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Biological Invasions

ISSN 1387-3547
Volume 15
Number 8

Biol Invasions (2013) 15:1751-1763
DOI 10.1007/s10530-013-0406-2

Springer

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ORIGINAL PAPER

Invasive alien plants in the Pampas grasslands: a tri-national cooperation challenge

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Received: 20 March 2012 / Accepted: 2 January 2013 / Published online: 13 January 2013

Abstract The challenge of managing biological invasions requires novel approaches and coordinated efforts, especially among countries linked by intense trade routes and sharing common biomes. This is the case in Southern South America, where Argentina, Brazil and Uruguay maintain intense commercial relationships, whilst sharing continuous portions of the Pampas grasslands. Transnational similarities in this case exceed ecological features, including a common colonization history and similar development trends. This study represents a tri-national cooperation effort to describe the alien plant flora invading the Pampas grasslands of Argentina, Brazil and Uruguay and analyses their characteristics in order to detect species and traits that are shared among the three countries and those that have not yet managed to invade the whole region. Furthermore, we highlight the opportunities and needs of a common approach across countries to deal with plant invasions. Information about alien plant species was retrieved from the IABIN Invasives Information Network (I3N) project databases of Argentina, Brazil and Uruguay, complemented with some national herbaria. Three hundred and fifty-six alien plant species were recorded growing in natural or semi-natural habitats of the Pampas. A total of 50 species were found in Pampas

Electronic supplementary material The online version of this article (doi:10.1007/s10530-013-0406-2) contains supplementary material, which is available to authorized users.

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grasslands of the three countries. Argentina shared 48 and 36 species with Brazil and Uruguay, respectively, while the Brazilian and the Uruguayan Pampas shared only 20 species. Poaceae, Asteraceae and Fabaceae were the families with the highest number of invasive species, and herbs were the most common life form (75 %). Most invasive plants originated from Europe, Asia and Africa, and almost one-quarter of the species is associated with some human use, especially gardening. We discuss the opportunities and needs for international cooperation, as the prevention of introductions from one country to another through the use of risk analysis tools, definition of priority invasive species, as well as the detection, containment, eradication and control of common invasions. Furthermore, we suggest the establishment of coherent regional legislation and the inclusion of social issues and the public perception in the biological invasion quest.

Keywords Biological invasion · Prevention · Grasslands · International cooperation · Management · Policy

Introduction

Political decisions about environmental issues are frequently made within countries, states and municipalities. However, for many relevant conservation problems, such as the invasion of alien species, this approach is expected to be ineffective once species expansions are not inhibited by political boundaries (Elton 1958; Mack et al. 2000; Schneider et al. 2004; Metz et al. 2007; Arrivillaga and Windevoxhel 2008). Therefore, the invasive species quest calls for international agreements. The Convention on Biological Diversity, for instance, recommends that countries collaborate regionally to address threats of invasive alien species in ecosystems crossing international boundaries (CBD 2000; 2005).

Biological invasions are one of the main threats to biodiversity (Mooney et al. 2005) and are also associated with significant economic loss (Perrings et al. 2000; Pimentel et al. 2005) and impacts on peoples' livelihood and health (McGarry et al. 2005; Perrings 2005). Invasive alien plants, for instance, are able to transform the invaded environment by replacing the native biota and causing local extinctions, but also by driving drastic abiotic changes (Peterson and Vieglais 2001; Wiens and Graham 2005). Once successfully introduced outside their original range, invasive alien plant species may be able to spread across the whole landscape if their ecological needs are fulfilled. Some ecosystems have proved to be particularly vulnerable to the introduction and to the effects of invasive alien plant species. This is the case for grasslands and savannas in North and South America, Australia, Africa and Southeast Asia (Archer et al. 2001). A whole set of invasive plants, including many trees and shrubs, but also herbaceous dicots, annual grasses and forbs, thrive in grasslands usually in response to changes in fire regimes, replacement of native herbivores and overgrazing (Calder et al. 1992; Richardson 1998; Briggs et al. 2002). Alien plants do not just threaten prairies biodiversity, but also the provision of ecosystem services and the sustainability of livestock grazing (DiTomaso 2000; McCulley and Jackson 2012; Scott et al. 2006), and are therefore a priority target for prevention and control.

Managing invasive alien species is not an easy task. One of the main challenges is the fact that biological invasions do not respect national boundaries. Once an alien species is introduced into a country, voluntarily or not, it raises the risk of invasion of the adjacent countries. Examples of this include the spreading of the grass *Eragrostis plana* (Poaceae) introduced in Argentina (1940) and Brazil (1950–1960), and then dispersed to Uruguay (Matthews and Brand 2005; InBUy 2011), and the vine *Lonicera japonica* (Caprifoliaceae) spreading throughout the Paraná River basin into Brazil, Argentina and Uruguay (Matthews and Brand 2005). The problem of alien species invasion across countries is widespread since neighbouring countries frequently share similar habitats, environmental conditions and biomes. Hence, international cooperation should aim to develop common management guidelines (Wittenberg and Cock 2001) and financial mechanisms to support the control and eradication of undesirable species (Le Maitre et al. 2000; Pimentel et al. 2001).

