cactaceae	*Puna bonniae*		Tinogasta–Belen
Cactaceae	*Pyrrhocactus umadeave*	0.992	Jujuy
Cactaceae	*Pyrrocactus kattermannii*		SIA valleys
Cactaceae	*Pyrrocactus sanjuanensis*	0.992	Southern San Juan
Cactaceae	*Rebutia deminuta*		Jujuy-Tucuman
Cactaceae	*Rebutia margarethae*		Victoria
Cactaceae	*Rebutia marsoneri*		Jujuy
Cactaceae	*Rebutia minuscula*	0.983	Jujuy–Tucuman
Cactaceae	*Tephrocactus alexanderi*	0.953	SIA valleys
Cactaceae	*Tephrocactus geometricus*	0.912	Tinogasta–Belen
Cactaceae	*Tephrocactus molinensis*		Salta
Cactaceae	*Tephrocactus weberi*		NOA
Cactaceae	*Trichocereus andalgalensis*	0.945	NIA valleys-Cat_LRi
Cactaceae	*Trichocereus angelesii*		Salta
Cactaceae	*Trichocereus cabrerae*	0.827	NIA valleys-Cat_LRi
Cactaceae	*Trichocereus fabrisii*		Jujuy
Cactaceae	*Trichocereus huascha*	0.924	NIA valleys-Cat_LRi
Cactaceae	*Trichocereus pseudocandicans*		Famatina
Cactaceae	*Trichocereus schickendantzii*		Tucuman
Cactaceae	*Trichocereus smrzianus*		Salta
Cactaceae	*Trichocereus terscheckii*	0.917	NOA
Cactaceae	*Trichocereus thelegonus*		Jujuy–Tucuman
Cactaceae	*Trichocereus vatteri*		Famatina
Cactaceae	*Tunilla tilcarensis*		Jujuy

Table 2 continued

Family	Endemic species	AUC	Area of endemism
Calceolariaceae	*Boopis castillonii*		Ambato
Calceolariaceae	*Calceolaria lepidota*		Tinogasta–Belen
Caryophyllaceae	*Pycnophyllum convexum*	0.982	NOA
Caryophyllaceae	*Pycnophyllum mucronulatum*		Jujuy
Caryophyllaceae	*Silene bersieri*		Jujuy
Caryophyllaceae	*Silene haumanii*	0.985	Jujuy
Caryophyllaceae	*Silene margaritae*		Tinogasta–Belen
Caryophyllaceae	*Stellaria aphanantha*		Tucuman
Caryophyllaceae	*Stellaria cryptopetala*	0.978	Jujuy–Tucuman
Celastraceae	*Maytenus cuezzoi*	0.991	Jujuy
Convolvulaceae	*Cuscuta argentiniana*	0.919	Ambato
Convolvulaceae	*Cuscuta friesii*		Jujuy
Convolvulaceae	*Ipomoea lilloana*	0.978	Jujuy–Tucuman
Convolvulaceae	*Ipomoea volcanensis*	0.983	Jujuy
Crassulariae	*Sedum jujuyense*		Jujuy
Cucurbitaceae	*Pteropepon argentinense*	0.851	Jujuy–Tucuman
Cucurbitaceae	*Sicyos ignarus*		Jujuy
Cyperaceae	*Carex humahuacaensis*		Others
Cyperaceae	*Carex pseudomacloviana*		Jujuy–Tucuman
Cyperaceae	*Carex tucumanensis*		Tucuman
Dioscoreaceae	*Dioscorea castilloniana*	0.889	Jujuy
Dioscoreaceae	*Dioscorea entomophila*		Tucuman
Dioscoreaceae	*Dioscorea stenopetala*	0.973	Salta
Dioscoreaceae	*Dioscorea trifurcata*		Ambato
Euphorbiaceae	*Acalypha friesii*	0.962	Jujuy
Euphorbiaceae	*Euphorbia marayensis*	0.840	NOA
Euphorbiaceae	*Euphorbia vervoorstii*		Salta
Fabaceae	*Adesmia arenicola*	0.987	Jujuy
Fabaceae	*Adesmia crassicaulis*	0.928	Others
Fabaceae	*Adesmia cytisoides*	0.951	NOA
Fabaceae	*Adesmia friesii*	0.930	Jujuy
Fabaceae	*Adesmia hunzikeri*	0.867	SIA valleys
Fabaceae	*Adesmia nanoligera*	0.980	SIA valleys
Fabaceae	*Adesmia pseudoincana*		NIA valleys-Cat_LRi
Fabaceae	*Adesmia sanjuanensis*		Western San Juan
Fabaceae	*Astragalus boeckly*	0.962	Western San Juan
Fabaceae	*Astragalus burkartii*	0.909	Jujuy-Tucuman
Fabaceae	*Astragalus crypticus*	0.918	Others
Fabaceae	*Astragalus fabrisii*		Jujuy
Fabaceae	*Astragalus joergensenii*	0.973	Jujuy–Tucuman
Fabaceae	*Astragalus nelidae*	0.988	Western San Juan
Fabaceae	*Astragalus pulviniformis*		Western San Juan
Fabaceae	*Astragalus punae*		Jujuy

