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The folk biology of South American-native shrub, *Mimosa pigra* L. [Leguminosae] and its invasive success in Rwanda

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Although, the probability of an alien plant species to become invasive in natural or semi-natural habitats is relatively low, the introduction of new taxa should always be regarded as a sensitive issue because the effects of an insertion of an invasive species are likely to be prohibitive as well as external. Ideally, plant species with an invasive potential should not be allowed to enter a country and, if they do, the next best scenario is early detection and eradication. Unfortunately, in Rwanda, despite its location in the Albertine Rift, a biodiversity hotspot with many endemic and endangered species, little is known about the status of introduced taxa. In this article, we combine the insight from library resources, herbarium records and vegetation surveys to document the status of an introduced species, *Mimosa pigra* L. The results comprise evidence that this species has reached the invasive status in Rwanda and support the plea that it be officially listed as such. We suggest that Egypt through Uganda may have been the primary source of *M. pigra* L. propagules that first infested Rwanda through the Akagera-Nyabarongo river system, earlier than Mid-19th century. We presume that under the shadow of its non-specific Kinyarwanda name 'u-mu-gey-o', it was able to spread undisturbed and invade Rwanda's central and eastern floodplains before scientists could take notice of its true identity.

Key words: Mimosa, invasive, Nyabarongo, floodplain, Umugeyo, infestation, range.

INTRODUCTION

According to Yates et al. (2004), 'plant invasions are a current threat to biodiversity conservation, second only to habitat loss and fragmentation'. Indeed, introduction of invasive species in critical ecosystems such as wetlands, croplands, waterways and high-endemism forests, although a subtle action whose harmful effect might require several years to be realized, poses insidious and potentially long-range threat to environmental security and can cost infested countries billions of dollars in lost revenue, property damage and eradication expenses (Kapustka, 2007). In financial terms, the estimated annual damage from displacement of local taxa by invasive species in the United States alone amounts to more than US$120 billion (Pimentel et al., 2005); equivalent to nearly 65 times the 2011/2012 annual budget of the Republic of Rwanda. In particular, environmental weeds, a subset of plants that invade natural vegetation, adversely affecting native biodiversity and/or ecosystem functioning, are considered to be one of the greatest threats to nature conservation (Williams and West, 2000).

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Although, the probability of an alien plant species to become invasive in natural or semi-natural habitats is relatively low [approximately 0.01 in New Zealand, where only 240 out of nearly 20 000 non-indigenous plant species are considered weeds (Fowler et al., 2000)], the introduction of new taxa should always be regarded as a sensitive issue because the effects of an insertion of an invasive species are likely to be not only prohibitive (cost so high that it prevents people from taking rehabilitating action), but also external (cost not carried by those who caused the damage). For instance, a decision as simple as that of bringing in a few propagules of *Eichhornia crassipes* (Mart.) Solms [Pontederiaceae] for ornamental purposes resulted in a disastrous situation for Rwanda's eastern river and lake systems, prompting policy makers to ban its cultivation [by Order No. 51/162 of 4/5/1955] since the 1950s. This step did not successfully hinder its spread due to its incredibly high propagule pressure. Instead, the species expanded its range to become a trans-boundary concern and was officially recognized to invade the world's second largest lake, East Africa's Lake Victoria, in 1988 (Moorhouse et al., 2001). Furthermore, by the time a species is declared invasive under existing legislation, it often has little impact because the spread of the species and its associated damage to ecosystems has already begun (www.dpi.qld.gov.au, 2012.03.03).

Ideally, plant species with an invasive potential should not be allowed to enter a country and, if they do, the next best scenario is early detection and eradication (Fowler et al., 2000). Unfortunately, in Rwanda, located in the Albertine Rift, a biodiversity hotspot with many endemic and endangered species (Eilu et al., 2004; Plumptre et al., 2007; Rutagarama & Martin, 2006), little is known about the invasive status of the majority of introduced species. Among these is the south American-native *Mimosa pigra* L. [Leguminosae], which has almost unnoticeably invaded Rwanda's floodplains for decades.

M. pigra has been on the African continent for not less than 200 years, with the known earliest record date being that of 1826 in Egypt (GISP, 2007). A recent study suggests that it immigrated from South America, its ancestral area, during late Miocene through trans-Atlantic long-distance dispersal (Simon et al., 2011). The presence of *M. pigra* as a naturalized or invasive taxon in North-eastern Africa has been attested by many authors (Sheded and Hassan, 1999; Vilà et al., 1999; EIAR, 2010). In neighbouring Uganda, *M. pigra* was found to be particularly abundant in the Lake Victoria eastwardly-adjacent district of Rakai (Byenkya et al., 2004; Chapman et al., 2001). Its presence was also noted in Doho wetland, north to Lake Victoria and 60 km from Kilimandjaro Mountain (Kalema and Ssegawa, 2007). In Burundi, *M. pigra* has been reported to threaten Lake Tanganyika's riparian communities (lta.iwlearn.org, 10.07.2012). Still in Burundi, but closer to south eastern Rwanda, *M. pigra* was referred to as one of the most potential harmful species whose spread should be contained before it invades the Ruvubu National Park via the Ruvubu River (Masharabu, 2011).

Not only it is prickle-armed to form impenetrable thickets which protect it against trembling or destruction by humans and foraging animals, but also has incredible powerful reproductive machinery with a single plant being able to produce up to 9000 seeds per year. In addition, the pods containing these seeds are light and hairy enough to ease propagation by wind and water, especially during flooding periods (Lonsdale, 1993). According to the same author, even in case of wind dispersal alone, it still would achieve a spread rate of up to 18.3 m per year. However, in a natural environment, this rate can be tremendously magnified as illustrated by records in Zambia's Kafue Flats (Douthwaite and van Lavieren, 1977). With an original population size of 100 ha in 1986, *M. pigra* infestation had expanded to cover 2500 ha by 2003, achieved an average spread rate of 132 m year^{-1} (Indira, 2007). In this article, we discuss the unusual distribution pattern of *M. pigra* in Rwanda, identify its primary source of infestation and elucidate its identity.

