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Ecological Impacts and Management Strategies of *Acacia melanoxylon* Specis in the African Ecosystems

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Abstract

Alien invasive plants can alter ecosystem services, reducing biodiversity and having negative social and economic consequences. The leguminous Acacia melanoxylon is one of the most problematic acacia tree species native to Australia on a global scale. The invasive species is currently invading the forest ecosystem in Africa, with severe consequences for ecosystem services. There have been very few reviews of the ecological effects of Acacia melanoxylon species on the ecosystems of African forests. Consequently, it is necessary to comprehend its ecological effects and management strategies to mitigate its negative effects. Scopus, Web of Science, and Google Scholar were used to conduct an exhaustive bibliographic search for scientific and technical articles as well as government documents on Acacia melanoxylon species invasions in African countries and documented management strategies. The ecological effects include reduced species diversity and local seed dispersal of the tree layer. The rapid spread of A. melanoxylon in forest areas has the potential to alter the forest structure and composition. Additionally, it affects the growth and spread of forest plant species. The proposed management strategies of A. melanoxylon include uprooting young shoots and applying herbicide to the stumps of mature trees to prevent regrowth. Herbicide-coated bark (basal bark methods) can also be effective. Ring barking can be utilized to kill large trees. Young plants can be sprayed with foliar solutions. The study provides baseline information regarding the ecological impacts and management strategies of Acacia melanoxylon, which serves as a management tool for the preservation of native species. The study recommends implementing policies, legislation, and incentives to guide public and private investment in controlling invasive alien plant species and passive or active restoration as needed. Additionally, this study recommends further research to address the deficiency in species management and its ecological impact on the Eastern and Southern parts of Africa.

Keywords: *Acacia melanoxylon,* Management, Forest, Species, Africa, Acacia, Control

INTRODUCTION

Human activities knowingly or unintentionally introduce alien species throughout the world (Gozlan et al., 2012; Turbelin et al., 2017; Pyšek et al., 2011). Invasive alien plants (IAPs), are defined as non-native plant species that have been introduced outside of their native range and produce offspring that spreads in large numbers at great distances from their parents. (Potgieter et al., 2019; Pandey et al., 2020). In some cases, invasive species refer to plants that have been accidentally introduced from other regions and have spread like wildfire to become completely dominant in their new habitat (Van Wilgen & De Lange, 2011). Invasive alien plants are extremely aggressive and notorious for invading, outcompeting natives, and dominating new environments (Shackleton & Shackleton, 2016; Moos et al., 2019). Moos et al., (2019) explain that invasive species pose a threat to biodiversity by altering ecosystems. Acacia is one of the most controversial and studied genera in the world, along with a large number of genera that contain species classified as invasive (Souza-Alonso et al., 2017; Lozano et al., 2020; Hirsch et al., 2021). A large number of Acacia species (Global Invasive Species Database, GISD) are among the invasive species that pose significant threats to ecosystems (Kohli et al., 2012). The alteration of the structure and function of ecosystems and the homogenization of the landscape are their most severe effects (Lorenzo et al., 2010).

Acacia trees and shrubs come from the *Acacia* genus, Fabaceae (legume) family, and *Mimosoideae* subfamily (Taylor & Dhileepan, 2019; Miller et al., 2011). The invasive alien species records extracted from the Global Invasive Species Database (GISD), spanned 243 countries and overseas territories, with 1517 different species represented (Richardson et al., 2011). The majority of these species occur in Australia (Boland et al., 2006; Maslin & McDonald, 2004), but some Acacia species are found in Africa, Europe, Asia, and North and South America (Marshall et al., 2012). The movement of Acacias to other continents began in the late 1700s, but unprecedented dispersal rates have occurred in the latest two centuries (Fernandes et al., 2019). They are generally long-lived and fast-growing plants, often with deep roots that make them thrive under drought conditions (Otieno et al., 2005). Most of the invasive species of Acacia not only take advantage of environmental disturbances but also possess high clonal growth and allelopathic ability that reduce native biodiversity in the understory (Souza-Alonso et al., 2017). As a result, there is a large diversity of Acacia that have been reported and can thrive in several environments. Currently, 24 Acacia species are confirmed as invasive worldwide (Yapi et al., 2018; Wilgan, 2021).

Acacia melanoxylon R.Br. is one of the most significant Acacia species due to its invasive potential and widespread distribution in Africa (Australian blackwood) (Arán et al., 2017; Miles et al., 2022). This species is indigenous to the temperate forests of Southeast Australia and Tasmania (Hussain et al., 2011; Burrows et al., 2009). According to Binggeli et al. (1999), *A. melanoxylon* is a highly invasive species, and it has become invasive in Kenya, South Africa, Tanzania, Argentina, and California, United States.

Acacia melanoxylon is a fast-growing tree species that can grow on a variety of soil types, is extremely prolific, produces seeds with high longevity and viability at a young age, and can spread via shoot-borne roots (Campagnaro et al., 2018). Due to its tolerance for aridity and eroded soils, this species is widespread in tropical and subtropical Africa, from South Africa to Sudan and Kenya, and North to Kenya (Raddad et al., 2005). The species exhibits high dominance at the trophic and community levels and may have ecological and socioeconomic effects on ecosystem processes and properties such as primary production, respiration, energy, carbon, and nutrient flow through food webs, reproduction, and decomposition in a new environment (Parra-Tabla et al., 2019). In Kenya and South Africa, *Acacia melanoxylon* is classified as a highly invasive species (Witt et al., 2018). It is unknown when Acacia was introduced to Kenya, possibly due to the overlapping histories of several species (Shackleton et al., 2019). Extensive research has been conducted on the impacts of acacia species in general however; there have been very few studies on the ecological impacts of *Acacia melanoxylon* species in the African forest ecosystems. Therefore, there is a need to understand its ecological impacts and management strategies to reduce its negative impacts.

METHODOLOGY

Scopus, Web of Science, and Google Scholar were used to conduct an exhaustive bibliographic search to find scientific and technical articles as well as government documents on *Acacia melanoxylon* species invasions in African countries and their management strategies. To accomplish this, the following keywords were included in the searches and combined with the corresponding Boolean operators (AND and OR): Acacia*, biodiversity, *Acacia melanoxylon*, l, habitat, dispersal, distribution, effect*, control ecological, eradication, management, impacts, Africa, Kenya, South Africa, impact*, invasive*, and water. These search terms focused on the countries in Africa that have been most affected by the spread of *Acacia melanoxylon*, as well as the ecological impacts and potential management solutions.