Table 2 continued

Family	Endemic species	AUC	Area of endemism
Fabaceae	*Lupinus alivillosus*		NIA valleys-Cat_LRi
Fabaceae	*Lupinus austrorientalis*	0.956	Jujuy–Tucuman
Fabaceae	*Lupinus burkartianus*		Ambato
Fabaceae	*Lupinus hieronymii*		Famatina
Fabaceae	*Lupinus jujuyensis*		Jujuy
Fabaceae	*Lupinus tucumanensis*	0.992	NIA valleys-Cat_LRi
Fabaceae	*Lupinus ultramontanus*		Jujuy–Tucuman
Fabaceae	*Prosopis calingastana*		Southern San Juan
Fabaceae	*Ramorinoa girolae*	0.975	Talampaya
Fabaceae	*Senna fabrisii*	0.963	SIA valleys
Fabaceae	*Senna pachyrrhiza*		Ambato
Fabaceae	*Senna rigidicaulis*	0.985	Salta
Fabaceae	*Sophora rhynchocarpa*		Tucuman
Gentianaceae	*Gentianella bromifolia*	0.993	Jujuy–Tucuman
Gentianaceae	*Gentianella cabrerae*		Victoria
Gentianaceae	*Gentianella claytonioides*	0.960	NIA valleys-Cat_LRi
Gentianaceae	*Gentianella cosmantha*	0.793	Jujuy–Tucuman
Gentianaceae	*Gentianella hieronymi*	0.994	Jujuy–Tucuman
Gentianaceae	*Gentianella kurtzii*	0.973	NIA valleys-Cat_LRi
Gentianaceae	*Gentianella multiflora*		Jujuy
Gentianaceae	*Gentianella pulla*	0.975	NIA valleys-Sal_Cat
Gentianaceae	*Gentianella punensis*		Others
Gentianaceae	*Gentianella riojae*		Famatina
Gentianaceae	*Gentianella tubulosa*	0.969	Jujuy–Tucuman
Geraniaceae	*Geranium leucanthum*	0.836	Jujuy–Tucuman
Geraniaceae	*Geranium tafiense*		Salta
Hypoxidaceae	*Hypoxis catamarcensis*		Tucuman
Iridaceae	*Cardenanthus venturi*		Jujuy–Tucuman
Iridaceae	*Cypella elegans*		Jujuy
Iridaceae	*Ennealophus fimbriatus*		Jujuy–Tucuman
Iridaceae	*Ennealophus simplex*		Jujuy–Tucuman
Iridaceae	*Mastigostyla brachiandra*		Victoria
Iridaceae	*Mastigostyla implicata*		Victoria
Iridaceae	*Mastigostyla johnstoni*		Tucuman
Iridaceae	*Sisyrinchium biflorum*		Ambato
Iridaceae	*Sisyrinchium tucumanum*		Tucuman
Juncaceae	*Oxychloe castellanosi*	0.963	Western San Juan
Ledocarpaceae	*Balbisia calycina*	0.985	NOA
Loasaceae	*Caiophora aconquijae*	0.994	Tucuman
Loasaceae	*Caiophora mollis*	0.919	NOA
Loasaceae	*Caiophora nivalis*	0.982	Jujuy–Tucuman
Malvaceae	*Lecanophora jarae*	0.908	Tinogasta–Belen
Malvaceae	*Nototriche cabrerae*		Jujuy