This paper describes a tri-national initiative created to face the challenge of the invasive alien plant species associated with the South American Biogeographic Province of Pampas (Cabrera and Willink 1980; Soriano et al. 1992). The Pampas covers 892.711 km^2 in Southern South America, including part of Argentina, Brazil and the whole territory of Uruguay (Fig. 1).

Its native vegetation is dominated by grasses and herbs. Woody species are absent or very scarce in the south, increasing towards the north. Protected areas are scarce in the whole province (Overbeck et al. 2007), while the preservation status of the remaining natural Pampean vegetation in the three countries is quite different. In Argentina, 30 % of the natural vegetation remains relatively undisturbed, in Brazil 48 %, while the best scenario is seen in Uruguay where around 70 % of its territory is covered by Pampas grasslands (Bilenca and Miñarro 2004). The Pampas exhibits notable historical, economic and social coincidences among the three countries, including an initial colonization from the Mediterranean region of Europe (Spain and Portugal) and an economy formerly based on cattle ranching, and later in agriculture and forestry. It is plausible to expect that these environmental and social similarities would lead to similar patterns of invasion across the Pampas and to common lists of invasive alien species. Hence, a transnational strategy would be an efficient tool to understand the magnitude and tendencies of biological invasions in Pampas and to prevent and control invasive alien species. On the other hand, despite the described similarities, the Pampas Province is large enough to exhibit national and regional singularities that could be useful to understand some general issues in invasion biology at a regional level.

Determinants of plant invasion include ecological and historical factors that result in particular land use types and spatial patterns. Considering that the whole Pampas region has suffered disturbances associated with cattle ranching, nutrient addition, changes in fire regimes and enrichment with non-native forage species, Pampas remnants may be especially vulnerable to invasive alien species (Hobbs and Huenneke 1992; Chaneton et al. 2002). Here, we synthesize the information regarding alien plant species stored in the IABIN I3N project databases of Argentina, Brazil and Uruguay. The IABIN Invasives Information Network (I3N) is an initiative launched in 2002 with the aim of integrating information from countries throughout the Americas to support the detection and management of invasive alien species (http://i3n.iabin.net/). We aimed to compile information on alien plants present in the Pampas Province in order to explore patterns associated with species that are shared among the Pampas in the three countries and also with species that are restricted to only one or two countries but have not yet invaded the whole region. We also aimed to identify the most represented botanic families and genera, life forms and socioeconomic uses, as well as to unveil the areas of origin of the alien species to draw novel recommendations on how to face the challenge of biological invasions at a regional scale.

Materials and methods

The Pampas Province: environment and vegetation

The Pampas includes subtropical and temperate grasslands in Southern South America (Cabrera and Willink 1980), from 27° to 38°S and from 30° to 39°W (Fig. 1). It covers Southern Brazil (176.496 km^2 of the state of Rio Grande do Sul, IBGE 2004), all of Uruguay (176.215 km^2, SGM 2010) and the east of Argentina (540.000 km^2 in the provinces of Buenos Aires, La Pampa, San Luis, Santa Fe and Entre Ríos; Viglizzo et al. 2005). Soriano et al. (1992) recognize nine subdivisions in this region based on variations in geomorphology, climate, soils and plant species composition. Annual rainfall and mean temperature increase northwards, from 600 mm and 13° to 1,200 mm and 17 °C.

Vegetation is characterized by grasslands with distinct physiognomies, and differing in the abundance of trees and shrubs. Trees occur in the southwest, at the transition with dry forests (Espinal), and increase progressively in importance towards the north. In higher latitudes, woods grow at the margins of the rivers, sometimes extensively, like along the Uruguay River. Many Uruguayan and Brazilian grasslands include a shrub layer integrated within the herbaceous matrix, although abundance of shrubs could be related to fire and grazing history (Paruelo 2001). Mountain prairies at rocky outcrops and flooding grasslands associated with wetlands and floodplains are other vegetation types included in this province.

Although a complete flora is not available, probably at least 3,500 species occur in the whole province (Rosengurtt 1944; Del Puerto 1987; Boldrini 2006). In the Brazilian Pampas, a total of 1,356 species from 421 genera have been recorded (Forzza et al. 2010). Poaceae is the dominant or co-dominant family, including ca. 550 species (Bilenca and Miñarro 2004), and shows a high diversity of life forms and

