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Exotic *Acacia* Species in Zimbabwe: A Historical and Ecological Perspective

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ABSTRACT The present study investigated the history, occurrence, geographical distribution and invasiveness of the exotic *Acacia* species in Zimbabwe using herbarium and literature records. At least 17 *Acacia* species originating from Australia were introduced to Zimbabwe, with nine species (52.9% of total) documented as casuals, naturalized or invasive. *Acacia mearnsii* and *A. melanoxylon* were recognized as invasive, *A. dealbata, A. decurrens, A. elata* and *A. podalyriifolia* as naturalized, and *A. baileyana, A. longifolia* and *A. salicina* as casuals. All nine exotic *Acacia* species were introduced as ornamentals, *A. dealbata, A. decurrens* and *A. mearnsii* were also introduced for tanbark, and *A. longofolia, A. mearnsii* and *A. melanoxylon* were also introduced for timber. The majority (88.9%) of exotic *Acacia* species were introduced in the eastern part of Zimbabwe, a region characterized by tropical to semi-temperate climate, which is similar to the areas of origin of *Acacia* species.

INTRODUCTION

Ecologists are now paying more attention to plant invasion impacts and their history (Wu et al. 2003; Casado et al. 2015), mainly because of conservation problems they cause. Invasions by alien plant species are considered as one of the most serious environmental threats to natural ecosystems around the world and viewed as a global problem caused by humans (Vitousek et al. 1997; Vilà et al. 1999; Byers et al. 2015; Casado et al. 2015). Invasions by exotic plants species is often associated with human activities such as disturbance and fragmentation of the natural ecosystems, urbanization, home gardening activities where exotic plants are used as food and ornamentals (Vilà et al. 1999; Byers et al. 2015; Casado et al. 2015). According to Clout and Williams (2009), alien species are agents of ecological change, which lead to extinction or decline of vulnerable endemic species, alteration of the structure and composition of communities, loss of ecosystem services and disruption of successful pathways. The increasing number of invasive plant species and their range expansion in many areas of the world calls for urgency in documenting the naturalized flora, biological processes of plant invasion, establishment and spread. Herbarium records are regarded as one of the most reliable primary sources of information to reconstruct introduction patterns, establishment, colonization history, and range expansion of alien plant species (Strother and Smith 1970; Mack 1991; Wu et al. 2003; Barney 2008).

Trees and shrubs of the genus *Acacia* (family Mimosaceae) from Australia have been widely introduced in tropical and subtropical regions (Midgley and Turnbull 2003; Brockwell et al. 2005; Kull et al. 2007). *Acacia* is one of the most widely planted genus covering 4.3 percent of all planted area (FAO 2001). Members of the *Acacia* genus are drought tolerant, and therefore, are widely cultivated in the dry parts of Africa for timber, firewood, tanbark and gums (Cronk and Fuller 1995; Richardson 1998). Despite the global recognition of the importance of invasive species (Vitousek et al. 1997; Vilà et al. 1999; Wu et al. 2003; Clout and Williams 2009; Byers et al. 2015; Casado et al. 2015), this basic information on naturalized plant species, invasions and ecological impacts of exotic plant species in Zimbabwe is lacking. Although occasional attention has been paid to alien plants and weeds in Zimbabwe (Wild 1955; Drummond 1975, 1984; Biegel 1977, 1980; Mullin 1996, 2000; Timberlake et al. 1999; Mapaura and Timberlake 2004; Maroyi 2006, 2012; Hyde et al. 2015), comprehensive studies on plant invasions are still lacking. Ge-

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nus *Acacia* is among the largest naturalized genera in Zimbabwe (Maroyi 2012), and therefore, a good model for this study. The objective of this study was to analyze the history and estimate the invasiveness of exotic *Acacia* species in Zimbabwe based on herbarium and literature records.