FINDINGS

Description and Habitat of *Acacia melanoxylon*

Acacia melanoxylon is commonly called Tasmanian Blackwood or Swamp Blackwood (Nicholas & Brown, 2002; Harrison et al., 2008; Clayton, 2012). *Acacia melanoxylon* is a 20-m tree with a 150-cm bole (plate 1). Older trunks have fissured, scaly, greyish-black bark (Grubben, 2008). Young branches are ribbed, angular, or flattened and greenish (Orchard, 2009). Younger plant stems are sometimes hairier than older branchlets (densely pubescent) (Grubben, 2008). New shoots have partially formed phyllodes with bipinnate leaves. As the seedling grows, each new 'leaf' has more fully formed phyllodes and the tips lose their leaves. Older plants may have bipinnate leaves on the phyllodes (1-2 m or more tall) (Pinkard & Beadle, 2002). The 4-16 cm long, 6-30 mm wide phyllodes vary in shape. They are narrowly elliptic to lanceolate and 4-12 times longer than wide. They are straight to sub-falcate and tapered at the base (Grubben, 2008). These hairless, glossy, coriaceous phyllodes are glabrous. They have three to five longitudinal veins and are rounded to pointed tips (obtuse to acute apices). A 2-4 mm long pulvinus connects the phyllodes to the stem. A 1-10 mm above each phyllode's base is a small raised structure (gland) (Grubben, 2008).

The fluffy yellow, cream, or whitish flowers have many stamens. Each cluster (5-10 mm across) contains 30-56 flowers (Bekele-Tesemma et al., 1993) (plate 2). Each sessile flower has five inconspicuous petals and sepals. The flower clusters are borne on stalks (peduncles) 5-14 mm long and alternately arranged on a short branch (6-40 mm long) (phyllode axil). Axillary racemes contain 2-8 small globular flower clusters. Flowers bloom year-round (Weber, 2017).

The fruit is a 4-15 cm long, 3.5-8 mm wide, curved, twisted, or coiled pod. These glabrous pods are only slightly constricted between seeds (Grubben, 2008). Young plants are green and leathery but mature to brown or reddish-brown and woody. After opening to release their seeds, pods become twisted and contorted (Marcar et al., 1995). The seeds are 3-5 mm long, 1.7-3 mm wide, glossy, and black. They're surrounded by a pink, pinkish-red, or dark red fleshy structure (aril) (Grubben, 2008).

Plate 1: *Acacia melanoxylon* Tree.

Plate 2: *Acacia melanoxylon* flowers and leaves.

The *Acacia melanoxylon* species grow in a variety of natural habitats, but is most prevalent in moist woodlands (e.g., wet sclerophyllous forests) and closed forests (e.g. cooler rainforests) (Macphail, 1984). It prefers the fertile soils of valleys, which are frequently found in mountainous regions, as well as clayey and basalt soils (Marcar et al., 1995). In Northwestern Tasmania, it grows as a tall dominant tree in forested seasonal swamps (Bradbury et al., 2010; Unwin et al., 2006; Bradbury, 2010). It is also commonly found growing along creeks (Reid, 2004). In the Southwestern region of Western Australia, it grows on gravelly lateritic soils and is most commonly naturalized in wetlands. In South Africa, it has naturalized in forests (especially gaps and margins), along waterways and roadsides, in open woodlands and shrublands, as well as in grasslands (Weber, 2017). In other regions of the world, Blackwood (*Acacia melanoxylon*) has been found in coastal environments, disturbed sites, urban areas, forest plantations, and wetlands (Oliveira, 2020).

Global distribution of *Acacia melanoxylon*

From the Atherton Tableland in Northern Queensland South through the tablelands and coastal escarpments of Southeast Queensland, New South Wales, the Australian Capital Territory, and Victoria to Tasmania, the native distribution of *A. melanoxylon* in Australia is extensive and widespread in eastern Australia (as far west as the Mount Lofty Ranges) (Vize *et al*., 2005; Bradbury, 2010; Searle, 2000; Nicholas, 2007; Kull & Rangan, 2008; Arán et al., 2017; Bradbury et al., 2011; Burrows et al., 2009).

Acacia melanoxylon is recognized as one of the most successful invasive species in the European countries of France, Chile, Italy, Portugal, and Spain. It can be found in every province of Portugal, as well as in the northwestern part of Spain, the southeastern part of France, and certain regions of Italy. Belgium and the United Kingdom both contributed to the recording. In lawns, gardens, and parks, *A. melanoxylon* can be grown for its ornamental value. It also serves the purpose of a street tree. Its wood is utilized in the production of timber in Portugal (Arán et al., 2017; Souza-Alonso et al., 2017).

Acacia melanoxylon distribution in Africa

Acacia melanoxylon is found in cool and wet mountainous regions of tropical Africa (Grubben, 2008). It grows along riparian zones, roadsides, open woodlands, shrublands, and grasslands in Eastern Africa (Grubben, 2008). It thrives in coastal regions, disturbed sites, urban open spaces, forests, and wetland habitats. In Tanzania, it can be found growing between 1500 and 2500 metres above sea level (Mapunda & John, 2021). Introduced to Uganda, it grows in

Muko and Mafuga Forest plantations in the southwestern highlands (Sabiiti & Wein, 1987). It also dominates forest edges in Kenya and Rwanda (Omondi et al., 2010).

Impacts of Invasive Acacia Plant Species on Forest Ecosystems

Both above- and below-ground compartments, as well as ecosystem services such as soil formation, water flow, and nutrient cycling, are impacted by invasive Acacias (Le Maitre et al., 2011). Invasive Acacias produce homogeneous and dense vegetation formations that drastically reduce light availability for understory plants, thereby preventing their establishment (Lorenzo et al., 2016). Under the Acacia, the survival rate of light-dependent native forest species is lower than that of shade-tolerant species. This indicates that the effect of Acacia on light conditions is significant in ecosystems with native open canopies, but negligible in ecosystems with closed canopies. Dense Acacia canopies result in a high accumulation of biomass and litter, which increases the frequency and intensity of fires in invaded ranges. In turn, fires promote the germination of acacia seeds while diminishing the viability of native seeds, thereby favouring the invasive process (Le Maitre et al., 2011). This fact has greater ecological significance in ecosystems where dominant species do not rely on fire for germination. In certain regions, model projections predict that Acacia will only disperse in the presence of fire when combined with browsing and/or cutting (Verbruggen et al., 2013).

