Risk analysis of alien grasses occurring in South Africa

By

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Declaration

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Abstract

Alien grasses have caused major impacts in their introduced ranges, including transforming natural ecosystems and reducing agricultural yields. This is clearly of concern for South Africa. However, alien grass impacts in South Africa are largely unknown. This makes prioritising them for management difficult.

In this thesis, I investigated the negative environmental and socio-economic impacts of 58 alien grasses occurring in South Africa from 352 published literature sources, the mechanisms through which they cause impacts, and the magnitudes of those impacts across different habitats and regions. Through this assessment, I ranked alien grasses based on their maximum recorded impact. *Cortaderia sellonoana* had the highest overall impact score, followed by *Arundo donax, Avena fatua, Elymus repens,* and *Festuca arundinacea.* As with other plant groups, alien grasses cause the most impacts through competition with native species (72% of species) and agricultural crops (57% of species). There was variation in impact magnitudes between regions, and among habitat types, however, these differences were not statistically significant. I also found no correlation between impacts recorded from elsewhere and those recorded in South Africa.

I then looked at these impacts and risks in South Africa using six alien *Paspalum* species as a test case. I used species distribution modelling to determine the extent of their potential distribution and a risk analysis framework to determine their overall risk in the country. The species distribution models indicate that *P. dilatatum* has higher relative occurrence rate in relation to other alien *Paspalum* species in South Africa, and *P. nutans* has the lowest relative occurrence rate. The environmental variable which influenced the relative occurrence rate of most *Paspalum* species was annual mean temperature and was the most contributing variable of three species: *P. dilatatum, P. nutans,* and *P. urvillei.* Temperature seasonality was the main environmental variable for *P. quadrifarium,* while the relative occurrence rate of *P. virgatum* and *P. nutans* was best predicted by annual precipitation. The risk analyses show that *P. dilatatum, P. notatum* and *P. quadrifarium* have high risk with medium management feasibility, and the other three (*P. nutans, P. urvillei,* and *P. virgatum*) are low risk in South Africa.

Finally, based on the results of the risk analysis and the distribution models, I conducted a field assessment of the impacts of *P. quadrifarium* on the local plant community. I compared sites where *P. quadrifarium* currently invades, to those that had been invaded and subsequently cleared of the species and to those that had not been invaded. I found that *P. quadrifarium* altered the plant species composition and reduced their abundance, i.e. it appears to impact plant communities through competition. I also found no regrowth of *P. quadrifarium* in the site where it was cleared mechanically by uprooting the whole plant. However, there was evidence of secondary invasions by other alien plants in the site, highlighting the need for active restoration. The results of this thesis are relevant for the management of alien grasses in South Africa as they can be used to motivate for their prioritisation and regulation in the country.

Opsomming

Uitheemse grasse het ‘n groot impak in hul ingedringde reekse veroorsaak, insluitend die omskepping van natuurlike ekosisteme asook die vermindering van landbouopbrengste. Dit is duidelik kommerwekkend vir Suid-Afrika. Die impak van uitheemse grasse in Suid-Afrika is egter grootliks onbekend, en maak dit moeilik om die bestuur daarvan te prioritiseer.

In hierdie proefskrif het ek die negatiewe omgewings- en sosio-ekonomiese impakte van 58 uitheemse grasse in Suid-Afrika ondersoek uit 352 gepubliseerde literatuurbronne, die meganismes waardeur hulle impak veroorsaak en die omvang van die impakte oor verskillende habitatte en streke. Deur hierdie assessering het ek uitheemse grasse gegrond op hul maksimum aangetekende impak. *Cortaderia sellonoana* het die hoogste algehele impak telling, gevolg deur *Arundo donax*, *Avena fatua*, *Elymus repens* en *Festuca arundinacea*. Soos met ander plantegroepe, veroorsaak uitheemse grasse die meeste impak deur die kompetisie met inheemse spesies (72% van spesies) en landbougewasse (57% van spesies). Daar was variasie in impakgroottes tussen streke, en onder habitatsoorte was hierdie verskille egter nie statisties betekenisvol nie. Ek het ook geen verband gevind tussen impakte wat elders aangeteken is en dié wat in Suid-Afrika aangeteken is nie.

Ek het toe na hierdie impakte en risiko's in Suid-Afrika gekyk deur ses uitheemse *Paspalum* spesies te gebruik as 'n toetssaak. Ek het spesieverspreidingsmodellering gebruik om die omvang van hul potensiële verspreiding te bepaal, en 'n risiko-analise raamwerk om hul algehele risiko in die land te bepaal. Die spesies verspreidingsmodelle dui daarop dat *P. dilatatum* 'n hoër relatiewe voorkoms-koers het in verhouding tot ander uitheemse *Paspalum* spesies in Suid-Afrika, en *P. nutans* het die laagste relatiewe voorkoms-koers. Die omgewingsveranderlike wat die relatiewe voorkoms van die meeste *Paspalum* spesies beïnvloed het, was jaarlikse gemiddelde temperatuur en was ook die mees bydraende veranderlike van drie spesies: *P. dilatatum*, *P. nutans*, en *P. urvillei*. Temperatuur seisoenaliteit was die belangrikste omgewingsveranderlike vir *P. quadrifarium*, terwyl die relatiewe voorkoms van *P. virgatum* en *P. nutans* die beste voorspel is deur jaarlikse neerslag. Die risiko ontledings toon dat *P. dilatatum*, *P. notatum* en *P. quadrifarium* 'n hoë risiko

het met medium bestuur haalbaarheid, en die ander drie (*P. nutans*, *P. urvillei*, en *P. virgatum*) is lae risiko in Suid-Afrika.