METHODOLOGY

A database of exotic *Acacia* species occurring in Zimbabwe was compiled based on herbarium records and literature survey. All exotic *Acacia* species ever recorded in Zimbabwe as garden escapes or naturalized at least once in the wild were included in the database used in this investigation. *Acacia* species introduced or cultivated without any evidence of having escaped were not considered. This study utilized a wide range of published literature and websites (Wild 1955; Brenan 1970; Wild et al. 1972; Drummond 1975, 1984; Biegel 1977, 1980; Timberlake et al. 1999; Mapaura and Timberlake 2004; Maroyi 2006, 2012; Hyde et al. 2015; IPNI 2015). The National Herbarium, Harare (SRGH, abbreviation according to Holmgren et al. 1990) was visited in December 2013, and information on the labels of herbarium specimens of exotic *Acacia* species was examined, including habitat and year of collection. The information on exotic *Acacia* species collected in Zimbabwe captured on the National Herbarium, Pretoria, South Africa (PRE, abbreviation according to Holmgren et al. 1990) database was also requested, each specimen included a voucher or accession number, date collected and collection locality. Where duplicate specimens were held by both herbaria, only a single occurrence was tabulated. Specimens having incomplete or imprecise information about the sampling location or collection date were excluded from further analysis.

For all exotic *Acacia* species, information on the year when exotic *Acacia* species was first collected, mode or purpose of introduction in Zimbabwe and its invasion status were extracted from literature and herbarium records. Each documented *Acacia* species was allocated to more than one use category if different uses applied to it. The International Plant Name Index (www.ipni.org) and the Royal Botanic Garden and Missouri Botanic Garden plant name database (www.theplantlist.org) were used to validate *Acacia* scientific names and authorities. Each *Acacia* species' distribution in Zimbabwe was indicated by letters showing the floristic divisions used in Flora Zambesiaca as explained by Pope and Pope (1998), with the northern region represented by (N), western region (W), central region (C), eastern region (E) and southern region represented by (S).

Analysis of Data

The data collected was entered in the Microsoft Excel 2007 program and later analyzed for descriptive statistical patterns. To summarize the general trend in the accumulation of exotic *Acacia* species in Zimbabwe, the cumulative number of recorded *Acacia* species was plotted against time (1902-2010). Exotic *Acacia* species were divided into three categories: casual, naturalized and invasive aliens. According to Richardson et al. (2000) and Pyšek et al. (2004), casual aliens reproduce occasionally outside cultivation, do not form self-sustaining populations and rely on repeated introductions for their persistence. Naturalized species are defined by Richardson et al. (2000) and Pyšek et al. (2004) as aliens that reproduce consistently without direct human intervention, and invasive aliens as naturalized species producing offspring in large numbers and at considerable distances from the parent plants with the potential to spread over a large area. This definition of invasive alien species used in this study is different from the Convention on Biological Diversity (CBD) Conference of Parties' definition of an invasive alien species, where an alien is defined as a species outside its indigenous geographic range, whose introduction and spread threatens biodiversity (UNEP 2002).

RESULTS

At least 17 Acacia species were introduced to Zimbabwe, and there is no herbarium nor literature record indicating that the following species have escaped from cultivation: *Acacia cultriformis* G. Don, *A. cyclops* G. Don, *A. farnesiana* (L.) Willd, *A. pendula* G. Don, *A. prominens* G. Don, *A. retinodes* Schltdl, *A. saligna* (Labill.) Wendl, and A. *schinoides* Benth. Nine exotic *Acacia* species (52.9% of the total exotic *Acacia* species in Zimbabwe) were documented as ca-

Table 1: List and characterization of the *Acacia* species introduced in Zimbabwe

Species	*Earliest herbarium record*	*Purpose*	*Provenance in Zimbabwe*	*Status in Zimbabwe*
A. baileyana F. Muell.	1941	Ornamental	E	Casual
A. dealbata Link	1902	Ornamental, tanbark	E	Naturalized
A. decurrens Willd.	1903	Ornamental, tanbark	E	Naturalized
A. elata Benth.	1944	Ornamental	E	Naturalized
A. longifolia (Andr.) Willd.	1932	Ornamental, timber	CE	Casual
A. mearnsii De Wild.	1931	Ornamental, tanbark, timber	CE	Invasive
A. melanoxylon R. Br.	1903	Ornamental, timber	CE	Invasive
A. podalyriifolia G. Don	1971	Ornamental	WCE	Naturalized
A. salicina Lindl.	1993	Ornamental	NC	Casual