Invasions of Acacia generally reduce plant cover, species richness, and biodiversity (Grice, 2006; Gaertner et al., 2009; Lorenzo et al., 2012; Murugan et al., 2020). Reduced biodiversity as a result of Acacia invasion leads to the replacement of native species with other native or exotic plants (Rodríguez et al., 2020; Mostert et al., 2017). Several Acacia species have exhibited a greater capacity to affect plant diversity (Hejda et al., 2017; Nsikani et al., 2019).

The rapid observation of the understory below the canopy of Acacias indicates substantial changes in the structure of the soil surface, linking Acacia invasion with the concept of niche construction (Lorenzo et al., 2010). The overwhelming surface root development of Acacia trees dominates and drastically transforms the soil surface. Acacia creates a root net in the upper soil layer due to its extensive creeping rhizomatous system and also reduces soil bulk density (Langdon et al., 2019). Similarly, Acacia develops roots reaching 6 m during the first 4 years thus, below the canopy, a thick layer of organic matter is progressively accumulated by the continuous litterfall (Bordron et al., 2021).

Acacias provide litter with different C-sources compositions that can affect nutrient cycling and decomposition, with possible ecological ramifications (Pereira et al., 2018). Nevertheless, decomposed plant material of Acacia did not produce significant changes in the functional and structural profile of soil microbial communities and soil chemical properties compared to the decomposition of similar quantities of native plant material (Rodríguez et al., 2017).

As Nitrogen (N_2) fixers, Acacias increase (Ammonium) NH_4^+ pools (Tchichelle et al., 2017). Acacia modifies N cycling through the production of higher amounts of litter, resulting in more N being returned to the soil and an increase in the availability of inorganic N (Lazzaro et al., 2014). Acacia provides large quantities of N to the surrounding vegetation; however, at the same time, requires substantial amounts of P itself which creates an N/P imbalance at the community level (Meira-Neto et al., 2018). Moreover, acacias substantially and progressively change C content in long-time invaded soils (Souza-Alonso et al., 2015). Other parameters, such as the content of organic matter or interchangeable P, were significantly increased by acacia in soils from different ecosystems (Souza-Alonso et al., 2017).

The variation in pH might be highly dependent on the studied ecosystem. Acacia drastically increased the content of C and N, C/N ratio, pH and litter in ecosystems with poor soils, such as dunes and coastal areas (Bachega et al., 2016), resulting in differences in the catabolic diversity of microbial communities. Interestingly, these soil changes lead to positive feedback between Acacias and invaded soils. Soils previously invaded by Acacia favour the growth of their seedlings and increase the mortality of the co-occurring native *Pinus pinaster* (Chilpa-Galván et al., 2013; Rodríguez-Echeverría et al., 2013). This legacy effect of persistent change in the long term may continue even after acacia removal.

Water availability is often indicated as one of the main limiting factors of plant growth in several regions (Raab et al., 2015). Across their range of introduction, invasive Acacias are considered water-consuming species, and their presence leads to a reduction in the quantity and quality of available water in the soil and an increase in the evapotranspiration rate (Lorenzo et al., 2017). In the non-native range, water consumption by Acacia was higher than that measured for highly competitive species such as *Eucalyptus globulus* or *P. pinaster* (Correia et al., 2016). In South Africa, besides the use of groundwater, *A. dealbata* and *Acacia mearnsii* collected an important part of the estimated reduction of the mean annual runoff produced by all invasive plants (Le Maitre et al., 2011). This is particularly relevant in areas that present very low surface runoff, as in coastal arid regions. Novel *A. mearnsii* populations presented higher water losses compared to natives, whereas *A. longifolia* reduced the water flow on average by 26% in pine forests of coastal dunes (Nsikani et al., 2019).

At the same time, changes in hydrologic dynamics produced by Acacia were also associated with decreased C fixation rates of native trees (Rascher et al., 2011a). Interestingly, high water consumption is generally considered a strategy for individual fast growth. Nevertheless, due to the ability of Acacias to sprout, water consumption could be alternatively seen as a community-level strategy promoting the collective rather than individual plants in the long term (Rascher et al., 2011b). Acacias can also influence the water availability for surrounding plant communities through other strategies at the root level. High molecular weight alkanes exuded from roots by Acacia can induce water repellence, thereby reducing the accessible water for native seedlings (Morris et al., 2011). However, under stressful conditions of limited water supply, several species of Acacia revealed high drought sensitivity in terms of biomass and N-uptake efficiency, which was even more marked when plants grew with intra- or interspecific competition (Boy and Witt, 2013).

There have been species of Acacia showing lower water potential at 50% hydraulic conductivity loss (P_{50}), suggesting drought tolerance (Crous et al., 2012). Field xylem water potentials also support that Acacia has a significant advantage over some native species under drier conditions. The removal of Acacias might facilitate the replenishment of water for native vegetation, becoming a key factor to be considered in management operations, particularly in several areas. It has been suggested that the removal of invasive Acacias does not immediately imply water availability, but they consider it an important part of a package of several actions to optimise water supply. It has been observed that clearing lands invaded by Acacia, besides the increase in water availability due to the reduction in evapotranspiration, may also reduce the contamination of groundwater by nitrate (Souza-Alonso et al., 2017). Notwithstanding, to be realistic, changes in water regimes attributed to Acacia invasions or plantations should also include climatic conditions (rainfall patterns) as a potential source of variability.

Studies found substantial changes in soil microbial communities at structural and functional levels produced by Acacia invasion (Souza-Alonso et al., 2015; Lorenzo et al., 2017). These changes are more pronounced in the long term or heavily invaded areas and depend on the invaded ecosystem. In addition, bacteria seemed to be more affected than fungi (Lorenzo et al., 2010). Bacteria Acacia invasion affects both the structure and functional diversity of soil bacterial communities (Lorenzo & Rodríguez-Echeverría, 2015). Particularly, *A. longifolia* and *A. dealbata* alter the structure of bacterial communities from dunes, grasslands and mixed forests, relating the duration of the invasion with the magnitude of the effect produced (Correia et al., 2016). On the other hand, the functional catabolic diversity of soil bacteria also varies after the invasion by Acacia species (Lorenzo & Rodríguez-Echeverría, 2015).