Ten slotte, op grond van die resultate van die risiko-analise en die verspreidingsmodelle, het ek 'n veldassessering gedoen rakende die impak van *P. quadrifarium* op die plaaslike plantgemeenskap. Ek vergelyk plekke waar *P. quadrifarium* tans indring, met plekke wat reeds ingedring is (en daarna van indringerspesies verwyder is), en ook met plekke wat nog nie ingedring is nie. Ek het bevind dat *P. quadrifarium* die plantspesiesamestelling verander het en hul oorvloed verminder het, met ander woorde, dit wil voorkom asof dit plantegroei beïnvloed deur mededinging. Ek het ook geen hergroei van *P. quadrifarium* gevind op die terrein waar dit meganies skoongemaak is, deur die hele plant te ontwortel nie. Daar was egter bewyse van sekondêre indringing deur ander uitheemse plante in die terrein, wat die behoefte aan aktiewe herstel beklemtoon. Die uitslae van hierdie proefskrif is van belang vir die bestuur van uitheemse grasse in Suid-Afrika, aangesien dit kan dien as motivering vir hul prioritisering en regulering in die land.

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To God be the glory.

List of tables

List of figures

Table of contents

Chapter 1 : General introduction

Globalisation has intensified the movement and introduction of different alien taxa beyond biogeographical ranges in which they naturally occur (Meyerson and Mooney 2007, Hulme 2009, Amano et al. 2016, Early et al. 2016). Many alien taxa are intentionally introduced for their beneficial attributes, e.g. as a source of food, medicine, pasture, or for their aesthetic value as ornamental plants and pets (Bever et al. 2001, Niemiera and Holle 2009, da Rosa et al. 2018), as well as for environmental purposes such as biocontrol agents, hyper-accumulators and soil stabilisers (Kester and Jackson 1996, Badgery et al. 2008). Other alien taxa have been accidentally introduced and spread across the globe as contaminants or transport stowaways (Bax et al. 2003, Whinam et al. 2005).

Whether intentionally or unintentionally introduced, some alien taxa can negatively affect the environment, or socio-economy in their introduced ranges (Cambray 2003, Vilà et al. 2011). It is important to understand such negative impacts for the successful management and prioritisation of the taxa introduced (Ewel et al. 1999, Charles and Dukes 2008).

1.1 Risk analysis for better management of alien taxa

In order to minimise the impacts of alien taxa while retaining the desired benefits, a comprehensive analysis of the risk of introducing those alien taxa should be conducted (Keller and Kumschick 2017). Risk analyses synthesise the available scientific evidence in a form that can be used by decision makers to determine whether alien taxa should be introduced, and to prioritise alien taxa already introduced for regulation and control (Pheloung et al. 1999, D'hondt et al. 2015, Keller and Kumschick 2017). This standardized process assesses the likelihood of an alien taxon to establish and spread in the recipient environment, its potential to cause negative impacts, as well as determines options available to manage the taxon after introduction (Roy et al. 2015, Keller and Kumschick 2017).

Many countries have adopted the use of such tools and processes to manage alien taxa occurring within a given area or to motivate the prevention of alien taxa with the potential to be introduced in the future (Keller et al. 2007, Gordon et al. 2016). For example, a quarantine risk analysis tool known as the 'Weed Risk Assessment' has been developed and adopted since 1998 in Australia to pre-screen intentional introductions of all alien plants (Pheloung et al. 1999). Studies show that adopting these risk analysis tools prior to introduction can over time be economically beneficial to the recipient country (Keller et al. 2007).

1.2 Management and prioritisation of alien taxa in South Africa

In South Africa, the management of alien taxa is governed by the National Environmental Management: Biodiversity Act (NEMBA), 2004 (Act no. 10 of 2004) under the Alien and Invasive Species Regulations (Department of Environmental Affairs 2014), hereafter called the NEMBA A&IS Regulations. Alien grasses occurring in South Africa are a good case study to address issues associated with the current management of the alien taxa as they are: (i) not well represented in the NEMBA A&IS Regulations; (ii) locally not well studied; but (iii) there is a large body of literature from elsewhere in the world reporting their negative impacts.

1.3 Alien grasses occurring in South Africa

Grasses are one of the largest plant families and they have been introduced globally for purposes such as agriculture, horticulture and restoration (Reed 2014, Visser et al. 2016). Grasses are highly valued economically - they are the source of the most consumed staple foods in the world, including cereal grains like corn, rice, sorghum and wheat (Prescott-Allen and Prescott-Allen 1990), and they are pasturage for livestock (Boval and Dixon 2012).

Although many alien grasses are beneficial to their recipient environment, they have been recorded and observed to be problematic around the globe. This is especially the case in tropical and temperate regions with similar climatic conditions to South Africa such as the Americas, and Australasia (D'Antonio and Vitousek 1992, D'Antonio et al. 2000). Over time, these grasses may establish, become integrated into native communities, and disrupt the natural functioning of their recipient ecosystems

(D'Antonio and Vitousek 1992, Gaertner et al. 2014). For example, *Andropogon gayanus* was primarily introduced in Australia for pasture and has since invaded native savanna systems, altering nitrogen cycles, and reducing tree cover and invertebrate species richness (Rossiter et al. 2004, Setterfield et al. 2010). Alien grasses have also been recorded to negatively impact the economy in their introduced range. In the Santa Ana River in Queensland alone, *Arundo donax* is estimated by Csurhes (2009) to use drinking water valued at 18 million US$ each year. Furthermore, pollen from *Dactylis* species can cause breathing difficulties in asthmatic individuals (Roberts et al. 1992, Takahashi et al. 2008).

1.4 Current management status of alien grasses occurring in South Africa

Generally, grasses are not seen to be as invasive in South Africa as they are reported to be in other parts of the world (Visser et al. 2017). However, information paucity could have led to some negatively impacting species being excluded in the prioritisation and management of alien species in the country. Awareness of alien grasses as problematic species is currently rising through impacts caused in other parts of the world, as illustrated in the examples above. Such information can be used to motivate for the management of alien grasses, as it could be very costly to wait for the species to become invasive before management actions are considered (Leung et al. 2002).