suals, naturalized or invasive (Table 1). Known usages included cultivation for ornament, tanbark or timber (Table 1). The term ornamental is used here in a wide sense to include all decorative uses, that is, street trees, hedging plants and houseplants. All nine exotic *Acacia* species were introduced as ornamentals, *A. dealbata, A. decurrens* and *A. mearnsii* were also introduced for tanbark, and *A. longofolia, A. mearnsii* and *A. melanoxylon* were also introduced for timber (Table 1). Based on the specimen records in the national herbaria in South Africa (PRE) and Zimbabwe (SRGH), the first specimen of exotic *Acacia* species to be collected in Zimbabwe was of *A. dealbata,* collected in 1902 (Table 1 and Fig. 1). The accumulation of casual, naturalized and invasive *Acacia* species shows an approximately linear increase from 1902 to 1993 (Fig. 1). The accumulation of exotic *Acacia* species in Zimbabwe from 1902 to 1993 is illustrated in Fig. 1. The collection of *Acacia dealbata* in 1902 was followed by collection of *A. decurrens* and *A. melanoxylon* in 1903. No new naturalized *Acacia* species were collected between 1904 and 1930. *Acacia mearnsii* was collected in 1931, followed by collection of *A. longifolia* in 1932, *A. baileyana* in 1941 and *A. elata* in 1944. There were no new exotic *Acacia* species recorded between 1945 and 1970. *Acacia podalyriifolia* was collected in 1971 and *A. salicina* was collected in 1993 (Fig. 1).

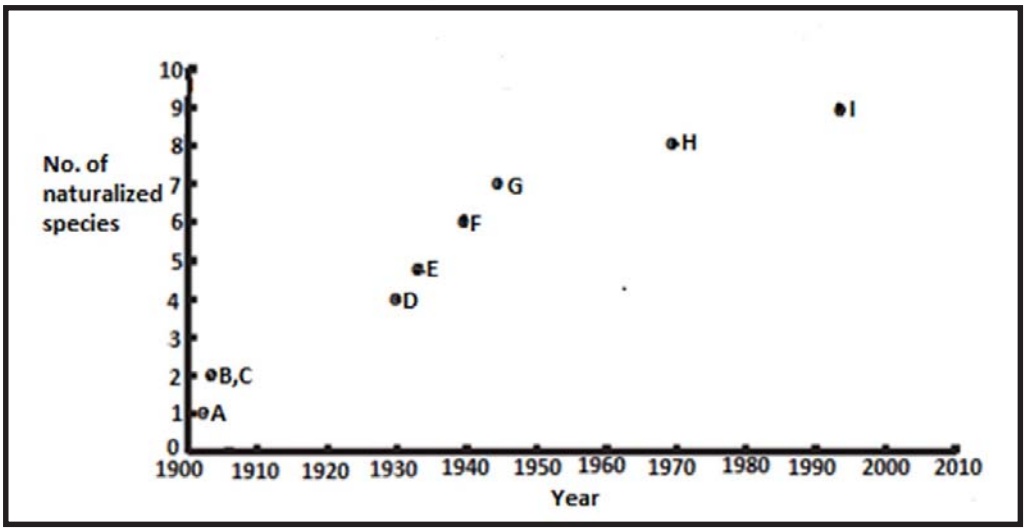

Fig. 1. Number of naturalized *Acacia* species in Zimbabwean flora during the period 1902-2013. A: *Acacia* *dealbata*; B: *A. decurrens*; C: *A. melanoxylon*; D: *A. mearnsii*; E: *A. longifolia*; F: *A. baileyana*; G: *A. elata*; H: *A. podalyriifolia* and I: *A. salicina*.

Exotic *Acacia* species' localities were plotted against minimum residence time (MRT) (Fig. 2). The exotic *Acacia* species collected from the highest number of localities was *A. mearnsii*, followed by *A. melanoxylon*, *A. dealbata*, *A. decurrens* and *A. longifolia* (Fig. 2). More than seventy-five percent of the exotic *Acacia* species have been present in Zimbabwe for more than 70 years. *Acacia salicina* with the shortest MRT (20 years) has already been collected from two localities (Fig. 2). Only two *Acacia* species, *A. mearnsii* and *A. melanoxylon* are recognized as invasive in Zimbabwe (Table 1). A third (33.3%) of the exotic *Acacia* species: *A. baileyana*, *A. longifolia* and *A. salicina* are casuals, while about forty-five percent of the species, *A. dealbata*, *A. decurrens*, *A. elata* and *A. podalyriifolia* are naturalized (Table 1).