The effect of invasion on soil fungal communities was mainly studied in soils invaded by *A. dealbata*, which modifies the community structure of generalist fungi in pine forests and shrublands, but the effect depends on the studied ecosystem (Lorenzo et al., 2010). Nevertheless, fungal communities seemed to evolve tolerance to invasion since they tended to return to the structure of pre-invaded communities after long periods (>25 years) of invasion (Souza-Alonso et al., 2015). Acacia invasion also modified specific fungal groups such as arbuscular mycorrhizal fungi (AMF) and ectomycorrhizal fungi (EM). Structural changes in AMF communities caused were accompanied by reduced growth of the highly AMF-reliant plant *Plantago lanceolata* (Guisande-Collazo et al., 2016). Similarly, *A. mearnsii* significantly altered the structure and composition of EM which, in consequence, produced a decrease in the early growth of the native tree *Quercus suber* L. (Boudiaf et al., 2013).

The relationships between native plants and the community of decomposers can be also altered due to the presence of acacias (Pereira et al., 2021). However, despite its fundamental role, studies addressing the impacts of acacias on groups implicated in the breakdown of organic matter are scarce. There was a significant reduction in richness, abundance and body size of arthropods (Coleoptera) in grasslands invaded by acacia compared to non-invaded areas (Litt et al., 2014). Additionally, the presence and litter production of *A. mearnsii* in riparian habits altered the structure of invertebrate communities, reducing the abundance of some cobble-dwelling taxa but increasing particle-feeding mayflies and chironomids (Van Schalkwyk, 2015). Below Acacia canopies, invertebrate richness was reduced compared to that under native species, and this reduction was higher at the species level than at the family or order level, indicating that changes in the dominant species have probably lower implications at the functional level. Furthermore, qualitative changes in litter composition produced by acacia invasion result in poor nutrient material for terrestrial isopods key components of macro-decomposer communities leading to smaller individuals (Souza-Alonso et al., 2015).

Ecological Impacts of *A. melanoxylon* on Forest Ecosystems in Africa

The impacts of *A. melanoxylon* at the ecosystem level include alteration to trophic structures, as well as changes in the availability of resources such as water (Sitzia et al., 2018; Jarić et al., 2019). The species can cause fragmentation, alteration or complete replacement of habitats which in turn, has cascading effects on species composition and diversity in the forest (Witt et al., 2018; Tomasetto et al., 2019). Within a given forest, *A. melanoxylon* is likely to affect the overall growth and proliferation of forest plant species (Pathak et al., 2019). In-depth studies of *Acacia melanoxylon* on forest growth (Kusmana and Suwandhi, 2019; Lowry et al., 2020), have shown four key features of the species concerning prolific seeding and early age of first reproduction; establishing itself in degraded environments, and profuse regeneration from direct seeds, stems or roots (Campagnaro et al., 2018). These features enable *A. melanoxylon* to smother forest plant growth and in cases where the planned establishment of forests is allowed, they limit their ability to take up nutrients to enhance their biomass volume (Chance et al., 2019). Thus *Acacia melanoxylon* establishment may affect the overall forest growth (Lowry et al., 2020).

Several studies report that *A. melanoxylon* in Kenya's forests were either introduced intentionally or accidentally and has evidence of fast proliferation, spread and smothers the forest ecosystems (Obiri, 2011). Larkin (2015) in Harkerville forest, South Africa, reported that *A. melanoxylon* did not affect soil moisture or organic matter but did affect phosphorus and ammonia. Phosphorus was lower near blackwoods. Higher soil nitrate concentration. Invasion reduced canopy closure, allowing light to reach the forest floor. Blackwood prefers open spaces. A dense stand of blackwood on private land and blackwood plantations were major sources of seed. Invaded and non-invaded phytosociology was similar. The blackwood reduced the tree layer's species diversity, according to the study. Blackwood's impact on measured environmental conditions was minimal. The measured environmental differences were slight but significant. The main issue was local seed dispersal. Under forest canopies, seeds don't germinate easily. Adult blackwood trees are ring-barked and seedlings removed near waterways.

Witt et al. (2018) stated that the Eastern African highlands, especially those in Kenya, Tanzania and Rwanda, have largely been invaded by introduced Australian wattles such as black wattle (*Acacia mearnsii*; Fabaceae) and blackwood (*A. melanoxylon*; Fabaceae). Mapunda & John (2021) studied the effects of wildfire on vegetation and understory avian communities in Tanzania's montane rainforests. They found that the invasive *A. melanoxylon* spreads rapidly in burn areas and could change the forest structure composition. In South Africa, *A. melanoxylon* was originally planted on 107,000 ha but is estimated now to have spread to a total area of 2,500,000 ha (Nyoka, 2003). In Kenya, the species was presented as a solution to some of East Africa's most pressing problems in drylands such as foliage and animal fodder in areas with little and meant to fortify and envisaged as a much-needed weapon against desertification. It has been blamed for many disastrous effects because of its aggressive growth. Some introduced plants and tree species have been known to remain in small localized populations for long periods but later turn into burgeoning populations of invasive (Kolar et al., 2001). Obiri (2014) while assessing the environmental risks posed by invasive plants in Kenya and Uganda's Kakamega and Mt. Elgon Forest Ecosystems. In the Mt. Elgon Forest, invasive levels of Acacia melanoxylon were reported.

Acacia melanoxylon emerged as the most critical invasive species in Mt Elgon forest alone. Serious levels of its invasion of forests have also been reported in South Africa (Bromilow, 2001). Henderson (1998) has reported *A. melanoxylon* as a drainer of fragile streams in Southern Africa. A similar danger exists in the delicate watercourses of Mt Elgon (e.g. rivers Koitobus and Malakisi) and thus action is needed to ensure that it is eradicated along these watercourses. Furthermore, since *A. melanoxylon* is fire resistant and strongly regenerates after fires, avoiding random forest fires is vital in checking this species. In Kakamega Forest, the greatest threat emanates from *Solanum mauritianum* and *Psidium guajava.* The latter is prevalent in forest margins and gaps and is dispersed into these areas by frugivorous birds that forage in farmland communities adjacent to the forest (Berens et al., 2008). As most invasive plants were light-demanding species it is prudent to limit unplanned felling or opening up of the forest canopy as this allows room for their entry. In Kenya, studies have been conducted on invasiveness but there is a lack of data on the aforementioned species in most parts of the forests.