It is for these reasons that evidence-based risk analyses should be conducted for all species before they are managed, regulated, and listed in the NEMBA A&IS Regulations. Such risk analyses are cost-effective, have higher accuracy than judgements based on expert opinion (D'hondt et al. 2015), and provide a framework for the analysis of species with fewer local studies or less evidence.

1.5 Aims and objectives

The overall aim of this study was to analyse the risks associated with alien grasses (Poaceae) occurring in South Africa. This was accomplished by:

- investigating published evidence on impacts of alien grasses occurring in South Africa with the widest alien ranges globally (Chapter 2);
- determining factors contributing to higher impact magnitudes for alien grasses (Chapter 2);
- evaluating the risk posed to South African natural ecosystems by alien species from a particular genus (*Paspalum*) (Chapter 3); and
- providing recommendations for the regulation of these *Paspalum* species in South Africa based on a newly developed risk analysis framework (Chapter 3).

1.6 Chapter synopsis

In chapter 2, I collated published literature in order to conduct a global systematic review of the socio-economic and environmental impacts of alien grasses. Using an impact quantification scheme, I determined the magnitudes of the potential impacts and ranked the alien grasses based on those impact magnitudes. I also investigated mechanisms used to cause those impacts, and the habitats impacted by the species. The global assessment provided the information necessary to correlate impacts recorded in South Africa and elsewhere in the world.

In chapter 3, I conducted full risk analyses focusing only on *Paspalum* species, a group of grasses containing species with different invasion statuses in South Africa. Using a recently developed framework and guidelines for conducting risk analysis under the NEMBA A&IS Regulations (Kumschick et al. 2018), I collated evidence on the likelihood of the species to establish, spread, and cause impacts in the country. I then looked at the beneficial uses of the species, the feasibility of their management and made recommendations for the appropriate categorisation of each species in the NEMBA A&IS Regulations based on the overall analysis. Based on the results of the risk analysis, I conducted a field-based impact study on *Paspalum quadrifarium*, which occurs in a natural environment in South Africa and has a very localised distribution. This was important in determining to what extent this species causes impacts to native biodiversity.

Lastly, in chapter 4, I provided a synthesis and discuss the meaning of the results presented in this thesis, their importance and what they add to the current knowledge of alien grass management in South Africa. I also looked at the limitations of the study and provided recommendations for further studies.

Chapter 2 : Environmental and socio-economic impact assessment of selected alien grasses occurring in South Africa

Declaration: this chapter was accepted for publication in the journal Neobiota under the title: Global environmental and socio-economic impacts of selected alien grasses as a basis for ranking threats to South Africa.

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KVN: Compiled the database, led the writing

VV & KVN: Statistical analysis

SK, VV, & JRUW: Provided guidance, comments and edited the manuscript

Abstract

Decisions to allocate management resources should be underpinned by estimates of the impacts of biological invasions that are comparable across species and locations. For the same reason, it is important to assess what type of impacts are likely to occur where, and if such patterns can be generalised. In this chapter, I aim to understand factors shaping patterns in the type and magnitude of impacts of a subset of alien grasses. I used the Generic Impact Scoring System (GISS) to review and quantify published impact records of 58 grass species that are alien to South Africa and to at least one other biogeographical realm. Based on the GISS scores, I investigated how impact magnitudes varied across habitats, regions and impact mechanisms using multiple regression. I found impact records for 48 species. *Cortaderia selloana* had the highest overall impact score, although in contrast to five other species (*Glyceria maxima*, *Nassella trichotoma*, *Phalaris aquatica*, *Polypogon monspeliensis*, and *Sorghum halepense*) it did not score the highest possible impact score for any specific impact mechanism. Consistent with other studies, I found that the most frequent environmental impact was through competition with native plant species (with 75% of cases). Socio-economic impacts were recorded more often and tended to be greater in magnitude than environmental impacts, with impacts recorded particularly often on agricultural and animal production (57% and 51% of cases respectively). There was variation across different regions and habitats in impact magnitude, but the differences were not statistically significant. In conclusion, alien grasses present in South Africa have caused a wide range of negative impacts across most habitats and regions of the world. Reviewing impacts from around the world has provided important information for the management of alien grasses in South Africa, and, I believe, it is an important component of management prioritisation processes in general.

Keywords: alien grasses, environmental impact, GISS, impact assessment, impact magnitude, impact mechanism, socio-economic impact.

2.1 Introduction

Grasses (family Poaceae) are among the most introduced species around the world; they occur on every continent and in various habitat types (Linder et al. 2018, van Kleunen et al. 2015, Visser et al. 2016). Alien grasses are often introduced for their high economic value. They are the source for the most consumed staple foods in the world (cereal grains) (Prescott-Allen and Prescott-Allen 1990), pasturage for livestock in agriculture (Boval and Dixon 2012), energy through biofuels (Pimentel and Patzek 2005), and they are used in alcoholic beverages such as beer and whisky (Solange et al. 2014). Alien grasses have also, however, been introduced to new areas as transport contaminants and stowaways. For example, a study by Whinam et al. (2005) found that the major source of alien grass (such as *Agrostis stolonifera)* introductions into sub-Antarctic islands was the transport used for ship to shore food transfers.

Whether such introductions were accidental or deliberate, and regardless of the many benefits they provide, the introduction of alien grasses can result in invasions that cause substantial negative environmental and socio-economic impacts (Early et al. 2016, D'Antonio and Vitousek 1992, Driscoll et al. 2014). Grasses such as *Andropogon gayanus* have been reported to increase fire frequencies and intensity in fire-prone ecosystems (Rossiter-Rachor et al. 2009, Rossiter et al. 2004, Setterfield et al. 2010). *Arundo donax* is known to change community structure, thereby causing habitat loss for birds and small mammals in the USA (Bell 1997). And in China, *Avena fatua* is reported to cause economic losses of US$500 million annually by invading agricultural land and reducing crop yields (Willenborg et al. 2005).