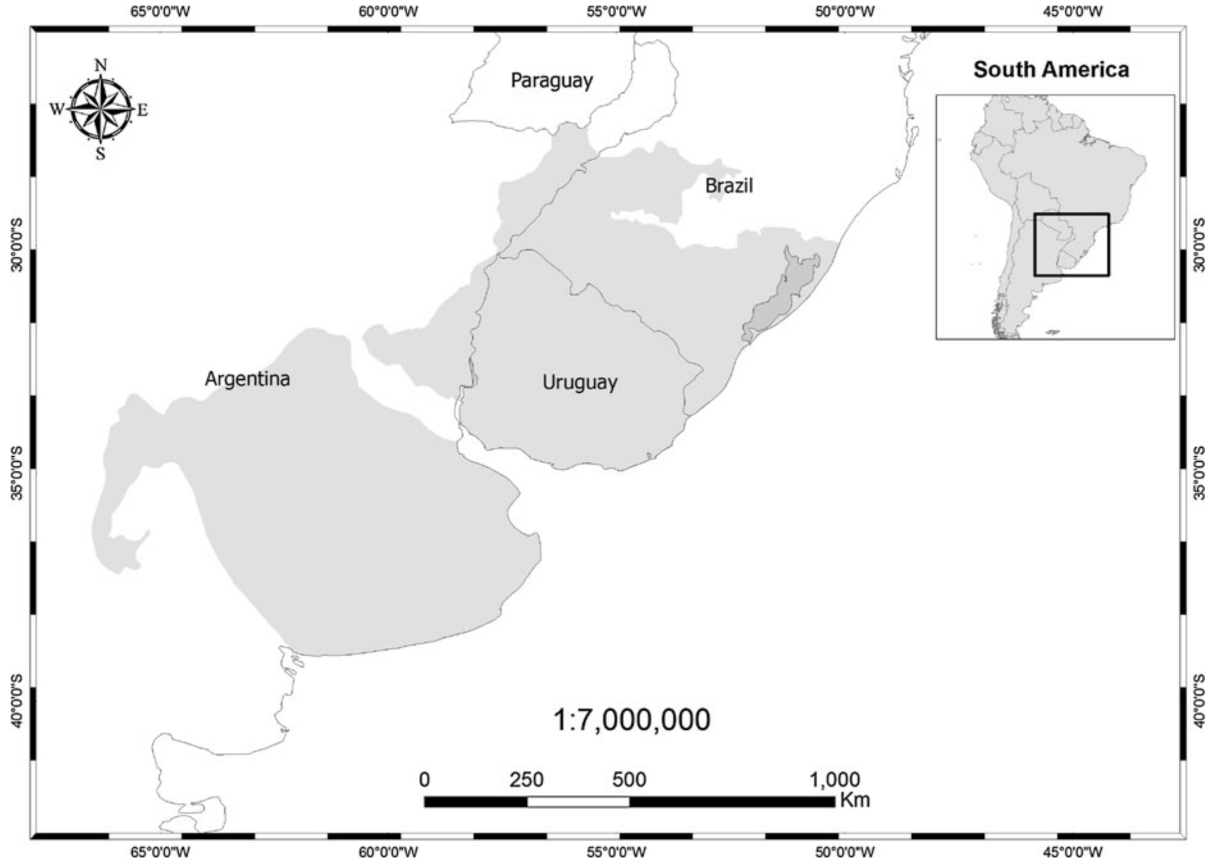

Fig. 1 Geographic distribution of the biogeographic province of Pampas in South America

vegetative cycles (rhizomatous, stoloniferous, annuals, perennials, summer and winter-cycle grasses). Other botanical families, including the Asteraceae and Fabaceae, are also relevant (450 and 200 spp. recorded in Brazil, respectively, Boldrini 2009, 315, 177 spp. recorded in Uruguay Marchesi 2004, and 250 spp. of Asteraceae recorded in Argentina Katinas et al. 2007).

Social and cultural influences

The Pampas region holds high historical, social, cultural and economic similarities among the three countries (Cruz and Guadagnin 2012). Before the European colonization, the area was occupied by semi-nomadic, hunter-gatherer ethnic groups. After the arrival of the Spanish and Portuguese, the region reached a high specialization in cattle ranching, especially during the eighteenth and nineteenth centuries (Souza 1985; Moraes Vázquez 2007). At the end of the colonial times, and until the nineteenth century, grasslands appeared as a key natural resource for the regional economy, centred around cattle ranching in very large rural properties (Barrán and Nahum 1978; Mayo 1995; Pesavento 2002). This common history of land occupancy resulted in a common cultural identity (Astrada 1982; Leenhardt 2002).

The Plata's economy declined at the end of the nineteenth century when the geopolitical and economic importance of the Pampas region changed and started to diverge in the three countries. In Argentina, the expansion of agriculture that started in the nineteenth century gave a new economic impulse to the Pampas that appeared as the most dynamic and economically important region of the country from the beginning of the twentieth century onwards. Today, the Argentinean Pampas is mostly occupied by wheat, maize and cattle ranching. In Uruguay, the Pampas covers the entire national territory, and it was occupied in a more complex fashion. Cattle ranching lost importance in the last decades of the twentieth century, concomitant with the increase in agriculture and forestry, but ranchers were able to modernize techniques and cattle ranching remains a major economic activity today. The historical role of ranching lost importance also in Southern Brazil, due to a delay in the adoption of new technologies. Alternatively, rice production became a significant component of the local economy and has been one of the main reasons for the reduction of naturally flooded grasslands in Brazil since the 1960s (Gomes and Magalhães 2004). Additionally, forestry, mostly based on *Pinus*, became a new and expanding component of the economy in recent years (Bacha and Barros 2004; Grando and Fochezatto 2008).