METHODS

Description of the study area

The study was carried out in Rwanda, Central Africa, between 1°03-2°50 south of the Equator and 28°52-30°54 east of the Greenwich Meridian Line. Field data collection lasted for three months, starting from Early-May 2012 to Mid-August 2012, and covered riparian and floodplain plant communities of Nyabarongo River. The area covered by this study is part of both the Albertine Rift, a biodiversity hotspot which harbors many endemic and endangered species (Eilu et al., 2004; Plumptre et al., 2007; Rutagarama and Martin, 2006), and the Nile River Basin, one of the great rivers of the world. The Ministerial Order No 008/16.01 of 13/10/2010, establishing the list of wetlands in Rwanda, classifies Nyabarongo-associated wetlands in the category of those to be fully protected and the process of giving part of them the RAMSAR site statute has already begun. Downstream Nyabarongo River, Akagera wetlands have been under special protection since 1934 when the Akagera National Park was gazetted.

Concept definition

Richardson et al. (2000), supported by Ipou et al. (2011) and Pysek et al. (2004), define an invasive species as a 'naturalized plant that produces reproductive offspring, often in very large numbers, at considerable distances from parent plants [with an approximated spread rate of more than 2 m/year], and thus have the potential to spread over a considerable area'. In Flora Europaea, a taxon is considered to be 'effectively naturalized' once it has 'established in a single station for at least 25 years, or is reported as naturalized in a number of widely separated localities' (Tutin et al., 1964). To be considered 'alien' a taxon should have moved at least 100 km from the nearest locality where it is native (Richardson et al., 2000).

Colautti and MacIsaac (2004) attempted to provide a practical reference as to when a species should be labeled invasive, suggesting that invasive species [also referred to as 'metaphytes' in opposition to 'diaphytes' or taxa established in a non-permanent way (Sobrino et al., 2002)] are 'those taxa that are non-native to the

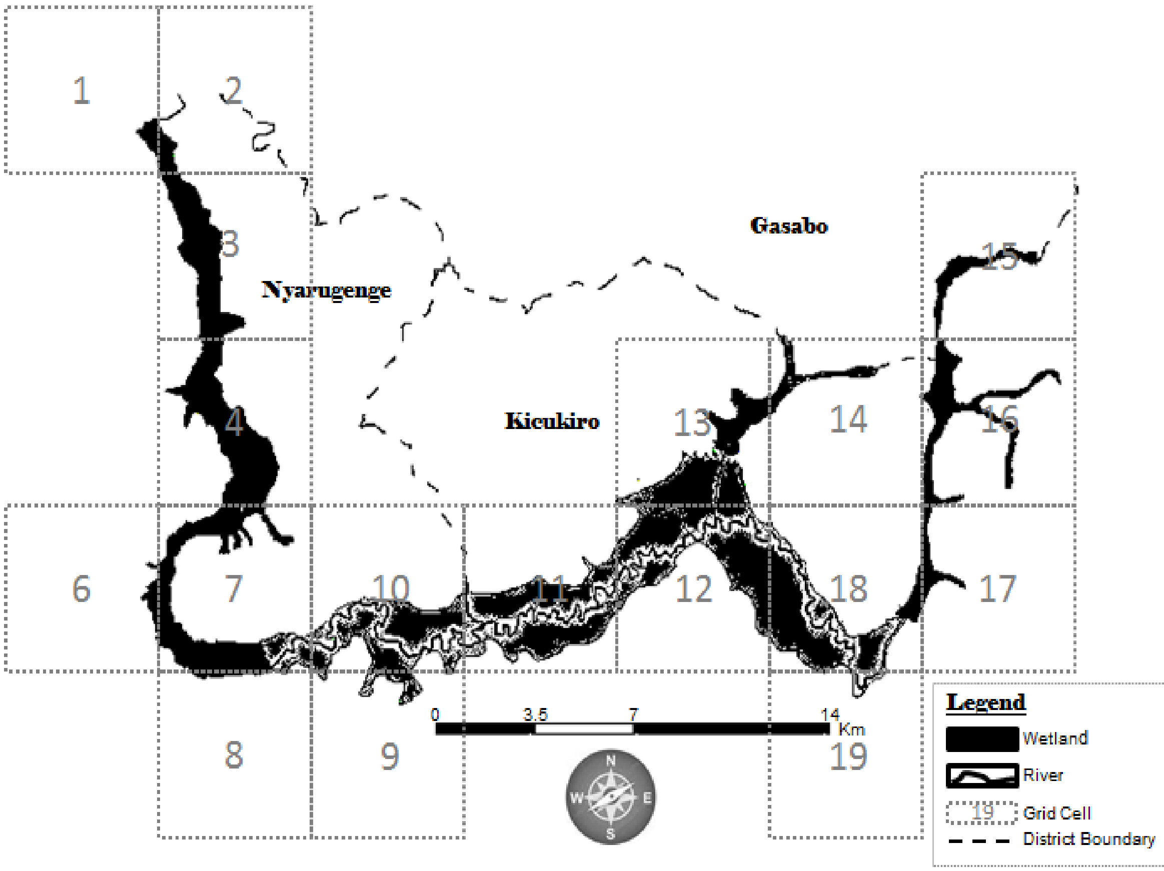


Figure 1. Localization of field data collection sites (Nyabarongo floodplains).

ecosystem under consideration and whose naturalization has resulted into either (1) widespread but rare, (2) localized but dominant or (3) widespread and dominant occurrence'. However, Simberloff (2010) still recognizes that there are no clearly defined operational criteria for a threshold above which a species can be said to have reached the status of invader in a given area.