Less is known about how these impacts vary across different introduced ranges, but it has been suggested that some introduced ranges experience fewer recorded impacts from alien grasses due to context-dependent factors (Hulme et al. 2013); e.g. the level of grass invasions might track variation in fire regimes, or because they have not yet been studied (Visser et al. 2016). Either way, impacts of alien grasses are most likely still increasing due to factors such as climate change and propagule pressure (Chuine et al. 2012, Fensham et al. 2013). We therefore need to understand these impacts and take precautionary measures in order to prevent or reduce them (Hulme

2003, 2006, Keller and Perrings 2011). Impact assessments are cost-effective tools used to estimate the impacts of alien species and help in the decision-making process during the prioritization of limited resources (Jeschke et al. 2014, Kumschick et al. 2012, Kumschick and Richardson 2013). Impact assessments have also been used to try to identify factors that predict impacts. Studies have found that traits such as a high fecundity, a habitat generalist strategy, a wide native range, a large body size and a large clutch size are associated with high environmental impacts for mammals, birds, and amphibians (Kumschick et al. 2013, Measey et al. 2016), and traits such as height, life form and life history are associated with greater impacts for plant species (Pyšek et al. 2012, Rumlerová et al. 2016). However, traits have generally been much more successful in predicting invasion success than in predicting impact magnitude. Moreover, impact magnitude has been found to be independent of invasion success (Ricciardi and Cohen 2007).

Similar to the ‘invasive elsewhere’ strategy of predicting invasion (Gordon et al. 2010), is the use of records of ‘impact elsewhere’ to quantify the potential impacts of alien species (Kumschick et al. 2015, Ricciardi 2003). This approach can be useful in predicting the impacts of species such as grasses with biased impact records, i.e. uneven research effort across their introduced ranges. This is because it allows species with limited information to be assessed, compared against other species, and be included in management strategies. Furthermore, the approach also facilitates the search for patterns related to the impact mechanisms and magnitudes, which can ultimately lead to a more predictive understanding of invasions.

Here I assess the environmental and socio-economic impacts of selected alien grasses occurring in South Africa by consolidating their impact records across their introduced ranges (e.g. see Kumschick et al. 2015 for examples of this for alien plants and animals in Europe, and Measey et al. 2016 for amphibians). I do this with the aim of providing quantitative estimates in order to determine which alien grasses have the greatest impacts, and to therefore assist decision makers when prioritising which alien grasses to manage. Furthermore, in order to improve the understanding of the likely impacts, I assess which factors contribute to an increased magnitude of impact in alien grasses by investigating habitats impacted by the species across different regions and determining the mechanisms through which impacts occur.

2.2 Methods

2.2.1 Species selection

There are approximately 256 alien grasses introduced into South Africa (Visser et al. 2017). Of these, I assessed impacts for the 58 species that occur as aliens in at least one of the other following regions: Australia, Chile, Europe or the USA. I adopted this approach because: (i) there is a limited number of studies of grass impacts in South Africa; (ii) these regions have a relatively large literature on alien grasses; and (iii) the regions are assumed to be representative of different major biogeographical realms across the world (Visser et al. 2016).

2.2.2 Literature search

Between May 2014 and June 2016 I searched for relevant literature on the impacts caused by the selected alien grasses using the Web of Science, Google Scholar, as well as biological invasion websites and databases such as Centre for Agriculture and Biosciences International (CABI) Invasive Species Compendium (www.cabi.org/isc), Invasive Species Specialist Group (ISSG) Global Invasive Species Database (www.iucngisd.org/gisd), Hawaiian Ecosystems at Risk project (HEAR) (www.hear.org), California Invasive Plant Council Inventory (www.cal-ipc.org). The grass species' scientific binomial names were used as search terms. I used synonyms and previous species names obtained from the Integrated Taxonomic Information System (ITIS) (www.itis.gov) as search terms for species with no literature record. I then selected relevant publications from the search results based on the titles and abstract content.

I used primary literature when possible, otherwise, I referred to the literature's reference list to acquire the cited literature, and the full reference to the cited literature was searched in Google Scholar. If I was still unable to access the primary literature, I noted this and recorded the primary literature as it is cited by the secondary source.

A total of 1300 published sources including >100 websites and databases were reviewed; 352 published references and 98 websites and databases were considered for the impact assessment (Appendix A). References that recorded alien grasses causing high magnitude impacts are listed in Appendix Table S1.

2.2.3 Impact scoring

Different methods have been developed to quantify the environmental and socio-economic impacts of alien species, with recent notable schemes including the Environmental Impact Classification for Alien Taxa (EICAT) (Hawkins et al. 2015) and the Socio-Economic Impact Classification for Alien Taxa (SEICAT) (Bacher et al. 2018). In this study, however, I chose to use the Generic Impact Scoring System (GISS) (Nentwig et al. 2016) (see Hagen & Kumschick 2018 for a comparison of the EICAT, SEICAT, and GISS schemes) as the GISS has been used widely to assess impacts of different species, and I wanted to relate the results with other previous assessments. The GISS classifies impacts into two major classes, namely (1) environmental and (2) socio-economic, with six impact mechanisms assigned for each impact class: (1.1) impacts on native plants or vegetation through mechanisms other than competition; (1.2) impacts on animals through predation, parasitism, or intoxication; (1.3) impacts on native species through competition; (1.4) impacts through transmission of diseases or parasites to native species; (1.5) impacts through hybridisation; (1.6) impacts on ecosystems (which includes changes in nutrient pools and fluxes, habitat modifications and changes in disturbance regimes); (2.1) impacts on agricultural production; (2.2) animal production; (2.3) forestry production; (2.4) human health; (2.5) human infrastructure and administration; and (2.6) human social life (Nentwig et al. 2016). For each impact mechanism a six-point ranked scale is used ranging from zero (no impact detectable) to five (highest impact possible at a site) (Kumschick et al. 2015). The GISS contains definitions and descriptions for the impact mechanisms and the impact scores within them. I assigned an impact mechanism and score to every recorded impact obtained according to the definitions and descriptions of the GISS. Scores can be summed over mechanisms to get a total score per species, with a potential overall maximum impact score of 60 (12 categories * a maximum impact score of 5 in each impact category) (see details on the scoring system in Kumschick et al. 2015, Nentwig et al. 2016). In this study, I used the maximum impact score recorded per mechanism of each species for both environmental and socio-economic impacts to rank species (see Table 2.1). This method of aggregating only the maximum impacts per species per mechanism was used by Kumschick et al. (2015), I also adopted it in order to make the results comparable.