Table 2 continued

Family	Endemic species	AUC	Area of endemism
Malvaceae	*Nototriche caesia*	0.866	Tucuman
Malvaceae	*Nototriche cajonensis*		Tucuman
Malvaceae	*Nototriche calchaquensis*		Tucuman
Malvaceae	*Nototriche castillonii*		Jujuy
Malvaceae	*Nototriche copon*	0.974	Western San Juan
Malvaceae	*Nototriche chuculaensis*		Tinogasta–Belen
Malvaceae	*Nototriche famatinensis*		Famatina
Malvaceae	*Nototriche friesii*		Jujuy
Malvaceae	*Nototriche glabra*	0.888	Famatina
Malvaceae	*Nototriche hieronymi*		Famatina
Malvaceae	*Nototriche kurtzii*		Famatina
Malvaceae	*Nototriche lorentzii*		Salta
Malvaceae	*Nototriche macrotuba*		Jujuy
Malvaceae	*Nototriche niederleinii*	0.999	Famatina
Malvaceae	*Nototriche pulvilla*		Famatina
Malvaceae	*Nototriche rohmederi*		Tucuman
Malvaceae	*Nototriche sleumeri*		Victoria
Malvaceae	*Nototriche tucumana*		Tucuman
Malvaceae	*Nototriche viridula*		Tinogasta–Belen
Malvaceae	*Tarasa latearistata*		Jujuy
Malvaceae	*Tarasa meyeri*	0.953	Jujuy–Tucuman
Malvaceae	*Tarasa trisecta*	0.958	NIA valleys-Sal_Cat
Martyniaceae	*Craniolaria argentina*	0.900	Jujuy–Tucuman
Nyctaginaceae	*Mirabilis bracteosa*	0.944	NOA
Onagraceae	*Oenothera lasciocarpa*	0.895	NOA
Onagraceae	*Oenothera pedunculifolia*	0.980	Tucuman
Orchidaceae	*Chloraea castillonii*	0.964	Tucuman
Orchidaceae	*Chloraea cogniauxii*	0.983	Jujuy
Orchidaceae	*Chloraea phoenicea*	0.985	Tucuman
Orchidaceae	*Chloraea subpandurata*	0.899	Jujuy–Tucuman
Orchidaceae	*Pelexia ovatifolia*		Salta
Orchidaceae	*Sacoila secundiflora*	0.998	Jujuy–Tucuman
Orobanchaceae	*Bartsia jujuyensis*	0.973	Jujuy
Oxalidaceae	*Oxalis famatinae*	0.766	NOA
Oxalidaceae	*Oxalis sleumeri*		NIA valleys-Sal_Cat
Piperaceae	*Peperomia aldrinii*		Jujuy
Plantaginaceae	*Plantago jujuyensis*	0.991	Jujuy
Plantaginaceae	*Plantago venturii*		Tucuman
Poaceae	*Agrostis ambatoensis*		Ambato
Poaceae	*Anatherostipa brevis*	0.989	Jujuy
Poaceae	*Anatherostipa henrardiana*		Jujuy
Poaceae	*Aristida amplexifolia*		Victoria
Poaceae	*Aristida pedroensis*		Jujuy