For the purpose of this study, the following minimal conditions were applied: [1] cultivated (CV): the taxon is represented by specimens that were planted by humans; [2] casual (CAS): the taxon is represented by at least one individual plant growing wildly; [3] naturalized (NAT): the species occur by a wild population sustained over at least 2 lifecycles (3 seasons for seasonal and annual plants and 2 generations of seedlings for perennial taxa); [4] invasive (INV): the taxon is naturalized in more than 3 localities separated by at least 100 to 1000 m, the estimated routine maximum dispersal range of most plant species in the tropics (Corlett, 2009); and [5] transformer (TRF): the taxon spreads over a continuous area of more than 500 m^2 [an average-sized ecotope or smallest ecologically distinct landscape feature (Ellis et al., 2006)], with a mean distance between individuals or groups of plants of less than one time the canopy range of an individual plant of the concerned species; equivalent to a canopy cover of more than 50% (Bernez et al., 2006; Westhoff and van der Maarel, 1978).

Data acquisition

Levels of infestation

A 5.5 x 5.5 km^2 grid was overlaid over the study area's map (Figure 1). Only grid cells adjacent to the wetlands were counted. In each grid cell, Six 200 x 100 m^2 quadrats were defined and thoroughly searched using the timed-meander method (Huebner, 2007). We left the quadrat when it was entirely walked or as soon as *M. pigra* was checked off (Gulezian and Nyberg, 2010).

Source of infestation

A desk-based study was conducted during which we delved into the available literature and herbarium collections to retrieve additional information on past distribution patterns of *M. pigra* in Rwanda and identify the probable source of primary infestation. Records at National Herbarium of Rwanda and references to *M. pigra* in the works of Troupin (1966, 1971, 1978, 1982, 1983, 1985a and b) and Bloesch et al. (2009) were the main source of these secondary data. Rigorously selected online plant databases were also accessed, including the Global Invasive Species Database <www.issg.org> managed by Invasive Species Specialist Group (ISSG) of the IUCN Species Survival Commission and the Agro-forestry Tree Database <www.worldagroforestrycenter.org> of the International Centre for Research in Agroforestry.

Adoption of a name

Rwanda's folk taxonomists, upon assigning to it the Kinyarwanda name of 'u-mu-gey-o', confused the identity of *M. pigra* with that of environmentally less harmful plant species, *Acacia brevispica* Harms [Leguminosae], *Ptelorobium stellatum* (Forsk.) Brenan. [Leguminosae], *Acacia monticola* Brenan ex. Exell. [Leguminosae], the yet to be declared invasive in Rwanda *Caesalpinia decapetala*

Table 1. Historical records of *M. pigra* L. in Rwanda (Source: National Herbarium of Rwanda).

Sites of record	Author's name	Sample code	Year of record
Rusumo (Kirehe District)	Runyinya, B.	644	1977
Kanyinya, Lac Ihema floodplains (ANP)	Bouxin and Radoux	1216	1969
Plain Ndayitarirahe (Uruwita, ANP)	Troupin, G.	6957	1958
Rusumo (nearby Akagera waterfalls	Troupin, G.	15855	1976
Kamurugenze (Akagera National Park	Troupin, G.	7466	1958
Karama Station (Bugesera District)	Bouxin and Radoux	1379	1972
Bigugu, Kigali- Kanombe (MVK)	Mvukiyumwami, J.	54	1982
Kijojo (Byumba, now Nyagatare District)	Christiaensen, A.R.	802	1954
Uruwita Plain (Akagera National Park)	Bouxin and Radoux	26	1969
Uruwita Plain (Akagera National Park)	Troupin, G.	5312	1957
Mwendo (Bugesera District)	Liben, L.	868	1953
Gabiro (Gatsibo District)	Robyns, W.	9573	1938
Gabiro- Kagitumba Road, Km 18	Der Veken, P.V.	10731	1974
Near Gabiro (Gatsibo Dstrict)	Germain, R.	1138	1942
Nyabarongo (Shyorongi, Rulindo Dstrict)	Bouxin and Radoux	1758	1970
Route Kigali- Butare, Km 15 (Kamonyi)	Bouxin and Radoux	1790	1970
Icyanya, Kigali	Becquet, A.	247	1932

(Roth) Alston [Leguminosae], and the taxonomically distant *Rosa* sp. [Rosaceae]. To derive the best predictors of this group denomination, we compared its scores on 21 key characters with the scores of three of its name sakes: *C. decapetala* (Roth) Alston [Leguminosae], *Rosa* sp. [Rosaeae] and *A. brevispica* Harms [Leguminosae]. The selected characters included the morphology (presence of prickles on stems, the hairy character of fruits, sensitivity of leaves, type of flowers …), ecology (ability for wild growth, most preferred habitats, ability to form dense thickets…), function of the plants (readiness for ornamental, medicinal, and live fencing use, source of animal fodder and possibility of soil fertility improvement through nitrogen fixation), and characteristic denomination of the species ('catclaw', in English, 'Umugeyo' and 'Bwara', in Kinyarwanda). Scoring was done in the form of binary coding system, in which '1' was assigned to a species if it tested positive for the character, and '0' assigned if it did not.

Data analysis

M. pigra range was mapped in ArcGis 9.3. ANOVA was used to determine the level of significance of observed differences between mean altitude and time of sample collection in relation to the sites of record (Akagera and Nyabarongo basins). Based on their respective scores on selected key characters and through PCA (Principle Component Analysis) and Hierarchical Clustering (UPGMA, Unweight Pair Group Method with Arithmetic Mean), predictors of association patterns of *M. pigra* and its close cousin species were identified. In particular, the question as to why *M. pigra* was given the Kinyarwanda name of 'u-mugey-o', normally used to refer to the Rwandan-Native *A. brevispica* Harms [Leguminosae], but also to the introduced *C. decapetala* (Roth) Alston [Leguminosae] and *Rosa* sp. [Roasaceae], was addressed. A predictor of this group denomination was recognized.

RESULTS

Levels of infestation

The first scientific record of *M. pigra* in Rwanda dates back to 1932, shortly after the arrival of European colonizers. However, the collections continued to be taken for decades and available specimens at the National Herbarium of Rwanda include samples deposited recently as of 1982. The majority of these samples were collected within two periods of time, separated by 10 years: 1948 to 1958 (35.3 % of samples) and 1968 to 1978 (47% of samples) (Figure 2a).