Because scores are based on published research, species that receive more research attention might be expected to have higher scores (Pyšek et al. 2008). Therefore, I tested the relationship between the species' overall impact scores and the number of published papers used per species using a Pearson correlation test. I also tested whether there is a correlation between the species' overall and maximum impact score in any impact mechanism using a Kendall's tau correlation test.

2.2.4 Impacts across habitat types and regions.

For each impact reference, I recorded the habitats where the impacts were said to occur, using the habitats classified according to the first level of the International Union for the Conservation of Nature (IUCN) Red List Habitat Classification Scheme (Version 3.1) (www.iucnredlist.org). In cases where the study was not in a natural habitat (e.g. greenhouse or laboratory) or the habitat was not stated, I recorded the habitat as 'not specified'.

I also noted the country where the impacts occurred for each impact recorded and determined whether the grass species was native or alien in that specific country. Impact records from the native range were excluded from further analyses. I did, however, retain cases where the country was not specified but the grass species was referred to as "alien", "introduced", or "non-native". I assigned each record to one of eight regions based on the location of the country in which the impacts were recorded. I used a Kendall's tau test to determine the correlation between the maximum impact of alien grasses in South Africa and the maximum impact elsewhere.

2.2.5 Statistical analysis

In contrast to the approach taken above to rank species, when testing the relationship between impact and habitats and region, I used the raw data on impact scores (i.e. each impact record was considered as a separate datum). The impact scores analysed here are therefore an ordinal variable in which the scores are ordered (but which closely resembles a logarithmic scale). As such I used a cumulative link mixed-effects model in the R package 'ordinal' (Christensen 2015) to test whether habitats and regions influence impact magnitude.

Since I found multiple studies that assess the same impacts for the same species in the same region or habitat, I included species identity, as well as mechanism nested in impact type (environmental or socio-economic) as random factors and impact mechanism, habitat type, and region as fixed effects. I also tested a model in which mechanism nested within impact type was included as a fixed effect but found this made no difference to the results. I did not investigate interactions among predictors because of the limited number of observations. To determine the goodness of fit for the model I calculated pseudo R2 by fitting a null model with no predictor variables and compared it against the full model using the 'nagelkerke' function within the R package 'rcompanion' (Mangiafico 2016). I tested the significance of fixed effects using analysis of deviance of single-term deletion models tested against the full model using a chi-squared distribution from the 'drop1' command. I used least-squares means with P values adjusted using the Tukey method, to determine significant differences between the levels of each predictor (mechanism, habitat and region).

All statistical analyses were performed using R version 3.4.4 (R Core Team, 2018).

2.3 Results

2.3.1 Grasses ranked by impact

Of the 58 alien grasses selected for impact assessment, I found records of impact for 48 species, i.e. 10 species (Table S1) were data deficient with no record of impact. The species with the highest summed impact score was *Cortaderia selloana* (impact magnitude = 18), followed by *Arundo donax, Avena fatua, Elymus repens,* and *Festuca arundinacea* (all with impacts of 17, Table 2.1). However, a different set of species scored the maximum possible impact of five on any one particular impact mechanism, namely, *Glyceria maxima* (animal production), *Nassella trichotoma* (animal production), *Phalaris aquatica* (predation or parasitism or intoxication and animal production), *Polypogon monspeliensis* (animal production), and *Sorghum halepense* (agricultural production) (see Table S1).

Table 2.1: Grasses alien to South Africa and one other region (Chile, Europe, Australia and the USA) ranked according to impacts. The numbers under environmental and socio-economic impacts are the respective sum of the maximum impact scores per impact mechanism of a species. Species that score a maximum of 5 in any one impact mechanisms are highlighted in bold. NA indicates that no impact found on that species, hence not applicable. Total impact represents the overall sum of the environmental and socio-economic impacts. Species marked with an asterisk* have impacts recorded in South Africa. Literature used and detailed maximum scores per mechanism are available in the Supporting Information (Appendix S1 and Table S1).

Species name	Environmental impacts	Socio-economic impacts	Total impact
*Cortaderia selloana**	7	11	18
*Arundo donax**	10	7	17
*Avena fatua**	10	7	17
*Elymus repens**	10	7	17
Festuca arundinacea	8	9	17
Nassella trichotoma*	6	9	15
Sorghum halepense*	6	8	14
Bambusa vulgaris	8	5	13
*Bromus tectorum**	7	8	13
Cortaderia jubata	7	8	13
Paspalum notatum	3	10	13
*Bromus rubens**	9	3	12

Species name	Environmental impacts	Socio-economic impacts	Total impact
Glyceria maxima***	4	8	12
Brachypodium distachyon	9	2	11
Vulpia myuros	2	9	11
Holcus lanatus	7	3	10
*Hordeum murinum**	7	3	10
Paspalum dilatatum	2	8	10
Phalaris aquatica	5	5	10
*Agrostis stolonifera**	6	3	9
Arrhenatherum elatius	5	4	9
Bromus rigidus	2	7	9
Dactylis glomerate	3	6	9
Hordeum jubatum	4	5	9
*Poa annua**	5	4	9
Polypogon monspeliensis	2	7	9
Vulpia bromoides	5	4	9
Bromus madritensis	5	3	8
Lolium multiflorum	4	4	8
Aira caryophyllea	4	3	7
Avena barbata	6	1	7
*Bromus catharticus**	6	1	7
Lolium perenne	2	5	7
Poa pratensis	5	2	7
Briza maxima	6	NA	6
Bromus diandrus	NA	6	6
Digitaria sanguinalis	3	3	6
Lolium temulentum	2	4	6
Paspalum urvillei	4	2	6
*Pennisetum setaceum**	5	1	6
Cenchrus spinifex	2	2	4
Cynosurus echinatus	4	NA	4