Data collection

The data set used in this study was made available by the international cooperation effort coordinated by the Inter-American Biodiversity Information Network (IABIN, http://i3n.iabin.net/). The Invasive Species Information Network (I3N), launched in 2002, concerns the organization and sharing of information on invasive alien species in the whole American continent using standardized data (Simpson et al. 2006, 2009; Grosse et al. 2009). Today, I3N provides a web-based national catalogue documenting invasive alien species, including information about their distribution, invasion status, as well as their impact on human health, economy and the environment. Additionally, it offers information regarding the prevention, control and eradication of invasive alien species (Grosse et al. 2004).

We used information provided by the official I3N databases from Argentina (INBIAR, www.inbiar.org.ar), Brazil (HÓRUS INSTITUTE, http://i3n.institutohorus.org.br) and Uruguay (INBUY, http://uruguayi3n.iabin.net). The Brazilian data were complemented with herbarium information from the Instituto Anchietano (PACA) and the Universidade Federal do Rio Grande do Sul (ICN). Although I3N databases contain the most comprehensive information available for the Pampas, coverage of the inventories should be improved in the near future. Today, the number of invasion records of many species is still underestimated and the inventory effort is not even over the whole region. Therefore, the relative frequency of the invader species and the geographic extent of the invasion processes were not analysed.

The I3N database includes information about alien plants with potential invasive behaviour. Species are classified as contained (growing exclusively under cultivation), detected in nature (species that have been recorded at least once in natural or semi-natural habitats), established (species forming one or more self-sustaining populations) and invasive (species spreading widely over natural or semi-natural habitats). In agreement with the CBD definition of invasive alien species, for the purposes of this study, invasive alien species is defined by the group of species recorded in any of the last three categories (CBD, COP 5 Decision V/8 Alien species that threaten ecosystems, habitats or species).

The key information taken from the databases was the presence of invasive alien species in the Pampas region of each one of the three countries (Argentina, Brazil and/or Uruguay), regardless of the number of records in the databases. Information was also retrieved on taxonomy (family and genus), life form (tree, shrub, herb, liana), geographic origin (North, Central and South America, Europe, Africa, Asia, Australia), and associated human uses related to the method of introduction (ornamental and landscaping, forage, woods, live fence, food, wind curtain, dunes fixation, chemical industry, transport of natural materials or no recorded use). Information about the geographic origin of the invasive alien species was complemented by information from the Global Biodiversity Information Facility (GBIF, www.gbif.org), Species Link (http://splink.cria.org.br/), Tropicus (www.tropicus.org/), Discover Life (www.discoverlife.org) and The New York Botanical Garden (http://sciweb.nybg.org/Science2/vii2.asp).

Results

A total of 356 invasive alien plant species was recorded in the Pampas (Fig. 2; Online Resource Table 1). The number of invasive species known to exist in the Argentinean Pampas (246 species) was larger than in the Uruguayan Pampas (161 species) and the Brazilian Pampas (153 species). The number of invasive species exclusive to the Pampas of a single country was higher for Argentina (112 species) than for Uruguay (55 species), and Brazil (35 species). The Argentinean Pampas shared 48 and 36 species with the Brazilian and Uruguayan Pampas, respectively, while the Brazilian and the Uruguayan Pampas shared only 20 species. A total of 50 invasive species was already found in the Pampas of the three countries.

Invasive alien species belonged to 230 genera and 77 families (Fig. 3). The ten families with the highest number of invasive species were Poaceae (66 species), Asteraceae (50), Fabaceae (30), Caryophyllaceae (15), Brassicaceae (14), Rosaceae (14), Lamiaceae (9), Apiaceae (8), Polygonaceae (9) and Scrophulariaceae (9). Thirty-seven families were represented by one species alone. The plant genera with the highest number of invasive species was *Eragrostis* (6 species), *Medicago* (6), *Pinus* (6), *Acacia* (5), *Bromus* (5), *Carduus* (5), *Rumex* (5), *Veronica* (5), *Agrostis* (4), *Crepis* (4), *Cyperus* (4), *Eucalyptus* (4), *Ligustrum* (4), *Malva* (4), *Melilotus* (4), *Mentha* (4), *Polygonum* (4) and *Sisymbrium* (4).

Herbs were the most common life form among the invasive species (267 species, 75 %). However, 54 trees and 24 shrubs also successfully invaded the Pampas. The frequency distribution of life forms varied significantly among countries, with Uruguay showing a lower occurrence of invasive trees than expected (Likelihood ratio chi-square = 18.58, g.l. = 6, $P = 0.005$, Fig. 4).