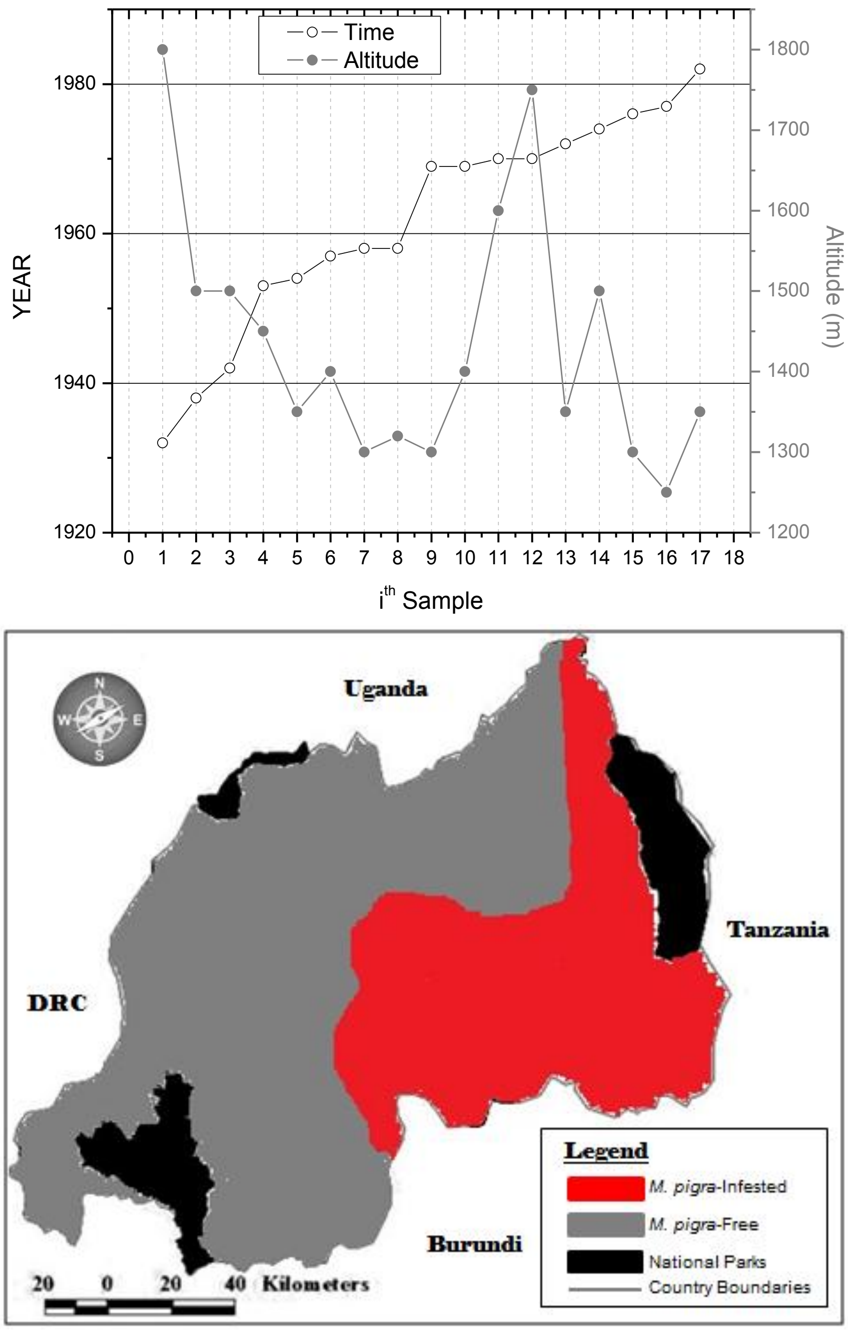
The findings of this study revealed that *M. pigra* occurs within Nyabarongo and Akagera basins, between 1°04' and 2°24' south latitude and between 1°54' and 30°54' east longitude. This range covers the entire Kigali City region, approximately two third of the Eastern Province and small areas of the Southern (Kamonyi District) and Northern Provinces (Rulindo and Gicumbi district) (Figure 2b). No record of its presence has so far been made outside this range. The majority of records were taken in Akagera National Park and its surrounding swamp system (Table 1).

The analysis of current levels of infestation showed that *M. pigra* was present in 72% of the total number sampling units, with higher frequency within the undisturbed wetlands than in the regularly plowed areas. Table 2 and Figure 3 illustrate the coordinates of key occurrence sites within Kigali city and neighboring rural districts.

Source of infestation

The optimal distribution of *M. pigra* in Rwanda ranges between 1300 and 1500 m of altitude, with more than ¾ of records having been collected in this range. A few cases of *M. pigra* striving at mid altitude (1600-1800 m) were observed within the Nyabarongo River Basin in Kicukiro, Rulindo and Kamonyi districts (Figure 4a).

The mean altitude of record was 1454 and 1377 m for records taken within floodplains of Nyabarongo and



a)

b)

Figure 2. Past (a) and modern-day (b) distribution range of MP in Rwanda.

Akagera rivers, respectively. However, the analysis of variance showed that the apparent difference between these means was not statistically significant ($F = 1.93$, $p>0.05$) (Figure 4b).

The majority of records in the Akagera Basin were taken by the year 1960 while, in the same period, only 33% of the samples had been collected in the Nyabarongo Basin (Figure 5a). As a whole, the collections in the Basin of Akagera River seem to be close in time, starting later and finishing earlier, despite the fact that they represent more than half of the records (Figure 5b). However, the statistical test showed that means of year of record are comparable (1961 and 1963, respectively) ($F = 0.074$, $p>0.05$).

Adoption of a name

A comparison of four name sake species' scores on 21

Table 2. Key modern-day occurrence sites of *M. pigra* L. in Kigali city and surrounding rural districts.