Species name	**Environmental impacts**	**Socio-economic impacts**	**Total impact**
Paspalum quadrifarium[*]	3	1	4
Avena sterilis	NA	3	3
Bromus hordeaceus	3	NA	3
Oryza sativa	2	NA	2
Panicum miliaceum	NA	2	2
Pennisetum villosum[*]	1	1	2

I used a total of 352 published literature sources, however, the literature was highly skewed, ranging from one to 23 publications per species. Some literature sources reported on more than one species. I found a significant positive correlation ($\rho = 0.48$, $P = 0.006$) between the overall impact scores per species and the number of publications used to score the impacts. However, this potentially only affects the relative rankings of species according to impact scores (Table 2.1), because for the mixed effect model analyses, I did not aggregate maximum records of the species and used each paper as separate records.

2.3.2 Impact magnitudes across mechanisms

I found that three-quarters (36 out of 48) of alien grass species have records of causing environmental impacts through competition with native species, and half (24 out of 48) of species have records of causing impacts on ecosystems (Figure 2.1). I found the fewest records and the lowest overall impact through the ‘plants or vegetation’ mechanism, which according to the GISS includes allelopathy or the release of plant exudates (Nentwig et al. 2016). Most socio-economic impacts are caused through agricultural and animal production, with 29 and 26 cases respectively, while forestry production was represented by few species (Figure 2.1). The maximum impact possible (5), was recorded for impacts on animals through predation or parasitism, animal production and agricultural production. When comparing scores between impact types, greater impact magnitudes of 4 and 5 were obtained for socio-economic than environmental impacts.

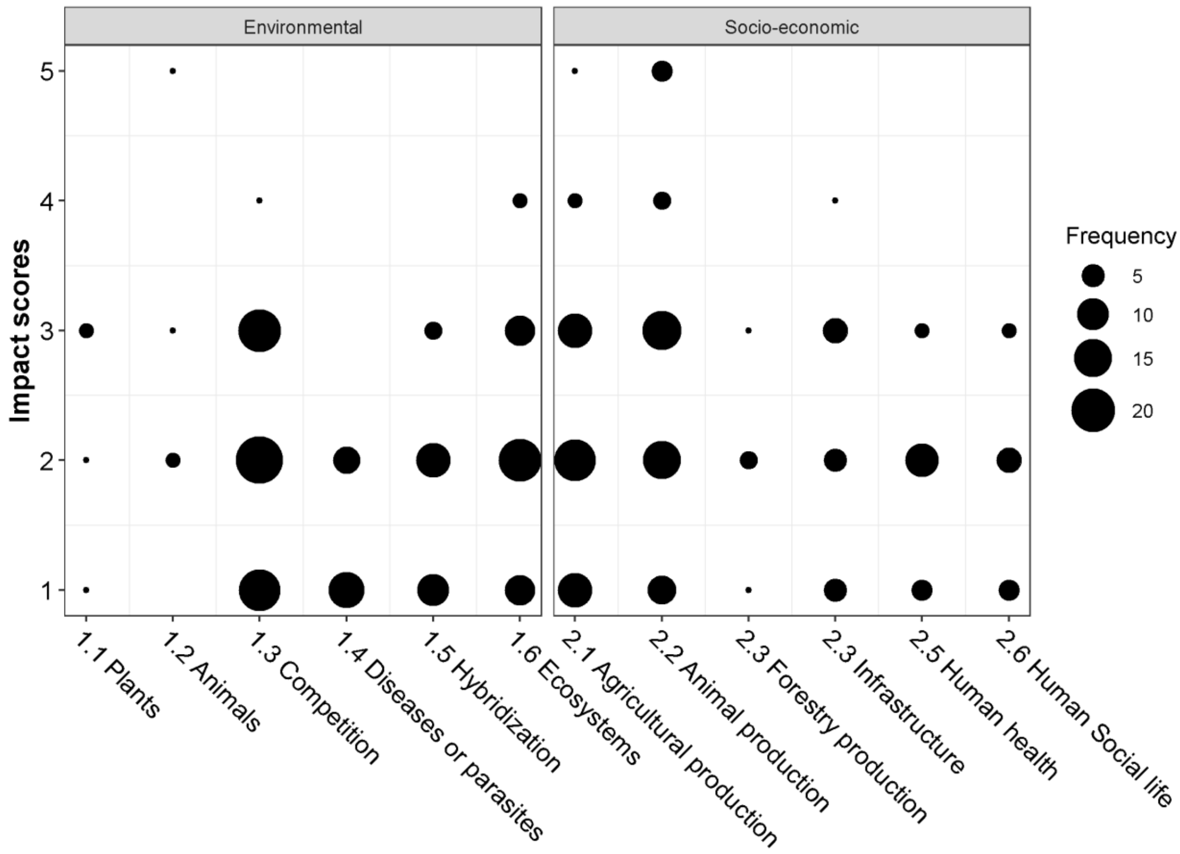

Figure 2.1: Number of alien grass species per impact mechanism for each impact magnitude. On the x-axes are the GISS environmental and socio-economic impact mechanisms, and on the y-axes are the impact scores according to GISS. The size of the points represents the number of species which had the corresponding maximum recorded impact score for that mechanism (out of the 48 species with impact records).

2.3.3 The effects of impact mechanisms, impacted regions, and habitat types on impact magnitude

I found that impact mechanism is the only statistically significant predictor of impact magnitude ($P < 0.001$, Table 2.2). Results from the model show that alien grasses cause lower impact magnitude through the transmission of diseases or parasites to native species and greater impacts on native animals through food availability or palatability and intoxication (Figure 2.2).