The invasive species associated with the Pampas exhibited a diverse biogeographic origin. Most of them occurred originally in Europe (242 species), Asia (121) and Africa (106), although species native to

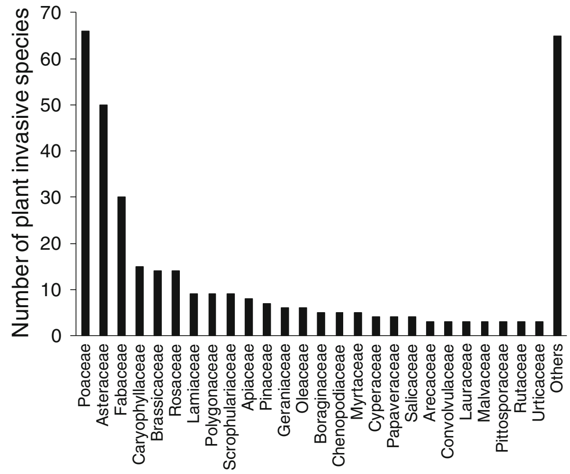

Fig. 3 Taxonomic distribution of the invasive alien plant species that occur in the Pampas grasslands

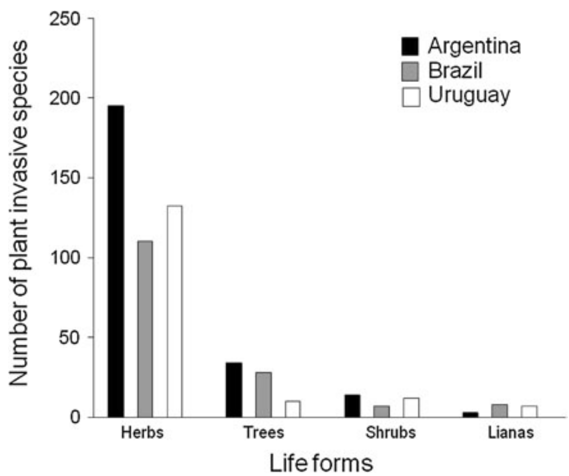

Fig. 4 Life forms of the invasive alien plant species that occur in the Pampas grasslands

North America (25) and Australia (16) were also recorded. Only two species, *Furcraea foetida* (Agavaceae) and *Passiflora alata* (Passifloraceae), were native to other regions of South America (Fig. 5).

Human use of invasive alien plant species, in at least one country, was registered for 74 species (21 %), while 282 species have no known use (Fig. 6). Ornamental purpose (43 species) and forage (21 species) were the most frequent uses. Food (5), wood (4), living fence (3), wind curtain (3), dunes fixation (1) and chemical industry (1) had lower uses. Human use varied substantially among life forms, with

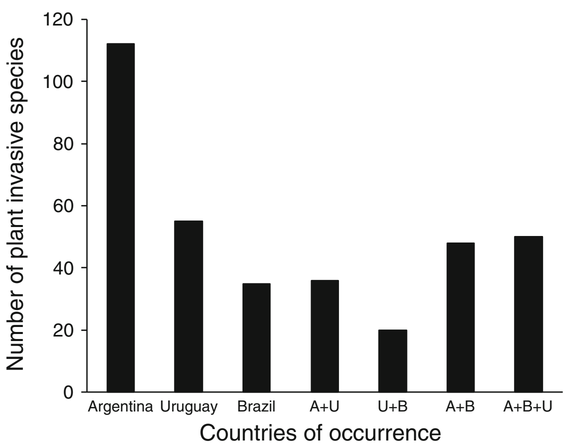

Fig. 2 Occurrence of the 356 invasive alien plant species in the Pampas grasslands of Argentina, Brazil and Uruguay. Many species are exclusive to Argentina (A), Uruguay (U) and Brazil (B) and some are shared between only two countries (A + U, U + B, A + B). Fifty invasive alien plant species are already present in the three countries (A + B + U)

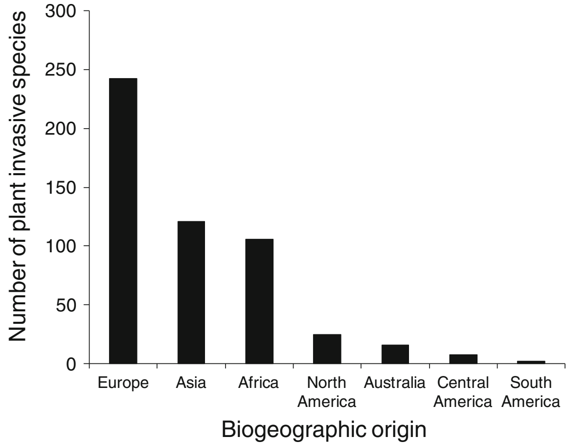

Fig. 5 Geographic origin of the invasive alien plant species that occur in the Pampas grasslands

lianas (64 %) and shrubs (46 %) being more used than trees (39 %) and herbs (13 %).