Table 2 continued

Family	Endemic species	AUC	Area of endemism
Poaceae	*Aristida pubescens*	0.987	Jujuy
Poaceae	*Bromus flexuosus*	0.925	NOA
Poaceae	*Chusquea deficiens*	0.990	Jujuy
Poaceae	*Danthonia rugoloana*		Victoria
Poaceae	*Digitaria catamarcensis*		Ambato
Poaceae	*Elymus tilcarensis*		Jujuy
Poaceae	*Eragrostis andicola*	0.993	Jujuy
Poaceae	*Festuca eriostoma*	0.973	NOA
Poaceae	*Festuca superba*	0.895	Jujuy–Tucuman
Poaceae	*Festuca uninodis*	0.756	Jujuy–Tucuman
Poaceae	*Glyceria saltensis*		Salta
Poaceae	*Jarava breviseta*		Jujuy
Poaceae	*Jarava hystricina*	0.825	Others
Poaceae	*Jarava media*	0.985	NOA
Poaceae	*Jarava scabrifolia*	0.913	NOA
Poaceae	*Muhlenbergia breviaristata*		Salta
Poaceae	*Nassella arcaensis*	0.892	Jujuy–Tucuman
Poaceae	*Nassella caespitosa*	0.986	NOA
Poaceae	*Nassella catamarcensis*		Ambato
Poaceae	*Nassella fabrisii*	0.996	Tucuman
Poaceae	*Nassella famatinensis*	0.964	Western San Juan
Poaceae	*Nassella leptothera*		Tucuman
Poaceae	*Nassella meyeri*	0.737	Others
Poaceae	*Nassella novari*	0.967	Jujuy
Poaceae	*Nassella parva*	0.827	Jujuy–Tucuman
Poaceae	*Nassella ragonesei*	0.997	Ambato
Poaceae	*Nassella yaviensis*		Victoria
Poaceae	*Neobouteloua paucirracemosa*		Talampaya
Poaceae	*Panicum chloroleucum*	0.982	NOA
Poaceae	*Pappostipa hieronymusii*	0.833	Others
Poaceae	*Poa cabreriana*	0.838	NIA valleys-Sal_Cat
Poaceae	*Poa dolichophylla*	0.964	NOA
Poaceae	*Poa hieronymi*		NOA
Poaceae	*Poa plicata*	0.997	NIA valleys-Cat_LRi
Poaceae	*Poa ragonesei*		Jujuy–Tucuman
Poaceae	*Sporobolux maximus*	0.967	NOA
Poaceaee	*Tragus andicola*	0.972	Jujuy–Tucuman
Polemoniaceae	*Giliastrum castellanosii*		Tinogasta–Belen
Polygalaceae	*Polygala argentinensis*	0.860	NOA
Polygalaceae	*Polygala jujuyensis*	0.905	NOA
Polygonaceae	*Rumex lorentzianus*	0.949	Jujuy–Tucuman
Portulacaceae	*Anacampseros vulcanensis*	0.899	Jujuy
Portulacaceae	*Schreiteria macrocarpa*		Tucuman

Table 2 continued

Family	Endemic species	AUC	Area of endemism
Portulacaceae	*Talinum punae*	0.974	Jujuy–Tucuman
Ranunculaceae	*Ranunculus hilii*	0.996	Tucuman
Ranunculaceae	*Ranunculus lancipetalus*	0.938	NIA valleys-Cat_LRi
Rosaceae	*Lachemilla asplenifolia*		NIA valleys-Cat_LRi
Rosaceae	*Lachemilla grisebachiana*		Tucuman
Rosaceae	*Tetraglochin paucijugatum*	0.986	Jujuy–Tucuman
Rubiacea	*Manettia jorgensenii*	0.838	Jujuy–Tucuman
Rubiacea	*Psychotria argentinensis*	0.989	Jujuy
Sapindaceae	*Guindilia cristata*	0.956	SIA valleys
Sclerophylacaceae	*Sclerophylax adnatifolia*	0.983	NOA
Sclerophylacaceae	*Sclerophylax caducifructus*	0.939	NOA
Sclerophylacaceae	*Sclerophylax cocuccii*	0.881	NIA valleys-Sal_Cat
Sclerophylacaceae	*Sclerophylax cynocrambe*	0.962	NIA valleys-Cat_LRi
Sclerophylacaceae	*Sclerophylax kurtzii*	0.951	SIA valleys
Sclerophylacaceae	*Sclerophylax tenuicaulis*		NOA
Solanaceae	*Cestrum kunthii*	0.966	Tucuman
Solanaceae	*Eriolarynx iochromoides*	0.856	Tucuman
Solanaceae	*Eriolarynx lorentzii*	0.999	Tucuman
Solanaceae	*Fabiana friesii*	0.880	NOA
Solanaceae	*Jaborosa cabrerae*		Tinogasta–Belen
Solanaceae	*Jaborosa lanigera*	0.893	Others
Solanaceae	*Jaborosa oxipetala*		Tucuman
Solanaceae	*Jaborosa sativa*	0.731	NOA
Solanaceae	*Lycium schreiteri*	0.917	NOA
Solanaceae	*Solanum calileguae*	0.923	Jujuy
Solanaceae	*Solanum collectaneum*		Jujuy–Tucuman
Solanaceae	*Solanum crebrum*		Ambato
Solanaceae	*Solanum delitescens*	0.980	Jujuy–Tucuman
Solanaceae	*Solanum fabrisii*		Jujuy
Solanaceae	*Solanum glaberrium*	0.967	Western San Juan
Solanaceae	*Solanum incurvipilum*		Salta
Solanaceae	*Solanum kurtzianum*		SIA valleys
Solanaceae	*Solanum montigenum*	0.938	Jujuy–Tucuman
Solanaceae	*Solanum mortonii*		Ambato
Solanaceae	*Solanum neorossii*		Victoria
Solanaceae	*Solanum salamancae*		Salta
Solanaceae	*Solanum sanctae rosae*	0.998	Tucuman
Solanaceae	*Solanum spegazzinii*	0.932	NOA
Solanaceae	*Solanum venturii*	0.897	Jujuy–Tucuman
Solanaceae	*Solanum vernei*	0.940	Jujuy–Tucuman
Solanaceae	*Solanum zuloagae*		Jujuy
Tropaeolaceae	*Tropaeolum argentinum*	0.950	Jujuy–Tucuman
Tropaeolaceae	*Tropaeolum atrocapillare*		Victoria