Site	District	Latitude	Longitude	Elevation (m)	Ecosystem
Kibuza	Kamonyi	1°58'51''	29°58'05''	1393	Swamp
Mugomero	Kamonyi	2°00'37''	29°53'38''	1611	Swamp
Karambo	Rulindo	1°52'29''	29°59'26''	1377	Floodplain
Nyabugogo	Gasabo	1°55'59''	30°02'52''	1371	Swamp
Gahanga	Kicukiro	2°03'39''	30°05'11''	1345	Riparian
Isumo	Rwamagana	1°56'13''	30°16'39''	1389	Floodplain
Ruliba	Nyarugenge	1°57'28''	30°00'14''	1365	Riparian
Kidogo	Bugesera	2°09'59''	30°13'50''	1316	Riparian

key characters revealed, as it was expected, that *Rosa* sp. is significantly different from the three others (Figure 6).

In contrast, unexpectedly, *M. pigra* was found to be significantly different from both *A. brevispica* Harms and *C. decapetala* (Roth) Alston, despite the fact that the three species belong to the same family of Leguminosae. Conversely, cluster analysis further compared the 21 characters in the light of the species' scores on each and showed two main clusters (Figure 7).

One cluster includes characteristics specific to only *M. pigra*, including: (1) densely hairy pods, (2) pods clustered around an insertion point, (3) sensitive leaves, and (4) almost a riparian-restricted growth. The other cluster comprises characters *M. pigra* shares with the other three species such as (1) the presence of prickles on stems, (2) the ability to form dense thickets, (3) the readiness to be used as a hedge and (4) the rambling growth of stems.

DISCUSSION

Levels of infestation

Based on its modern-day high occurrence score (present in 72% of the total number of quadrats), and considering its historical records (17 herbarium records made in spatially wide (altitude: 1250 to1800 m; maximum distance between two record sites: 137 km) and temporally long ranges (1930s-1980s) *M. pigra* seems to have started invading Rwanda's eastern riparian and floodplains decades ago, and therefore, in this study, was assigned an invasive status in Rwanda.

The classification of *M. pigra* under the category of invasive species in Rwanda is in line with Richardson et al. (2000), Ipou et al. (2011) and Pysek et al. (2004) who define an invasive species as a 'naturalized plant that produces reproductive offspring, often in very large numbers, at considerable distances from parent plants [with an approximated spread rate of > 2 m/year], and thus have the potential to spread over a considerable area'. This was confirmed by our findings on *M. pigra* range of occurrence in Rwanda. At least 17 records of *M. pigra* presence in Rwanda were made at different locations from 1932 to 1982, some of the locations being separated by more than 100 km. Thirty years after these records were made, this study revisited *M. pigra* occurrence in the floodplains of Nyabarongo River. The results showed that *M. pigra* was present in the majority of quadrats (72 %). Key coordinates of record sites are reported in this article to help in further studies. Although estimating the spread rate of *M. pigra* in Rwanda was out of the scope of this study, the opportunistic observations revealed that *M. pigra* patch size averages at 3 to 4 m and that in many places, patches can be as close as to only 1 to 5 m away from each other.

At the beginning of this study, we had the feeling that, *M. pigra* was significantly expanding to other districts of Rwanda. However, our findings suggest that its range was restricted to Nyabarongo and Akagera Basins and that its invasion success in the last decades can be attributed more to the expansion of its 'grain' than to the change in the 'extent' of its distribution pattern. Altitude, distance to source of infestation and land use systems in upstream areas may have acted as barriers to its establishment in other regions. Instead, it seemed to be busy filling in the gaps to dominate landscapes within the already infested areas. This is in accord with the predictions of Theoharides and Dukes (2007) who suggested that after the first three stages of invasion have occurred (transport, colonization and establishment), the plant species spends significantly a longer period of time (also referred to as the 'lag time') in landscape spread process or dispersal within the region. Apparently, the overall occurrence was still too low such that when the ever first syllabus of the spermatophyte flora of Rwanda was compiled in 1971 (Troupin, 1971), this plant did appear among the 200 plant species it aimed to describe. Both in Rwanda and Burundi, it has been characterized by modest occurrence until recently when its spread was accelerated to the point of receiving the attention of environmentalists (lta.iwlearn.org, 10.07.2012). Similarly, in Zambia, unparalleled spread rates of *M. pigra* were registered in Kafue flats since 1980s following the construction of hydro-electric dams which caused disturbance in the flood regimes and expanded the range of

Figure 3. Modern-day occurrence of *M. pigra* L. in Rwanda: [1] in Kibuza wetland, Kamonyi District (upper left corner), [2] in Gahanga sector, along the Kigali-Bugesera road (upper right corner); [3] in Karambo, along the road to Ruli; and [4] in Nyabugogo wetland, along the road to Kigali-Gatuna [Photos© J. L. Seburanga, 2012].

floodplains (Sheppe, 1985). This view was shared by GISP (2007) who recognized that *M. pigra* spread in Africa has increased in the last three decades, often resulting from changes in rain fall and flooding regimes (Davis et al., 2000). During the 30 years that followed the latest specimen collection in 1982, its grain was expanded such that, in a number of sites, it is now appropriate to put it in category of invasive plant species with widespread and dominant occurrence (Colautti and MacIsaac, 2004). If this spread tendency is maintained, the species will soon fall in the category of 'transformer' species (Richardson et al., 2000).

Although, the study of dispersal ecology was not conducted in the particular case of Rwanda, altitude seems to be the best predictor of *M. pigra* spread. For instance, it was never recorded in Lake Kivu shores [on the other side of the Congo-Nile ridge] despite the fact that this region appears to be rather suitable to its establishment and that its cousin *Mimosa invisa* Mart. ex Colla was reported to occur in the Rusizi District in 1980s (Troupin, 1982). Also encouraging is to realize that it was never encountered in the biodiversity-rich afromontane region of the Albertine rift hotspot (Plumptre et al., 2007).

However, there is a room to worry if nothing is done to contain its spread. It is intriguing to note its presence in Rwanda at 1600-1750 m (Figure 4) and in neighboring Uganda at 1900-2000 m (Kalema and Ssegawa, 2007). This issue is of significance in terms of biodiversity conservation as no dedicated conservationist would wish to see *M. pigra* penetrating into the montane forest belt of the Albertine Rift (1500-2500 m) (Plumptre et al., 2007). Therefore, environmentalists in Rwanda should stay alert and do all what it takes to prevent this species from entering these forests.