Discussion

A common threat

At least 356 invasive alien plant species that are present in the South American Pampas grasslands today represent a common threat for Argentina, Brazil and Uruguay. Here, we highlight that recognition of this common threat brings the opportunity for international cooperation. The benefits include at least five main components: (1) exchanging information to prevent the introduction of unwanted alien species that are already present in a neighbouring country, including a system of early detection and regional alarm, (2) joining initiatives for the development of management and prioritization tools, such as sound risk analysis, (3) sharing information about successful and unsuccessful control programs to foster expertise and effectiveness (4) integrating actions for the containment, eradication or control of common invasions, and (5) establishment of coherent regional legislation. By compiling information, organisms can be rapidly identified as potential invaders. Also, affected zones, dispersion routes and pathways of entrance can be detected. This approach allows the establishment of more effective actions of mitigation and management. International initiatives have been initiated in other regions of the world, initially focusing on the spread and control of agricultural plagues and diseases, and more recently including the broader issue of invasive species. This is the case, for instance, of NAPPO (North American Plant Protection Organization), an integrated initiative of USA, Canada and Mexico (http://www.nappo.org/en/). I3N also works on this direction, developing common databases and tools for risk analysis and mapping of invasion routes and vectors for the Americas. Our data emphasize the importance of such initiatives and suggest possible directions for improvement.

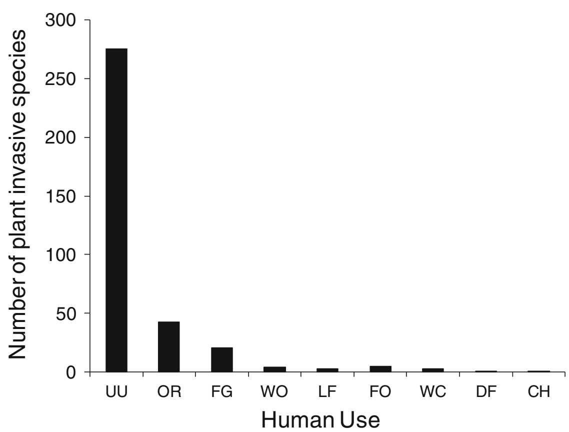

Fig. 6 Human uses associated with invasive alien plant species that occur in the Pampas grasslands. *OR* ornamental and landscaping, *FG* forage, *WO* wood, *LF* living fence, *FO* food, *WC* wind curtain, *DF* Dunes fixation, *CH* chemical industry, *UU* use unknown

Currently, there are no formal agreements among the Pampean countries focussed specifically on the management of biological invasions. Despite this, several efforts for controlling invasive plants and reducing their impact on grassland biodiversity have been implemented in the region. In Argentina, a strategy for adaptive management and restoration of montane grasslands affected by invasive pines and brooms is ongoing in the southern tip of the Biome (Cuevas and Zalba 2010; Sanhueza and Zalba 2009), together with prevention measures that include vectors and pathway analysis. Experimental management of invasive blackberries (Mazzolari et al. 2011), Chinaberry trees and privets has also been carried out in different protected areas. In Brazil, the Horus Institute for Environmental Conservation and Development, in cooperation with state governments, has been leading the efforts for prevention, prioritization and control of invasive plants, especially in state parks and other natural areas in the states of Parana, Santa Catarina and Rio Grande do Sul (http://www.institutohorus.org.br/). Uruguay, in turn, is organizing a national strategy for managing invasive species including components of prevention, control, monitoring, legislation, research and capacity building (Aber and Ferrari 2010).

The fact that the Argentinean Pampas holds more invasive alien species when compared to the Pampas of the other two countries can be partially explained by the fact that Argentina embraces 60 % of the biogeographic province and that it has the most severely transformed landscape due to intense agricultural activities (but see Arianoutsou et al 2010). An interesting finding is that broadly the traits of invasive alien plants are similar to those exhibited by native species, despite differences in taxonomy of invasive species across countries. The proportion of herbs, shrubs and trees in the invasive alien plant list was similar among the three countries, although Uruguay showed a shortage of invasive alien trees. However, invasive trees are particularly problematic in the treeless Argentinean Pampas causing a strong impact on the natural ecosystem (Zalba and Villamil 2002). This is exacerbated by the fact that a high proportion of the tree species introduced to the Pampas have some human use. The predominance of alien herbs in the Pampas database of the three countries is in accordance with the dominance of herbaceous vegetation in the biogeographic province. However, the successful invasion of the treeless Pampas regions in Argentina by a number of exotic tree species indicates that niche differentiation probably is an important determinant of the invasion process (Ordonez et al. 2010). In taxonomic terms, several families that are common among the invasive alien species (e.g. Poaceae, Asteraceae and Fabaceae) also dominate in the native vegetation (Boldrini 2009; Masciadri et al. 2010). The data suggest that phylogenetic affinity and life form similarity with the native flora can be used as a first surrogate for invasion success.