Table 2 continued

Family	Endemic species	AUC	Area of endemism
Tropaeolaceae	*Tropaeolum willinkii*		Jujuy
Urticaceae	*Pilea jujuyensis*		Jujuy
Urticaceae	*Urtica lilloi*	0.924	Jujuy–Tucuman
Valerianaceae	*Valeriana altoandina*	0.994	Jujuy
Valerianaceae	*Valeriana corynodes*		Western San Juan
Valerianaceae	*Valeriana lasiocarpa*	0.966	Tucuman
Valerianaceae	*Valeriana polybotrya*	0.975	Jujuy–Tucuman
Valerianaceae	*Valeriana tucumana*	0.873	Jujuy–Tucuman
Velloziaceae	*Barbaceniopsis humahuaquensis*	0.980	Jujuy
Verbenaceae	*Acantholippia riojana*		Famatina
Verbenaceae	*Aloysia castellanosi*	0.932	NOA
Verbenaceae	*Aloysia catamarcensis*	0.903	NIA valleys-Cat_LRi
Verbenaceae	*Glandularia ballsii*		Jujuy
Verbenaceae	*Glandularia lilloana*	0.954	Jujuy–Tucuman
Verbenaceae	*Lantana magnibracteata*	0.944	Jujuy–Tucuman
Verbenaceae	*Lantana tilcarensis*	0.920	Jujuy–Tucuman
Verbenaceae	*Verbena andalgalensis*		Ambato
Violaceae	*Viola calchaquiensis*		Tucuman
Violaceae	*Viola castillonii*	0.879	Jujuy–Tucuman
Violaceae	*Viola evae*		Others
Violaceae	*Viola flos-evae*		Western San Juan
Violaceae	*Viola hieronymi*	0.999	NOA
Violaceae	*Viola joergensenii*		Ambato
Violaceae	*Viola lilloana*		Tucuman
Violaceae	*Viola munozensis*		Tucuman
Violaceae	*Viola rodriguezii*	0.996	Tucuman
Violaceae	*Viola roigii*		Southern San Juan
Violaceae	*Viola triflabellata*	0.980	NIA valleys-Cat_LRi
Violaceae	*Viola tucumanensis*		Tucuman
Zygophyllaceae	*Bulnesia schickendantzii*	0.986	NOA
Zygophyllaceae	*Plectocarpa rougesii*	0.979	NOA

For author of species and details on distribution see Aagesen et al. (2012). We also present the AUC values for the 270 species modeled

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