Source of infestation

M. pigra occurrence appeared to be increasing as one moves downstream from Nyabarongo River (in Rwanda) to Lake Victoria (in neighboring Uganda); that is, from the central plateau (1350-1800 m of altitude) to the eastern lowlands (1250-1500 m of altitude). Considering the fact that the known earliest records of *M. pigra* in the great lakes region of East Africa dates back to 1862 in the Acholi District of Northern Uganda (GISP, 2007; plants.jstor.org, 01.09.2012), we suggest that *M. pigra*

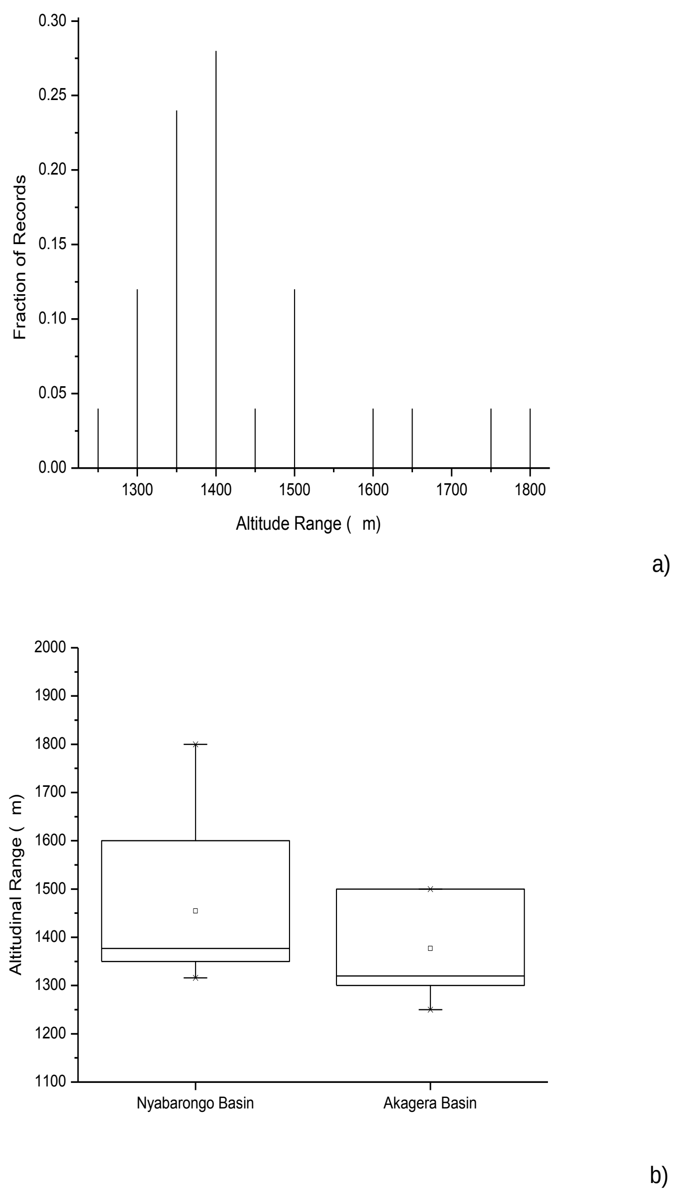


Figure 4. a and b: *M. pigra* distribution in Nyabarongo and Akagera basins in relation to altitude of record.

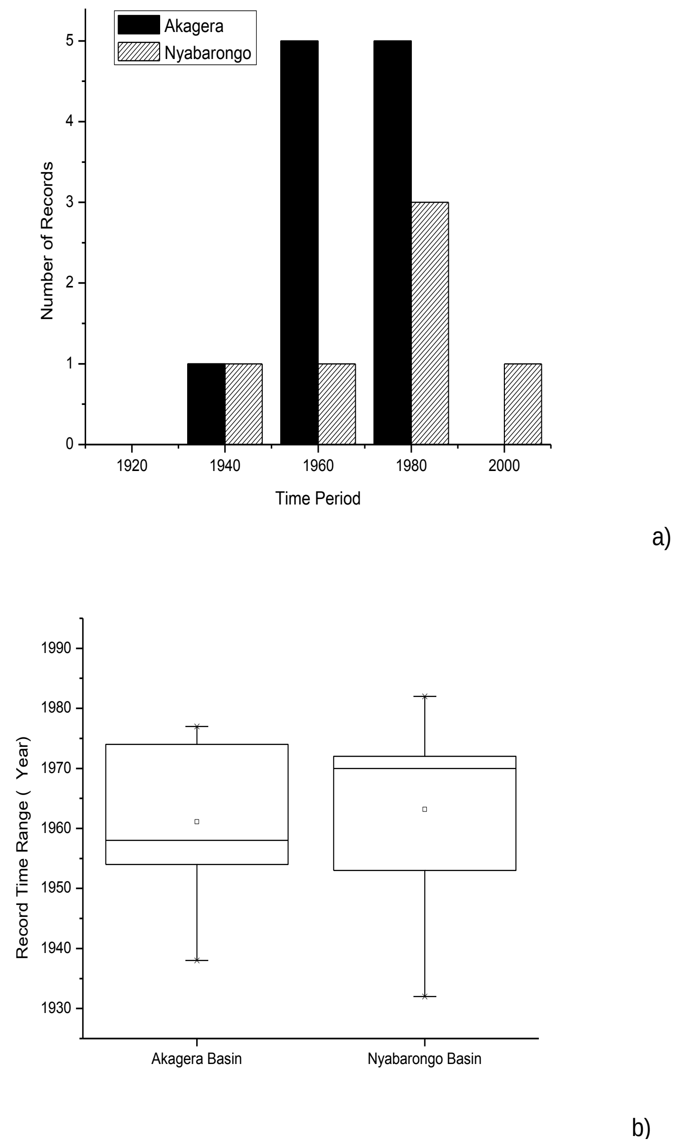


Figure 5. a and b: *M. pigra* distribution in Nyabarongo and Akagera basin in relation to year of record.