Management and Control Strategies

The appropriate management techniques that are implemented in response to any plant invasion will be determined by several factors, including the nature of the landscape, the cost and availability of labour, the extent of the infestation, and the presence of other invasive species.

Because *A. melanoxylon* reproduces vegetatively from root suckers, it is possible to uproot small plants; however, it is critical to remove all of the roots before doing so (Silva & Marchante, 2012; Arán et al., 2017). When cutting down mature trees, herbicides can be applied to the cut stump to prevent the tree from resprouting. Methods that involve painting herbicide onto the bark of the basal layer of the tree can also be effective. Ring barking is a technique that can be used to kill large trees. Additionally, it is essential to take control of any potential vectors of seed dispersal. To lessen the likelihood of seeds being spread throughout the neighbourhood, the landowner of the property where the dense stand of trees is located may be financially motivated to clear his land of these trees if they contain valuable timber. Chemical and mechanical methods of control have been used. However, it appears that biological control of the species has been the most effective of the control strategies. The seed-eating weevil known as *Melanterius acacia*, which originally came from Australia, is responsible for a significant drop in blackwood's normally high seed production. At this time, the weevil has successfully established itself in a significant number of the region's forests (Impson et al., 2004).

CONCLUSION AND RECOMMENDATION

There are reported cases of *A. melanoxylon* invasion in African Countries such as South Africa, Uganda, Kenya, Rwanda and Tanzania. Some of the management and control measures put in place in some of these regions, especially in South Africa include uprooted but it is important to remove the roots completely as *A. melanoxylon* reproduces vegetatively from root suckers. Mature trees can be cut and herbicide applied to the stump to limit resprouting. Basal bark methods (painting herbicide onto the bark) can also be effective. Large trees can be killed by ring barking. Foliar sprays can be used on young plants. When using any herbicide always read the label first and follow all instructions and safety requirements. A seed predating weevil *Melanterius acacia* was first released in South Africa in 1985 to control *A. melanoxylon.* The study recommends implementing policies, legislation, and incentives to guide public and private investment in controlling invasive alien plant species and passive or active restoration as needed. Invasion ecologists, managers of control operations, and restoration practitioners must learn from each other and work together to make progress. Additionally, this study recommends further research to address the deficiency in species management and its ecological impact on the Eastern and Southern parts of African.

REFERENCES

Abara, L., & Bekele, T. (2021). Evaluation of the Chemical Composition and Pulp and Paper making Potential of Acacia melanoxylon Grownat Chencha woreda in SNNPR, Ethiopia. *Ethiopian Environment and Forest Research Institute (EEFRI)*, 76.

Arán, D., García-Duro, J., Cruz, O., Casal, M., & Reyes, O. (2017). Understanding biological characteristics of *Acacia melanoxylon* about the fire to implement control measurements. *Annals of Forest Science*, *74*(3), 1-10.

Bachega, L. R., Bouillet, J. -P., de Cássia Piccolo, M., Saint-André, L., Bouvet, J. -M., Nouvellon, Y., de Moraes Gonçalves, J. L., Robin, A. and Laclau, J. -P. (2016). The decomposition of *Eucalyptus grandis* and *Acacia mangium* leaves and fine roots in tropical conditions did not meet the Home Field Advantage hypothesis. *Forest Ecology and Management*. 359(33-43Grice, A. C. (2006). The impacts of invasive plant species on the biodiversity of Australian rangelands. *The Rangeland Journal*, *28*(1), 27-35.

Bekele-Tesemma, A., Birnie, A., & Tengnas, B. (1993). Useful trees and shrubs for Ethiopia.

Regional Soil Conservation Unit (RSCU), Swedish International Development Authority (SIDA).

Binggeli, P., Hall, J. B., & Healey, J. R. (1999). Invasive woody plants. https://books.google.co.ke/books?hl=en&lr=&id=SAJQhK1fWDoC&oi=fnd&pg=PA383&dq=Binggeli,+P.,+Hall,+J.+B.,+%26+Healey,+J.+R.+(1999).+Invasive+woody+plants.&ots=RnpXdDqpfF&sig=ExhET7RjOjVkSspyAP5yNZ60ooM&redir_esc=y#v=onepage&q&f=false.

Boland, D. J., Brooker, M. I. H., Chippendale, G. M., Hall, N., Hyland, B. P. M., Johnston, R. D., ... & Turner, J. D. (Eds.). (2006). *Forest trees of Australia*. CSIRO publishing.

Bordron, B., Germon, A., Laclau, J. -P., Oliveira, I., Robin, A., Jourdan, C., Paula, R.R., Pinheiro, R., Guillemot, J., & Gonçalves, J. L. M. (2021). Nutrient supply modulates species interactions belowground: dynamics and traits of fine roots in mixed plantations of Eucalyptus and *Acacia mangium*. *Plant and Soil*. 460(1): 559-577.

Boudiaf, I., Baudoin, E., Sanguin, H., Beddiar, A., Thioulouse, J., Galiana, A., Prin, Y., Le Roux, C., Lebrun, M., & Duponnois, R. (2013). The exotic legume tree species, *Acacia mearnsii*, alters microbial soil functionalities and the early development of a native tree species, Quercus suber, in North Africa. *Soil Biology and Biochemistry*. 65(172-179.

Boy, G., & Witt, A. (2013). Invasive alien plants and their management in Africa. *Invasive alien plants and their management in Africa.*

Bradbury, G. J. (2010). *Environmental & genetic variation in blackwood (Acacia melanoxylon R. Br.) survival, growth, form & wood properties* (Doctoral dissertation, University of Tasmania).

Bradbury, G. J., Beadle, C. L., & Potts, B. M. (2010). Genetic control in the survival, growth and form of Acacia melanoxylon. *New forests*, *39*(2), 139-156.

Bradbury, G., Potts, B. M., Beadle, C. L., Dutkowski, G., & Hamilton, M. (2011). Genetic and environmental variation in heartwood colour of Australian blackwood (Acacia melanoxylon R. Br.). Walter de Gruyter Berlin New York. https://doi.org/10.1515/hf.2011.042.

Burrows, G. E., Virgona, J. M., & Heady, R. D. (2009). Effect of boiling water, seed coat structure and provenance on the germination of Acacia melanoxylon seeds. *Australian Journal of Botany*, *57*(2), 139-147.

Campagnaro, T., Brundu, G., & Sitzia, T. (2018). Five major invasive alien tree species in European Union Forest habitat types of the Alpine and Continental biogeographical regions. *Journal for Nature Conservation*, *43*, 227-238.