Based on herbaria specimens, *A. podalyriifolia* was collected in three floristic regions of Zimbabwe, western, central and eastern regions (Table 1, Fig. 3), which made it the most widespread exotic *Acacia* species in this study. All species, with the exception of *A. salicina* were recorded in the eastern part of the country, with *A. baileyana*, *A. dealbata*, *A. decurrens* and *A. elata* confined to the eastern part of the country (Table 1, Fig. 4). *Acacia longifolia*, *A. mearnsii* and *A. melanoxylon* had overlapping provenances, so far recorded in central and eastern floristic regions of Zimbabwe (Table 1, Fig. 5). *Acacia salicina* was collected in northern and central regions of Zimbabwe (Table 1, Fig. 3).

DISCUSSION

The five exotic *Acacia* species, namely *A. dealbata*, *A. decurrens*, *A. longifolia*, *A. mearnsii* and *A. melanoxylon* that have been present in Zimbabwe for at least 80 years occupy several localities (Fig. 2). Four of these species are either invasive or naturalized in Zimbabwe, with the exception of *A. longifolia* documented as a casual. These findings corroborate previous observations made by Rejmánek (2000), Pyšek and Jarošík (2005) and Byers et al. (2015) that the probability of invasion success or naturalization, and/or area of spread of introduced species increase with residence time. Moreover, the legume family Mimosaceae and in particular the Australian species of *Acacia* have a high percentage of invasive species compared to other

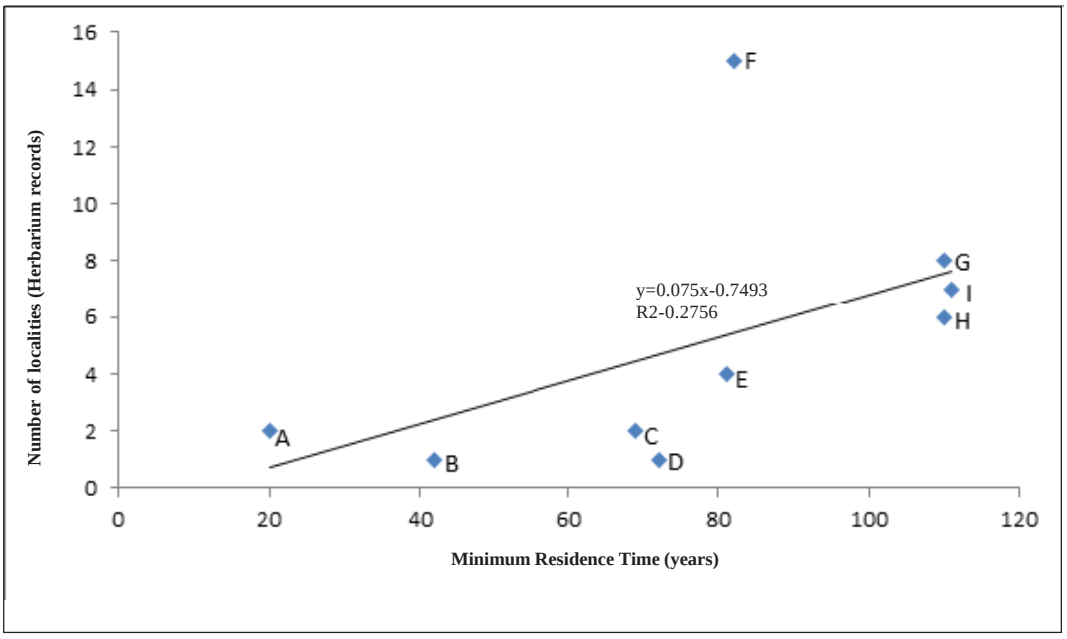

Fig. 2. Number of localities per species against minimum residence time of naturalized Acacia species in Zimbabwe. A: *Acacia salicina*; B: *A. podalyriifolia*; C: A. *elata*; D: *A. baileyana*; E: *A. longifolia*; F: *A. mearnsii*; G: *A. melanoxylon*; H: *A. decurrens* and I: *A. dealbata*.