There is a trend towards a greater impact magnitude in Antarctica (Figure S1), however, differences across regions are not significant (P = 0.057, Table 2.2). I found nine habitats impacted by alien grasses, however, just like regions habitat type was also not a significant predictor of variation in impact magnitude (P = 0.49, Table 2.2), and differences among the habitats were not statistically significant (Figure S2).

Including mechanism nested within impact type (environmental or socio-economic) as a random effect provided no improvement in model fit (Table S2). However, I kept this nested random effect in the analysis because it accounts and corrects for non-independence of the observations and reflects the actual design of this study.

Table 2.2: Cumulative link mixed effects model estimating the effect of habitat, region and impact mechanism on overall impact magnitude of the studied alien grasses (m1). The significance of predictor variables was determined using single-term (predictor) deletion models tested against the full model. Models were run with species identity, and mechanism nested within mechanism type (environmental or socio-economic) as random factors. AIC is the Alkaike's Information Criterion, and P is the chi-squared p-value.

Model	**Df**	**AIC**	**P**
m1		2203.4	
Habitats	9	2193.8	0.49
Regions	8	2202.5	0.05
Mechanism	11	2219.3	< 0.001

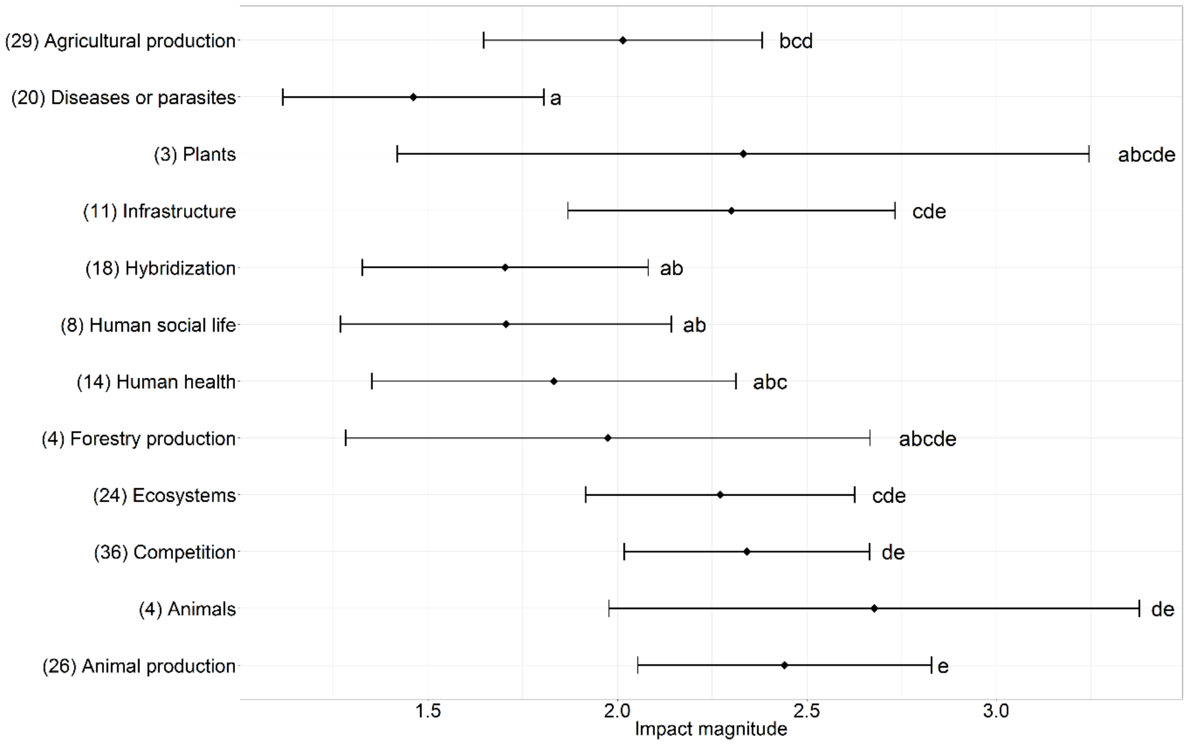

Figure 2.2: The impact magnitude of the 48 studied alien grasses across different impact mechanisms. On the x-axis are the least-squares means of the impact scores as derived from a cumulative link mixed effects model, and on the y-axis are the GISS impact mechanisms with the number of species in brackets. The points represent the impact magnitudes and the error bars represent 95% confidence intervals. Letters on the right side of the confidence intervals are level groupings indicating significant differences among the mechanisms (level groupings with the same letters are not significantly different, comparisons are Tukey adjusted).

2.3.4 Impact of alien grasses in South Africa versus elsewhere

I found that only 16 of the 58 alien grasses had recorded impacts in South Africa, 13 for inland and three for the offshore islands (Table 2.1). These impacts were mostly lower than elsewhere, with the exception of *Nassella trichotoma* and *Hordeum murinum* (Figure 2.3). However, there is no correlation ($\tau = 0.14$, $P = 0.28$) between impacts of alien grasses in South Africa and those recorded elsewhere in the world.