Chance, D. P., McCollum, J. R., Street, G. M., Strickland, B. K.,, & Lashley, M. A. (2019). Native Species Abundance Buffers Non-Native Plant Invasibility following Intermediate Forest Management Disturbances. *Forest Science*. 65(3): 336-343.

Chilpa-Galván, N., Tamayo-Chim, M., Andrade, J. L., & Reyes-García, C. (2013). Water table depth may influence the asymmetric arrangement of epiphytic bromeliads in a tropical dry forest. *Plant Ecology*. 214(8): 1037-1048.

Clayton, K. (2012). Australian timbers: Their significance in early Australian shipbuilding. *Journal of the Australasian Institute for Maritime Archaeology, The*, *36*, 55-76.

Fernandes, R. F., Honrado, J. P., Guisan, A., Roxo, A., Alves, P., Martins, J., & Vicente, J. R. (2019). Species distribution models support the need for international cooperation toward the successful management of plant invasions. *Journal for nature conservation*. 49(85-94.

Gozlan, R. E., Britton, J. R., Cowx, I., & Copp, G. H. (2010). Current knowledge of non-native freshwater fish introductions. *Journal of fish biology*, *76*(4), 751-786.

Grubben, G. J. H. (2008). *Plant Resources of Tropical Africa (PROTA)*. Prota.

Grubben, G. J. H. (2008). *Plant Resources of Tropical Africa (PROTA)*. Prota.

Guisande-Collazo, A., González, L., & Souza-Alonso, P. (2016). Impact of an invasive nitrogen-fixing tree on arbuscular mycorrhizal fungi and the development of native species. *AoB Plants*, *8*.

Harrison, S. R., Gregorio, N. O., Herbohn, J. L., & Dargusch, P. (2008, November). Designing and implementing best management practices in smallholder forestry nurseries. In *Proceedings from the FORTROP II International Conference* (pp. 17-20).

Hejda, M., Hanzelka, J., Kadlec, T., Štrobl, M., Pyšek, P., & Reif, J. (2017). Impacts of an invasive tree across trophic levels: species richness, community composition and resident species' traits. *Diversity and Distributions*. 23 (9): 997-1007.

Hirsch, H., Richardson, D. M., Pauchard, A., & Le Roux, J. J. (2021). Genetic analyses reveal complex introduction histories for the invasive tree Acacia dealbata Link around the world. *Diversity and Distributions*. 27(2): 360-376.

Hussain, M. I., González, L., Souto, C., & Reigosa, M. J. (2011). Ecophysiological responses of three native herbs to the phytotoxic potential of invasive *Acacia melanoxylon* R. Br. *Agroforestry systems*, *83*(2), 149-166.

Impson, F. A. C., Moran, V. C., & Hoffmann, J. H. (2004). Biological control of an alien tree, Acacia cyclops, in South Africa: impact and dispersal of a seed-feeding weevil, *Melanterius servulus*. *Biological control*, *29*(3), 375-381.

Jarić, I., Heger, T., Monzon, F. C., Jeschke, J. M., Kowarik, I., McConkey, K. R., Pyšek, P., Sagouis, A., & Essl, F. (2019). Crypticity in biological invasions. *Trends in ecology & evolution*. 34(4): 291-302.

Kohli, R. K., Batish, D. R., Singh, J. S., Singh, H. P., Bhatt, J. R., Singh, S. P., & Tripathi, R. S. (2012). Plant invasion in India: An overview. *Invasive alien plants: an ecological appraisal for the Indian subcontinent (Eds: Bhatt JR, Singh JS, Singh SP, Tripathi RS and Kohli RK) pp*, 1-9.

Kull, C. A., & Rangan, H. (2008). Acacia exchanges: wattles, thorn trees, and the study of plant movements. *Geoforum*, *39*(3), 1258-1272.

Kusmana, C., & Suwandhi, I. (2019, December). Diversity of plant species and the presence of Invasive Alien Species (IAS) in the Sub-Montane Forest at Pakenjeng Region, Southern Part of Garut, West Java. In *IOP Conference Series: Earth and Environmental Science* (Vol. 399, No. 1, p. 012035). IOP Publishing.

Langdon, B., Pauchard, A., & Bustamante, R.O. (2019). *Acacia dealbata* invasion in Chile: Surprises from climatic niche and species distribution models. *Ecology and evolution*. 9(13): 7562-7573.

Larkin, D. T. (2015). Impacts of *Acacia melanoxylon* R. Br. (blackwood) on the environmental conditions and phytosociology in forest communities in Harkerville forest, South Africa.

Lazzaro, L., Giuliani, C., Fabiani, A., Agnelli, A.E., Pastorelli, R., Lagomarsino, A., Benesperi, R., Calamassi, R., & Foggi, B. (2014). Soil and plant changing after invasion: the case of Acacia dealbata in a Mediterranean ecosystem. *Science of the total environment*. 497(491-498.

Le Maitre, D. C., Gaertner, M., Marchante, E., Ens, E. J., Holmes, P. M., Pauchard, A., ... & Richardson, D. M. (2011). Impacts of invasive Australian acacias: implications for management and restoration. *Diversity and Distributions*, *17*(5), 1015-1029.

Litt, A. R., Cord, E. E., Fulbright, T. E., & Schuster, G. L. (2014). Effects of invasive plants on arthropods. *Conservation Biology*. 28(6): 1532-1549.

Lorenzo, P., González, L., & Reigosa, M. J. (2010). The genus Acacia as invader: the characteristic case of Acacia dealbata Link in Europe. *Annals of Forest Science*. 67(1): 101.

Lowry, B. J., Lowry, J. H., Jarvis, K. J., Keppel, G., Thaman, R. R., & Boehmer, H. J. (2020). Spatial patterns of presence, abundance, and richness of invasive woody plants in relation to urbanization in a tropical island setting. *Urban Forestry & Urban Greening*. 48(126516.

Lozano, V., Marzialetti, F., Carranza, M.L., Chapman, D., Branquart, E., Dološ, K., Große-Stoltenberg, A., Fiori, M., Capece, P., & Brundu, G. (2020). Modelling *Acacia saligna* invasion in a large Mediterranean island using PAB factors: A tool for implementing the European legislation on invasive species. *Ecological Indicators*. 116(106516.