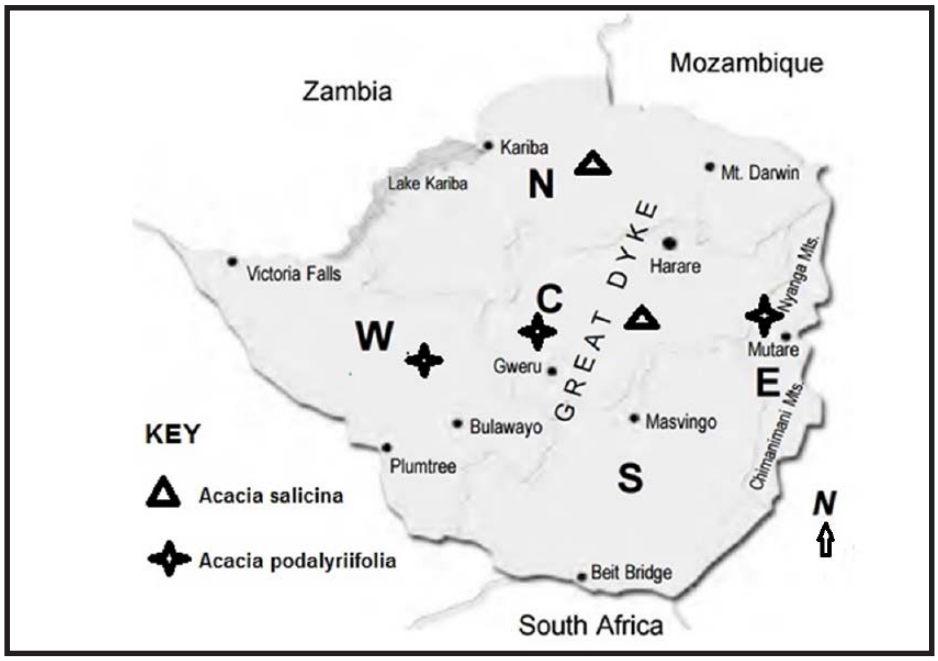

Fig. 3. Distribution of *Acacia podalyriifolia* and *A. salicina* in Zimbabwe, based on herbarium records

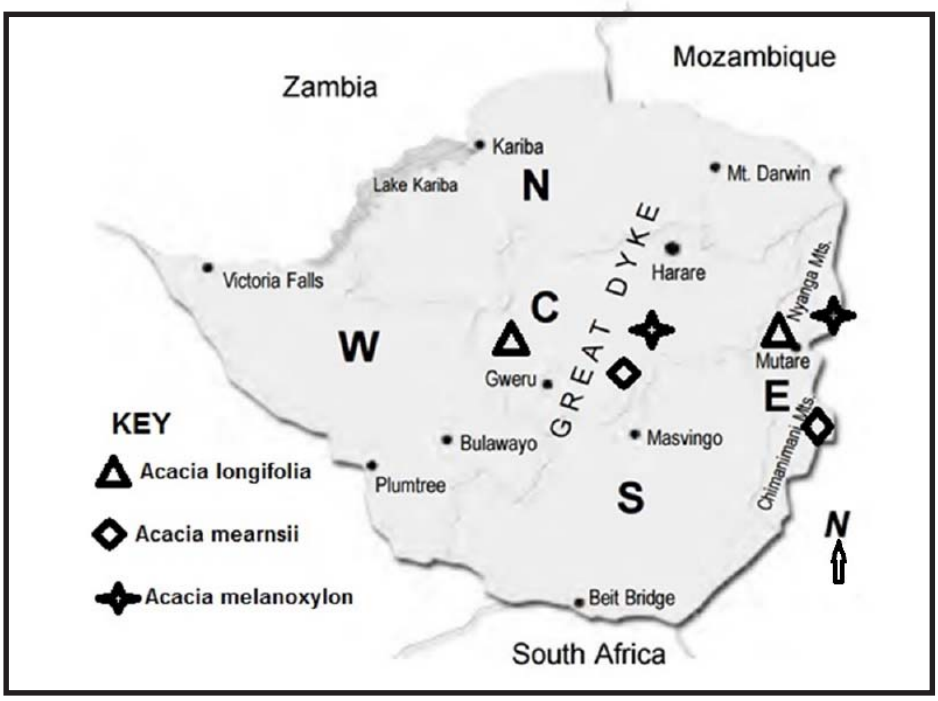

Fig. 4. Distribution of *Acacia longifolia, A. mearnsii* and *A. melanoxylon* in Zimbabwe, based on herbarium records