The geographic origin of most invasive species is consistent with the colonization history of the Pampas. A large group of invasive alien species were introduced from the Mediterranean region in Southern Europe, some of them possibly arriving from Spain and Portugal with the first colonization events. A few species were clearly introduced more recently, such as those colonizing from Australia due to initiatives of prairies afforestation. Only two invasive species are native to South America, which shows the unique environmental conditions of the Pampas (Alexander and Edwards 2010). Alternatively, biological constraints related to the presence of natural enemies could be limiting the establishment of plants spilling over from nearby ecosystems (Mitchell et al. 2006; Strauss et al. 2006). Only 23 % of the species are associated with some kind of human use in at least one country. This high proportion of non-utilitarian species is due to the high number of weeds that are usually unintentionally introduced in association with agriculture and cattle raising (Randall 2002; Ruiz and Carlton 2003). These results highlight the historical role of land use as major factors in the establishment of alien floras. Similarities in colonization patterns and socioeconomic forces associated with similar climates operating in the grasslands of Southern South America countries led to similar invasive flora. Such conditions contrast with other regions worldwide, such as Europe, where greater differences were reported for invasive species between countries, which are attributed to variation in propagule pressure and the nature and intensity of disturbances associated with different histories and socioeconomic processes. Furthermore, it also highlights the risk of further homogenization in the invasive floras among Argentina, Brazil and Uruguay, due to the introduction of new species and the dispersal of those that have not managed to cross national borders yet.

The list of invasive alien plant species of the Pampas provides valuable information for prioritization processes and international cooperation agreements. Invasive alien species that do not occur in the Pampas region of a given country, but are present in the adjacent countries, should receive special attention from the authorities. However, before formulating international agreements, it is important to verify whether the species are already present in other biogeographic provinces of the country. This is not important in Uruguay as the whole country is within the Pampas domain. In Brazil, only two of the 203 invasive alien species recorded in the Argentinean and Uruguayan Pampas, but not in the Brazilian Pampas, were also recorded in other parts of Brazil. In Argentina, 18 of the 110 invasive alien species not recorded in the Argentinean Pampas were recorded in other parts of Argentina (see Online Resource Table 1). Those species deserve special attention from the national authorities to avoid their spread into the Pampas.

Prevention and regional alerts

Prevention is by far the most cost-effective way to deal with the invasion problem (Leung et al. 2002). Previous invasive behaviour has proved to be a powerful predictor of the invasion risk of species introduced into a new region (Williamson 1996). Considering the relevance of climate, soil and biotic characteristics of the receiving region in determining invasive success, special attention should be given to species antecedents in the same biogeographic province. This is further exacerbated when the culture and social organization of local populations result in similar land uses. In the Pampas, 202 invasive alien species are presently restrained within the limits of a single country, while 104 invasive alien species have already succeeded in reaching two of the three countries. Therefore, the ecological success of such species in the Pampas should be taken as a serious warning sign for the countries yet to be reached. Moreover, economic uses of species with proven invasive ability, such as *Eucalyptus* and *Pinus* for timber production, are deliberately increasing throughout the Pampas. For those cases, all stakeholders should engage in discussions regarding the costs and benefits of the introduction and in the prevention politics and management actions that are needed to avoid the dispersal of such species to the natural environments. However, the fact that most invasive alien species (77 %) introduced in the Pampas have no uses highlights the vulnerability of the region to accidental introductions and the need for adequate analysis of risks associated with specific vectors, such as seed contamination. Also, this finding highlights the need for campaigns to raise the public awareness concerning the introduction of exotic species.

I3N developed a system for evaluating the risk of introducing new plant species at the continental level (Zalba and Ziller 2008, downloadable at http://i3n.iabin.net/tools/web_tools.html#Risk). This tool includes many criteria, some of which could be particularly accurate if the tool is adjusted for its use at the biome level. This is the case, for instance, of climatic coincidence and previous invasive behaviour of the species and also of some ecological features that could be particularly appropriate for a species to succeed in the Pampas, like tolerating grazing by big herbivores or ability to re-sprout after fire. I3N risk analysis also incorporates a complementary tool for calculating risk thresholds based on the previous invasion performance of a species. The tool could be further improved for analysis performed at the level of biogeographic provinces, more than for the whole country. The presence and invasive status of a given species in the same biogeographic province of a neighbouring country could be used as a good indicator for its potential performance.

Early detection and eradication

Opportunities to eradicate biological invasions are rare and transient. The effectiveness of eradication actions can strongly benefit from an integrated system of risk analysis based on a shared list of identified threats. Nowadays, national plans to quickly face catastrophes, flooding, plagues and pathogens are instrumented through emergency systems in Brazil and Uruguay (SNDC 2011; SNE 2011). These initiatives could be adapted for the implementation of a system of rapid response to biological invasions designed to conduct programs of early detection and joint eradication efforts.