Macphail, M. K. (1984). Small-scale dynamics in an early Holocene wet sclerophyll forest in Tasmania. *New Phytologist*, *96*(1), 131-147.

Mapunda, R., & John, J. R. (2021). Effects of wildfire on vegetation and understory avian communities in montane rainforests, north-eastern Tanzania. *African Journal of Ecology*, *59*(2), 466-478.

Mapunda, R., & John, J. R. (2021). Effects of wildfire on vegetation and understory avian communities in montane rainforests, north-eastern Tanzania. *African Journal of Ecology*, *59*(2), 466-478.

Marcar, N., Crawford, D., Leppert, P., Jovanovic, T., Floyd, R., & Farrow, R. (1995). *Trees for saltland: a guide to selecting native species for Australia*. Csiro Publishing.

Marshall, A. R., Platts, P. J., Gereau, R. E., Kindeketa, W., Kang'ethe, S., & Marchant, R. (2012). The genus Acacia (Fabaceae) in East Africa: distribution, diversity and the protected area network. *Plant Ecology and Evolution*, *145*(3), 289-301.

Maslin, R., & McDonald, M. W. (2004). Acacia search. *Evaluation of Acacia as a woody crop option for southern Australia, RIRDC. Union Offset Printers, Canberra, Australia*.

Meira-Neto, J. A. A., da Silva, M. C. N. A., Tolentino, G. S., Gastauer, M., Buttschardt, T., Ulm, F., & Máguas, C. (2018). Early Acacia invasion in a sandy ecosystem enables shading mediated by soil, leaf nitrogen and facilitation. *Biological Invasions*. 20(6): 1567-1575.

Miles, B., Baard, J. A., & Kraaij, T. (2022). Potential allelopathic effects of alien Acacia melanoxylon and indigenous Olea capensis macrocarpa on germination of Acacia melanoxylon. *South African Journal of Botany*, *148*, 326-329.

Miller, J. T., Murphy, D. J., Brown, G. K., Richardson, D. M., & González-Orozco, C. E. (2011). The evolution and phylogenetic placement of invasive Australian Acacia species. *Diversity and Distributions*, *17*(5), 848-860.

Moos, C., Toe, D., Bourrier, F., Knüsel, S., Stoffel, M., & Dorren, L. (2019). Assessing the effect of invasive tree species on rockfall risk–The case of Ailanthus altissima. *Ecological engineering*. 131(63-72).

Morris, T. L., Esler, K. J., Barger, N. N., Jacobs, S. M., & Cramer, M. D. (2011). Ecophysiological traits associated with the competitive ability of invasive Australian acacias. *Diversity and Distributions*. 17(5): 898-910.

Mostert, E., Gaertner, M., Holmes, P. M., Rebelo, A. G., & Richardson, D. M. (2017). Impacts of invasive alien trees on threatened lowland vegetation types in the Cape Floristic Region, South Africa. *South African Journal of Botany*, *108*, 209-222

Murugan, R., Beggi, F., Prabakaran, N., Maqsood, S., & Joergensen, R. G. (2020). Changes in plant community and soil ecological indicators in response to Prosopis juliflora and Acacia mearnsii invasion and removal in two biodiversity hotspots in Southern India. *Soil Ecology Letters*, *2*(1), 61-72.

Niang, A., Ugiziwe, J., Styger, E., & Gahamanyi, A. (1996). Forage potential of eight woody species: intake and growth rates of local young goats in the highland region of Rwanda. *Agroforestry systems*, *34*(2), 171-178.

Nicholas, I. (2007). understanding blackwood (Acacia melanoxylon) markets; an opportunity for improving blackwood plantation returns. *New Zealand Journal of Forestry*, *52*(3), 17.

Nicholas, I., & Brown, I. (2002). A handbook for growers and users. *New Zealand Forest Research Institute: Rotorua, New Zealand*.

Nsikani, M., Gaertner, M., Kritzinger-Klopper, S., Ngubane, N., & Esler, K. (2019). Secondary invasion after clearing invasive Acacia saligna in the South African fynbos. *South African Journal of Botany*. 125(280-289.

Obiri, J. F. (2014). An Assessment of invasive plants environmental risks in the Kakamega and Mt Elgon Forest Ecosystems in Kenya and Uganda.

Oliveira, C. C. C. B. (2020). *Valorisation of Forest Biomass Side-Streams in Add Value Green Products for Horticultural Industry* (Doctoral dissertation, Universidade de Lisboa (Portugal)).

Omondi, S. F., Kireger, E., Dangasuk, O. G., Chikamai, B., Odee, D. W., Cavers, S., & Khasa, D. P. (2010). Genetic diversity and population structure of Acacia senegal (L) Willd. in Kenya. *Tropical Plant Biology*, *3*(1), 59-70.

Orchard, A. E. (2009). A revision of Cassinia (Asteraceae: Gnaphalieae) in Australia. 6. Section Cassinia. *Australian Systematic Botany*, *22*(5), 344-376.

Otieno, D. O., Schmidt, M., Adiku, S., & Tenhunen, J. (2005). Physiological and morphological responses to water stress in two Acacia species from contrasting habitats. *Tree physiology*. 25(3): 361-371.

Pandey, V. C., Sahu, N., & Singh, D. (2020). Physiological profiling of invasive plant species for ecological restoration of fly ash deposits. *Urban Forestry & Urban Greening*. 54(126773.

Parra-Tabla, V., Angulo-Pérez, D., Albor, C., Campos-Navarrete, M. J., Tun-Garrido, J., Sosenski, P., ... & Arceo-Gómez, G. (2019). The role of alien species on plant-floral visitor network structure in invaded communities. *PloS one*, *14* (11), e0218227.

Pathak, R., Negi, V. S., Rawal, R. S., & Bhatt, I. D. (2019). Alien plant invasion in the Indian Himalayan Region: state of knowledge and research priorities. *Biodiversity and Conservation*: 1-30.

Pereira, A., Zagatto, M. R., Brandani, C. B., Mescolotti, D. d.L., Cotta, S. R., Gonçalves, J. L., & Cardoso, E. J. (2018). Acacia changes microbial indicators and increases C and N in soil organic fractions in intercropped Eucalyptus plantations. *Frontiers in microbiology*. 9, 655.

Pinkard, E. A., & Beadle, C. L. (2002). Blackwood (Acacia melanoxylon R. Br.) plantation silviculture: a review. *Australian Forestry*, *65*(1), 7-13.