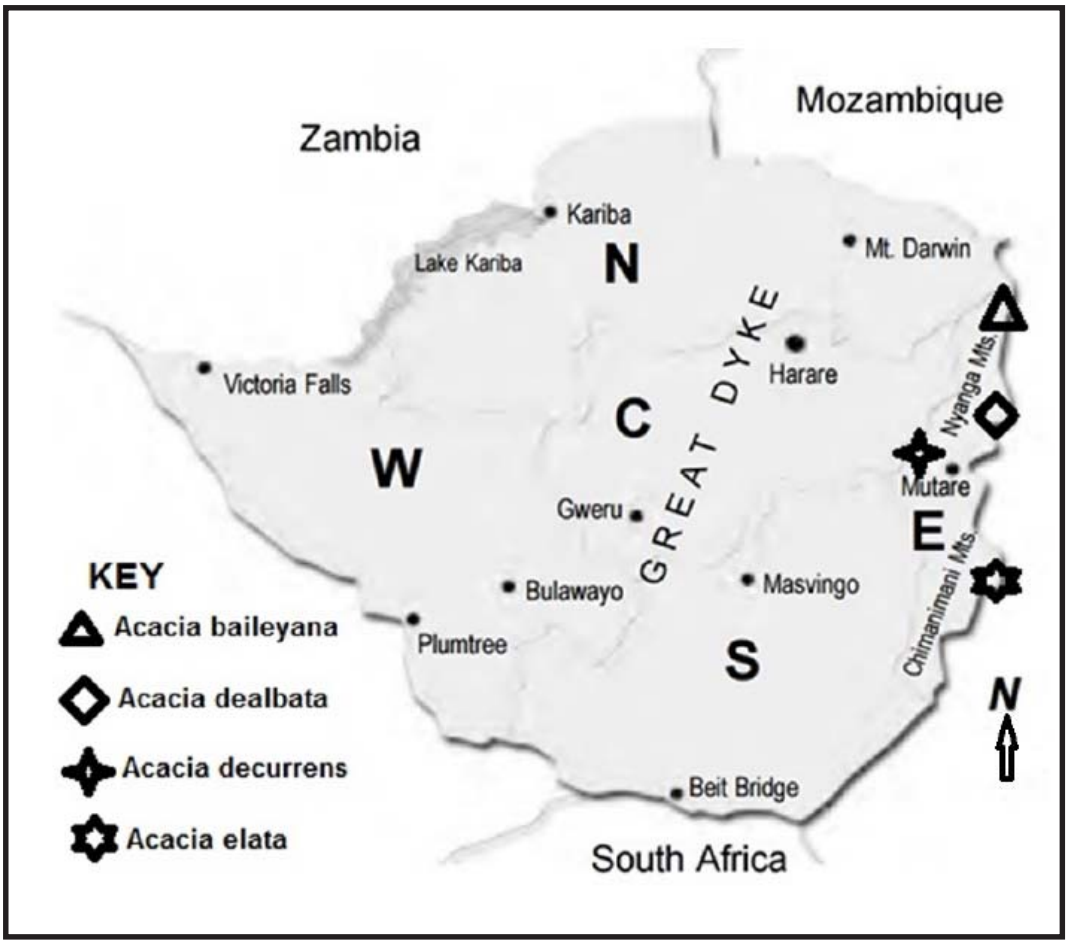

Fig. 5. Distribution of Acacia *baileyana*, *A. dealbata*, *A. decurrens*and *A. elata*in Zimbabwe, based on herbarium records

legumes (Miller et al. 2011). Eight of the nine *Acacia* species (88.9%) listed in Table 1 are declared weeds and invader plant species in South Africa, listed under the Conservation of Agricultural Resources Act (1983) No. 43 of 1983. *Acacia baileyana, A. dealbata, A. decurrens, A. elata, A. longifolia, A. mearnsii, A. melanoxylon* and *A. podalyriifolia* pose an immediate and significant threat by virtue of their aggressive qualities and having the capacity to invade natural habitats and overwhelm some of the indigenous species in South Africa (South Africa 1983; Department of Environmental Affairs 2015). Previous research by Nyoka (2003) documented the invasiveness of *A. mearnsii* in Zimbabwe, revealing its ability to produce large numbers of long-lived seeds and the development of a large crown that shades other vegetation. The same researcher argued that *A. mearnsii* threatens native habitats by competing with indigenous vegetation, replacing grass communities, reducing native biodiversity and increasing water loss from the riparian zones. Second to habitat destruction and modification, alien invasion is recognized as having the largest impact on natural vegetation, ecosystem processes and interfering with agricultural practices (Heywood 1995; Mooney and Hobbs 2000; Binns et al. 2001; Bigirimana et al. 2011, 2012). Invasive exotic *Acacia* species, therefore, have potential to pose a

significant threat to many of Zimbabwe's natural ecosystems.