Although a list of especially dangerous invasive species does not exist for the region, this cross-country analysis allows the identification of plants of particular concern for prevention, detection and early eradication purposes. This could be the case for species that are included in the category "invasive" in one country (or two), but are absent or are not causing problems in other countries. Species that have successfully invaded one or two countries could be expected to have a similar performance where they have not yet been introduced. Species that should receive high priority, due to their high impact, include *Acacia mearnsii* (invasive in Argentina and Brazil, absent in Uruguay), *Diplotaxis tenuifolia* (invasive in Argentina, not cited in Brazil and Uruguay), *Salsola kali* (invasive in Argentina and Uruguay, not cited for Brazil), all the *Cyperus* species (invasive in Brazil and Uruguay but still not causing problems in Argentina), *Cytisus monspessulanus* and *Gleditsia triacanthos* (aggressive invaders in Argentina and Uruguay, not cited as problematic in Brazil).

Control and management

Control of invasive alien plants would improve by sharing experiences among the countries of the region. For instance, 50 invasive alien species occur in the three countries, representing a common threat. Despite that, control actions are nowadays organized on a national basis, disregarding the experiences acquired by the other countries. Nevertheless, common cultural and biological characteristics across the region lead to similar constraints in technical, economic and social feasibility of management actions (Zalba 2005; Zalba and Ziller 2007). By sharing information, all countries can reduce the costs involved in the research for management tolls. For instance, I3N databases already include some information about the actions implemented for controlling invasive species at different locations across the three countries.

Laws and international agreements

In some cases, sharing information is not enough to assure consistent management of common threats (Hulme 2006; Simberloff 2005). Coherent policies have to be implemented in terms of avoiding the introduction of risky species or, at least, of informing neighbouring countries about these initiatives and taking relevant security measures. The same applies for the control of species with a high risk of spreading across boundaries, cases in which isolated efforts of eradication or containment are expected to render poor results.

The agreement and recognition of a common list of dangerous species (see Online Resource Table 1) can set the basis for coherent management policies in order to find more successful ways of preventing and mitigating the impact across national boundaries. The introduction of new species in any country should be subjected to international agreements as it implies regional risks, in a similar fashion as the management of common basins is regulated by consensus policies. Argentina, Brazil and Uruguay, as part of the MERCOSUR, have already organized information exchange activities and alert systems and tools in case of environmental accidents (PNUMA and CLAES 2008) and recognize eco-regions as a sound conceptual basis for planning (PNUMA and CLAES 2008; De Lisio 2009). Biological invasions have not been included in these mechanisms yet, probably because of the novelty of the issue in South America.

Social perception and education

Biological invasions are human-mediated processes. The total number of invasive alien species and the proportion that successfully establish in a region depends on how the local society perceives and values such species. People act as a vector of accidental or intentional introduction and also have the opportunity to promote prevention, control and management strategies. In this way, biological invasions exceed the biological perspective and need to incorporate a socio-environmental and educational viewpoints (Perrings et al. 2000; Perrings 2005; García-Llorente et al. 2008), involving several sectors of the society (McNeely 2001).

The status of the Pampas is worrying because natural prairies are not only ecologically susceptible, but also culturally vulnerable to invasions, particularly to woody species (Guadagnin et al. 2009). Several studies highlight that open environments like prairies receive less public consideration than woody landscapes (Ruddell and Hammitt 1987; Kaplan et al. 1989; Cook and Cable 1995). In addition, perception of the environmental impacts of biological invasions is scarce, and on the contrary, alien species are frequently perceived as a positive achievement (Baskin 2002). Afforestation even with invasive alien species is frequently perceived as a benefit to the environment (Wright et al. 2000; Vasques et al. 2007).

In the Pampas, a quarter of the invasive alien plants are associated with some human use, and this highlights the need for the awareness of the severity of the problem to be improved. Only few social sectors concerned about environmental issues recognize the value of the Pampas biodiversity (Guadagnin et al. 2009). Improving public awareness of the value of the Pampas landscape, biodiversity and ecological services is essential in order to prevent the impacts associated with the introduction of invasive species. Local initiatives to educate the public about the value of native species and ecosystems will be important for the exchange of information, taking advantage of the common history and similarities of culture, land uses and threats to local biodiversity. National education should receive special attention to allow recognition of this need and opportunity.

Acknowledgments Thanks to Beatriz Costa Górriz, Ana Julia Nebbia, Yannina Andrea Cuevas, Eliana Marcia Da Ros Wendland, Luís Fernando Carvalho Perello, Maria Carmen Sestren Bastos, Cristina del Carmen Sanhueza, Ana Elena de Villalobos, Katy Orford for the exchange of ideas and review of early versions of the manuscript. This paper is a product of collaborative scientific meetings held in Argentina, Uruguay and Brazil as part of the Programa Sul-Americano de Apoio às Atividades de Cooperação em Ciência e Tecnologia (PROSUL) and was fully supported by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq: 490629/2007-5, 476818/2008-7). CNPq also provided research fellowships to CRF (303714/2010-7) and DLG (309298/2009-1). SMZ and PG received additional support from CONICET and SGCyT Universidad Nacional del Sur.

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