migrated upwardly from Egypt [where it was first recorded in Africa] through White Nile to Uganda and continued to reach Rwanda's Nyabarongo floodplains via the trans-boundary Akagera River. This would have required millennia if applied an average dispersal rate of up to 76 m year^{-1} in a wetland system (Lonsdale, 1993) and considering the 6500 km of distance traveled. This suggests three scenarios: [1] *M. pigra* native to Africa had a loose time budget to spread, [2] *M. pigra* is exotic to Africa but was introduced to Egypt earlier than 1900th century, and more frequent and long range flooding insured an incredibly higher spread rate, [3] *M. pigra* is exotic to Africa but was introduced independently to Egypt, Uganda and Rwanda. our attempt to detect a relationship between the time and place of collection of historical *M. pigra* records and its expansion pattern in Rwanda was not statistically supported (F = 1.93, p>0.05 and F = 0.074, p>0.05) and seems to be in line with the third scenario. However, based on our expert judgment and the knowledge drawn from the extensive literature review, we suggest that this may have been due to the small character of our sample size (only 17 records collected between 1932 and 1982 were taken into account because we were dealing with a time-restricted research question, and we could not enlarge this sample by adding on modern-day records).

It follows that choosing between the scenarios would not be easy as long as the debate around the African versus South American origin of *M. pigra* is not closed. However, there is strong evidence of association of *M. pigra* occurrence and Nyabarongo, Akagera and Nile Rivers'

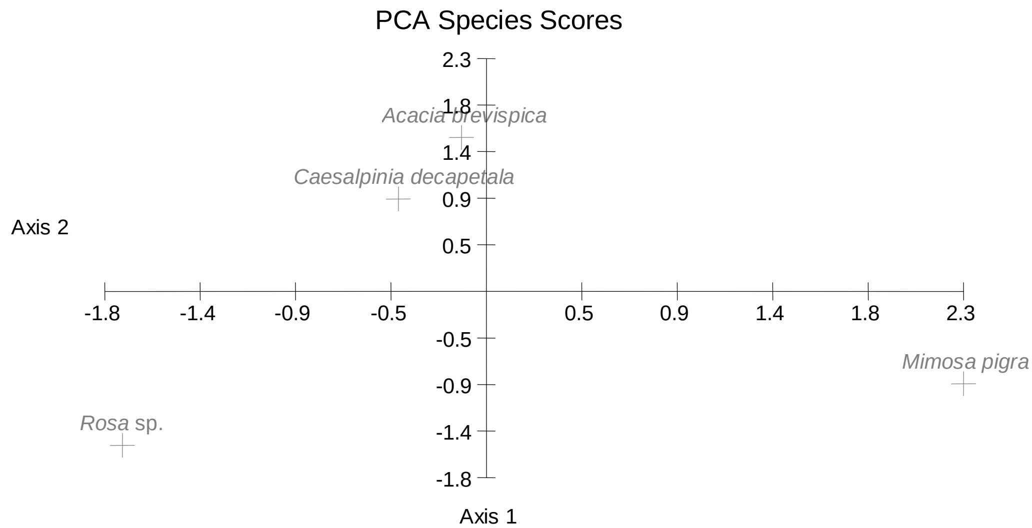


Figure 6. Species character-based PCA score chart of *M. pigra* and its three name sake plant species.

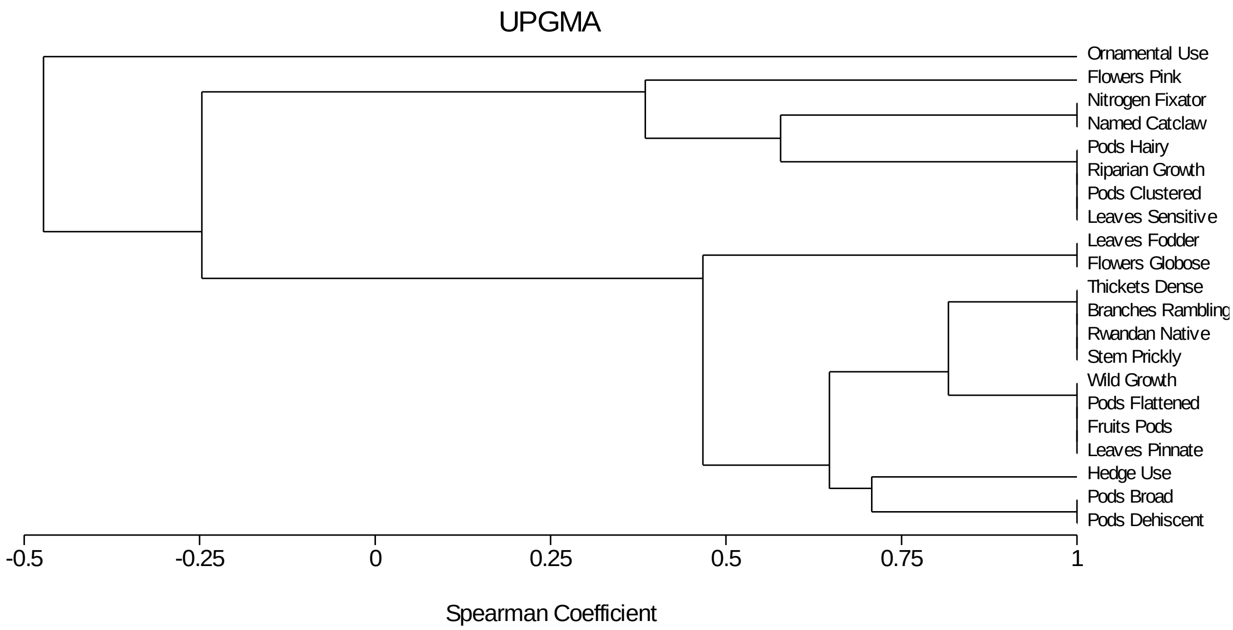


Figure 7. Clustering of *M. pigra* and its three name sake plant species' scores on key characters.

floodplains, tributaries and associated lakes, which, we believe, is in support of the first scenario. For instance, *M. pigra* was not recorded in Kenya's Nakuru National Park (Ng'weno et al., 2009) nor was reported in Uganda's Kibale forest (Chapman et al., 2001), two regions of East Africa naturally disconnected from the Akagera-Victoria-Nile system. Similarly, in their study, Hall et al. (2011) made a list of invasive non-native plant species occurring in agroforests and protected forests of East Usambara Mountains in neighboring Tanzania, but no reference to *M. pigra* was made. If the first scenario, is retained, and if taken into account the time needed for this species to move and migrate from Kagitumba (the probable port of entrance) to Icyanya locality in Kigali (the place where it was first recorded in Rwanda in 1932), we suggest that it should have been in the country not later than the second half of 19th century, well before the arrival of Europeans.