Potgieter, L. J., Gaertner, M., O'Farrell, P. J., & Richardson, D. M. (2019). Perceptions of impact: invasive alien plants in the urban environment. *Journal of environmental management*, *229*, 76-87.

Pyšek, P., Jarošík, V., & Pergl, J. (2011). Alien plants introduced by different pathways differ in invasion success: unintentional introductions as a threat to natural areas. *PloS one*, *6* (9), e24890.

Raab, N., Meza, F.J., Franck, N. and Bambach, N. (2015). Empirical stomatal conductance models reveal that the isohydric behavior of an Acacia caven Mediterranean Savannah scales from leaf to ecosystem. *Agricultural and Forest Meteorology*. 213, 203-216.

Raddad, E. A. Y., Salih, A. A., Fadl, M. A. E., Kaarakka, V., & Luukkanen, O. (2005). Symbiotic nitrogen fixation in eight Acacia senegal provenances in dryland clays of the Blue Nile Sudan estimated by the 15N natural abundance method. *Plant and Soil*, *275*(1), 261-269.

Rascher, K. G., Große-Stoltenberg, A., Máguas, C. , & Werner, C. (2011b). Understory invasion by Acacia longifolia alters the water balance and carbon gain of a Mediterranean pine forest. *Ecosystems*. 14 (6): 904-919.

Rascher, K. G., Große-Stoltenberg, A., Máguas, C., Meira-Neto, J. A. A. & Werner, C. (2011a). Acacia longifolia invasion impacts vegetation structure and regeneration dynamics in open dunes and pine forests. *Biological Invasions*. 13 (5): 1099-1113.

Reid, R. (2004). Silvicultural management of Australian blackwood (Acacia melanoxylon) in plantations and multi-purpose forests.

Rodríguez, J., Cordero-Rivera, A., & González, L. (2020). Characterizing arthropod communities and trophic diversity in areas invaded by Australian acacias. *Arthropod-Plant Interactions*, *14* (4), 531-545.

Rodríguez-Echeverría, S., Armas, C., Pistón, N., Hortal, S., & Pugnaire, F. I. (2013). A role for below-ground biota in plant–plant facilitation. *Journal of Ecology*. 101 (6): 1420-1428.

Sabiiti, E. N., & Wein, R. W. (1987). Fire and Acacia seeds: a hypothesis of colonization success. *The Journal of Ecology*, 937-946.

Searle, S. D. (2000). Acacia melanoxylon-A review of variation among planted trees. *Australian Forestry*, *63* (2), 79-85.

Shackleton, C. M., & Shackleton, R. (2016). Knowledge, perceptions and willingness to control designated invasive tree species in urban household gardens in South Africa. *Biological Invasions*. 18 (6): 1599-1609.

Shackleton, R. T., Richardson, D. M., Shackleton, C. M., Bennett, B., Crowley, S. L., Dehnen-Schmutz, K., Estévez, R. A., Fischer, A., Kueffer, C., & Kull, C. A. (2019). Explaining people's perceptions of invasive alien species: a conceptual framework. *Journal of Environmental Management*. 229, 10-26.

Silva, J. S., & Marchante, H. (2012). Post-fire management of exotic forests. In *Post-Fire Management and Restoration of Southern European Forests* (pp. 223-255). Springer, Dordrecht.

Sitzia, T., Campagnaro, T., Kotze, D. J., Nardi, S., & Ertani, A. (2018). The invasion of abandoned fields by a major alien tree filters understory plant traits in novel forest ecosystems. *Scientific reports*. 8 (1): 1-10.

Souza-Alonso, P., Rodríguez, J., González, L., & Lorenzo, P. (2017). Here to stay. Recent advances and perspectives about Acacia invasion in Mediterranean areas. *Annals of Forest Science*, *74* (3), 1-20.

Taylor, D. B., & Dhileepan, K. (2019). Implications of the changing phylogenetic relationships of Acacia sl on the biological control of Vachellia nilotica ssp. indica in

Australia. *Annals of Applied Biology*, *174* (2), 238-247.

Tchichelle, S. V., Epron, D., Mialoundama, F., Koutika, L. S., Harmand, J. -M., Bouillet, J. -P., && Mareschal, L. (2017). Differences in nitrogen cycling and soil mineralisation between a eucalypt plantation and a mixed eucalypt and Acacia mangium plantation on a sandy tropical soil. *Southern Forests: a Journal of Forest Science*. 79 (1): 1-8.

Tomasetto, F., Duncan, R. P., & Hulme, P. E. (2019). Resolving the invasion paradox: pervasive scale and study dependence in the native-alien species richness relationship. *Ecology letters*. 22 (6): 1038-1046.

Turbelin, A. J., Malamud, B. D., & Francis, R. A. (2017). Mapping the global state of invasive alien species: patterns of invasion and policy responses. *Global Ecology and Biogeography*, *26* (1), 78-92.

Unwin, G. L., Jennings, S. M., & Hunt, M. A. (2006). Light environment and tree development of young Acacia melanoxylon in mixed-species regrowth forest, Tasmania, Australia. *Forest ecology and management*, *233* (2-3), 240-249.

Van Schalkwyk, J. (2015). Biodiversity conservation in a fragmented landscape: arthropod assemblages in smaller corridors within a production landscape, Stellenbosch: Stellenbosch University.

Van Wilgen, B. W., & De Lange, W. J. (2011). The costs and benefits of biological control of invasive alien plants in South Africa. *African Entomology*, *19* (1), 504-514.

Verbruggen, H., Tyberghein, L., Belton, G.S., Mineur, F., Jueterbock, A., Hoarau, G., Gurgel, C.F.D., & De Clerck, O. (2013). Improving transferability of introduced species' distribution models: new tools to forecast the spread of a highly invasive seaweed. *PLoS One*. 8(6): e68337.

Vize, S., Killin, D., & Sexton, G. (2005). The Community Rainforest Reforestation Program and other farm forestry programs based around the utilisation of rainforest and tropical species. *Erskine, PD, Lamb, D. and Bristow, M.(eds)*, 7-22.

Weber, E. (2017). *Invasive plant species of the world: a reference guide to environmental weeds*. Cabi.

Witt, A., Beale, T., & van Wilgen, B. W. (2018). An assessment of the distribution and potential ecological impacts of invasive alien plant species in eastern Africa. *Transactions of the Royal Society of South Africa*. 73 (3): 217-236.