Establishment of a database of exotic *Acacia* species in Zimbabwe is the first step in the development of invasion biology in the country and also a stepping-stone to further detailed studies on the environmental impacts caused by *Acacia* species. Previous research by Maroyi (2006, 2012) showed that small-scale plantings of alien plant species in Zimbabwe started with the European settlement in the 1890s and early 20th century. This was a period when acclimatization societies and botanical gardens flourished in the British colonies and economic plants were transferred from one continent to another (Maroyi 2006). *Acacia dealbata, A. decurrens, A. elata, A. longifolia, A. mearnsii, A. melanoxylon* and *A. podalyriifolia* were promoted as a multipurpose tree species by foresters for fuel wood, ornamental, paper pulp and timber in Zimbabwe (Timberlake et al. 1999). According to these researchers, *A. dealbata, A. decurrens* and *A. melanoxylon* were introduced in Zimbabwe in the early 1900s, confirming the earliest herbarium records of the species provided in Table 1. Timberlake et al. (1999) also argued that *A. mearnsii* was introduced in eastern Zimbabwe from South Africa in the early 1920s. According to this study, the earliest herbarium record of *A. mearnsii* in Zimbabwe is 1932 (Table 1). The observations made in the current study confirms one of the most robust generalizations that herbaria are currently one of the most reliable sources of information to document past changes in a given flora regardless of some biases such as unequal sampling effort over time, non-random geographical representation, and disproportionately represented taxa (Delisle et al. 2003; Wu et al. 2005; Chauvel et al. 2006).

All the exotic *Acacia* species documented in this study have been introduced intentionally for economic purposes in Zimbabwe (Table 1). There were introduced mainly in the eastern part of Zimbabwe and none were introduced in the southern part of the country (Figs. 3-5) due to the harshness of the region's climate. Southern Zimbabwe is hot and dry, characterized by low and erratic rainfall. While the tropical to semi-temperate climate of eastern Zimbabwe encouraged the introduction forest *Acacia* species at various stages of Zimbabwean history (Maroyi 2006). Several Australian *Acacia* species were introduced under the auspices of Australian forestry and agricultural aid projects in the search for trees that would provide fodder, fuel, ornamentals, protection in semi-arid areas, tanbark and timber (Timberlake et al. 1999). Understanding the introduction history of invasive plant species is important for their management and identifying effective host-specific biological control agents (Dennill et al. 1999). An understanding of the establishment and distributional changes of exotic *Acacia* species over time is also important for making informed decisions in managing existing introductions, predicting future invasions and developing appropriate alien plant species management plans.

CONCLUSION

This inventory is a crucial starting point in trying to understand and initiate the management of biological invasions, and also important for monitoring new introductions and management of existing exotic *Acacia* species in Zimbabwe. This is especially important as several Australian *Acacia* species are declared environmental weeds throughout tropical Africa and Asia. Eight species (88.9% of the total naturalized *Acacia* species in Zimbabwe), including *Acacia baileyana, A. dealbata, A. decurrens, A. elata, A. longifolia, A. mearnsii, A. melanoxylon* and *A. podalyriifolia* pose an immediate and significant threat by virtue of their aggressive qualities and having the capacity to invade natural habitats and overwhelm some of the native species in Zimbabwe.

RECOMMENDATIONS

It is difficult to determine which course of action to take regarding naturalized and invasive *Acacia* species in Zimbabwe given limited understanding of their biology and ecological impacts of some of the species. More information is required concerning interactions between naturalized and invasive *Acacia* species with native species, as well as responses of exotic *Acacia* species to management and control methods being used at the present moment. There is also need to assess the key invasion drivers and economic effects of *Acacia* species in Zimbabwe. Based on field and herbarium records, all the nine *Acacia* species discussed in this study must be prioritized for monitoring based on the magnitude, duration of their invasion, ecological impacts, and also available informa-

tion on their ecological impacts from neighboring countries where they are invasive. Long-term studies on the ecological interactions between native and exotic *Acacia* species are recommended, as these are crucial for developing meaningful management and control strategies of naturalized and invasive species.

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