Furthermore, that many samples were taken in the Akagera Basin may indicate that, at the time of arrival of European botanists in Rwanda, *M. pigra* was more frequent there than in any other place in Rwanda. If this was the case, other factors hold constant, Akagera region could have been infested before upstream sites of the Nyabarongo Basin. This could also, in part, explain why colonial botanists did not report *M. pigra* as an invasive species in Rwanda. If they found it relatively more abundant in the park and surrounding natural forests than in the human-dominated landscapes, they would hardly imagine they were faced with a plant invasion case, unless they had prior knowledge of its status in other parts of the world. In addition, contrary to Simon et al. (2011) who suggested that African mimosas are most likely to have originated from South America through late Miocene trans-Atlantic dispersal, *M. pigra* was seen by many scientists obviously including Rwanda's folk ecologists as an African native species, and the conventional knowledge at that time was that an invasive species should be an exotic taxon having escaped from cultivation and expanding its range from human dominated landscapes to natural ecosystems.

Adoption of a name

That *M. pigra* was found to share the same Kinyarwanda name with *A. brevispica* Harms and *C. decapetala* (Roth) Alston [Leguminosae] which is understandable. They belong to the same family of Leguminosae, and highly resemble each other. For instance, they all have pinnate leaves, prickly stems and fruits in the form of pods. Instead, intriguing was to realize that *Rosa* sp., a species that belongs to such a distant family as that of Rosaceae, shares the same name.

The analysis of similarity between the four species showed that the possession of prickly stems, the rambling growth of branches, and the ability to form dense thickets are among the unifying characters of the four species- well in line with Barneby (1991) and Simon et al. (2011) who used morphological and ecological traits to explain affinities within taxonomic groups. This finding is supported by the fact that even in English, two of them, *M. pigra* and *C. decapetala* (Roth) Alston [Leguminosae], are referred to as 'catclaws', a name given after their 'prickles' that resemble the claws of a cat. In Burundi, Rwanda's neighboring country; both species have a similar denomination 'u-mu-bamb-a-n-gu-e'. Baerts and Lehmann (1989) translated this name into French 'l'épineux qui cloue le léopard au sol', which in English would be referred to as 'the spiny plant that nails the leopard to the ground'. Well in line with this, the third species, *A. brevispica* Harms [Leguminosae], has an alternative Kinyarwanda name 'Bwara', which if translated into English would mean 'small nails', of course not of a cat, because cats themselves are a recent introduction in Rwanda. It is important to note that, unfortunately, the Kinyarwanda name applied to the four species 'u-mu-gey-o' has no clear meaning in Kinyarwanda Language. However, it was also interesting to find that it could have been derived from 'I-gey-e', the equivalent denomination of this in the Tanzanian Kisukuma dialect (herbaria.plants.ox.ac.uk, 29.08.2012). These taxonomic relationships and identity confusions have a deeper implication for prevention and control of *M. pigra* invasion. In a developing country, due to high levels of taxonomic illiteracy, people often confuse newly introduced taxa with similar ones, be they native or exotic. This is problematic because it gives the species the opportunity to expand its range before the local communities come to realize that it is actually an alien invader and report it. For instance, *Lantana camara* L. [Verbenaceae], a notorious terrestrial invasive species in Rwanda, is called 'umuhenger-i' as its counterpart *Lantana trifolia* L. [Verbenaceae], a relatively less threatening taxon. Interestingly, as soon as its threat was noticed, local people named it 'a-ka-tey-e', denoting its 'alien' and 'invasive' attributes. Another example is that of *Eichhornia crassipes* (Mart.) Solms [Pontederiaceae], a globally known aquatic weed that shares its local name 'a-ma-reb-e' with species that belong to other families such as *Nymphaea nouchalii* Burm. [Nymphaeace], *Caldesia reniformis* (D. Don) Makino [Alismataceae], and, in some places, the North American-native *Pistia stratiotes* L. [Araceae], and even with the terrestrial *Begonia meyeri-johannis* Engl. [Begoniaceae]. In the case of *M. pigra*, we presume that folk taxonomists in pre-colonial Rwanda were unable to draw a clear demarcation line between *M. pigra* and its cousin species, probably due to the high interrelatedness between taxa within the legume family (Lewis et al., 2003). As a result, under the cover of a non-specific name, it spread almost unnoticeably to become a notorious invader shrub in Rwanda's eastern floodplains'.

Conclusion

In this study, we discussed the status of *M. pigra* in Rwanda, and pleaded for its inclusion in the invasive flora of Rwanda. Our findings suggest that its invasion success in the last decades can be better explained with reference to its 'grain' expansion than to the change in the 'extent' of its distribution patterns. We suggested that Egypt through Nile floodplains and riparian communities of Uganda's Lake Victoria may have been the primary source of *M. pigra* of propagules that infested Rwanda's Akagera-Nyabarongo river system. The altitude, distance to the source of infestation and land use systems in upstream areas best predict its establishment. We presumed that under the shadow of its Kinyarwanda name 'u-mu-gey-o', *M. pigra* was able to spread and become an invader before scientists could take notice of its true identity: an invasive [not environmentally harmless] alien [not Rwandan-native] Mimosa [not Acacia, Ptelorobium, Caesalpinia nor Rosa] species.

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