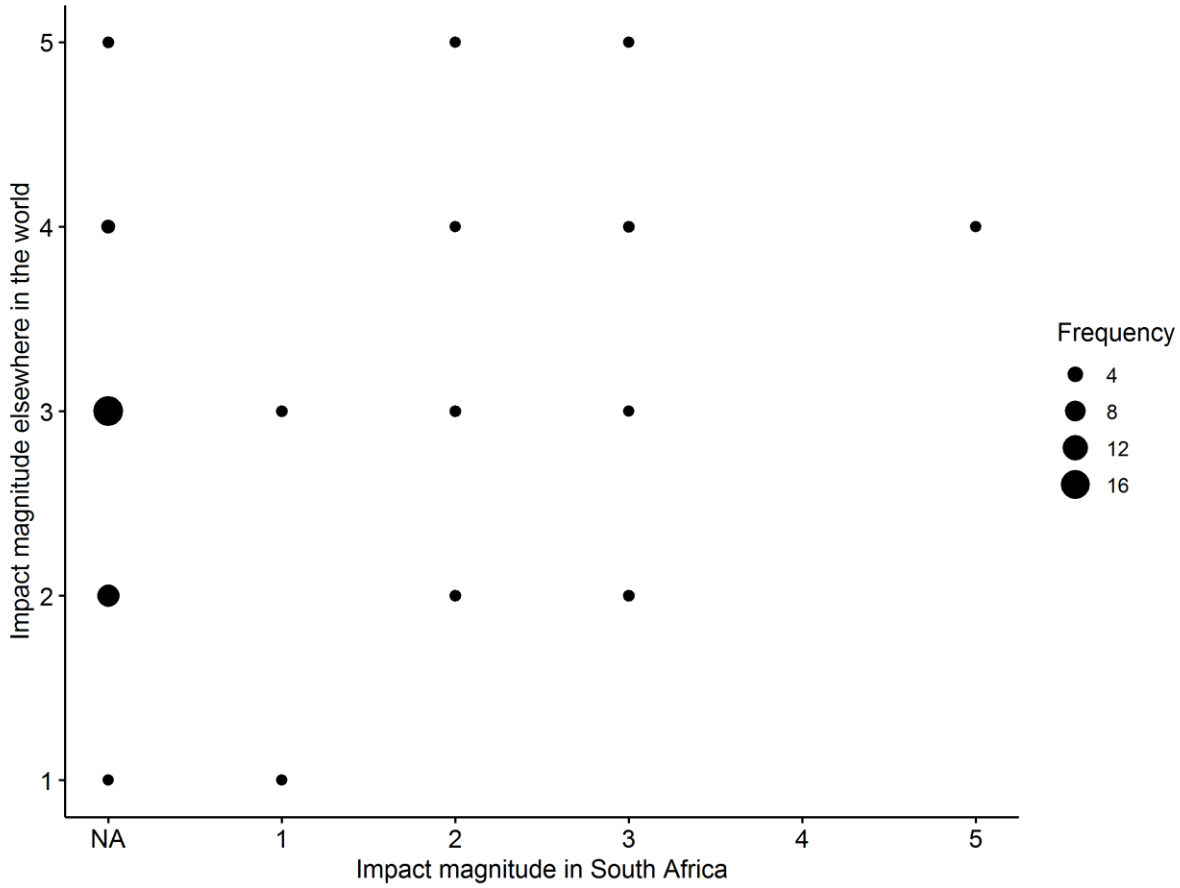

Figure 2.3: Comparison between impact magnitude of alien grasses in South Africa and elsewhere in the world. The values 1 to 5 on the x and y-axis represent the GISS impact magnitudes and NA indicates that no impact record found. The size of the points represents the frequency of species with impacts records.

2.4 Discussion

This study is the first environmental and socio-economic impact assessment to focus specifically on alien grasses. Using the GISS, I was able to quantify their impacts using information from across the globe. This study, therefore, provides a useful overview of the literature on evidence-based impacts of alien grasses and highlights potential risks to South Africa. Furthermore, it shows gaps in the available literature as some species could not be assessed due to a lack of impact studies.

I found that alien grasses generally scored higher for socio-economic than environmental impacts. Grass impact scores were particularly high for agricultural and animal production. This might reflect the large number of agricultural weeds that are grasses (Daehler 1998) or their initial introduction for agricultural purposes (Hancock 2012). Alien grasses scored the lowest for impacts caused via transmission of diseases or parasites to native species, with a maximum score of 2, which represents a minor impact (Nentwig et al. 2016), while the frequency under this mechanism was larger. On the contrary, mechanisms with scarce literature such as impacts on native animals have obtained higher impact scores. This could be because impacts through the transmission of disease or parasite between plant species is not readily observed in the wild, most of the literature under this mechanism are small scale laboratory studies which do not report impacts on the overall population.

Despite most grasses not having very high overall impact scores compared to other species (e.g., Kumschick et al. 2015), many alien grasses scored high across the full range of impact mechanisms (i.e. alien grasses can cause a wide range of environmental and socio-economic impacts) and so had high total impact scores. For example, *Cortaderia selloana* did not have any individual mechanism score over 3 but has the highest overall score (Table 2.1) due to the many different mechanisms through which it causes impacts. In contrast, *Polypogon monspeliensis* and *Phalaris aquatica* scored the highest impact (5) on certain impact mechanisms, but their overall score is lower. This trend is not observed in other studies such as the one conducted on alien aquatics by Laverty et al. (2015), where the species with the highest overall score also obtained an impact score of 5 for two different mechanisms. Grasses thus provide an interesting case to explore whether we should be more concerned with invasive species that cause a range of different types of impacts or invasive species that only cause a few types of impacts but with greater magnitude.

Grasses are one of the most cosmopolitan plant families in the world and are present in almost all terrestrial habitats. They also impact a wide range of habitats, as demonstrated in this study. Knowledge about which habitats are most severely impacted by alien grasses is essential for their management. Grasses can cause rapid and dramatic transformation of non-grassy habitats into grass-dominated communities. For example, *Bromus rubens* and *B. madritensis* have caused widespread transformation of shrubby systems in the Mojave Desert (DeFalco et al. 2007, Jurand et al. 2013). With regards to regions, I found that Antarctica (sub-

Antarctic islands mostly) on average has the highest alien grass impact scores. Grasses such as *Agrostis stolonifera* reduce moss diversity, liverwort populations, and replace the rosaceous dwarf shrub (*Acaena magellanica*) with dense grassland patches on Marion Island (Gremmen et al. 1998). It is not clear, however, whether this trend is due to differences in sampling effort or a greater susceptibility of islands to impacts than the mainland (Hagen and Kumschick 2018).

However, neither habitat nor region were found to be significant predictors of impact magnitude. This could suggest that the impacts are the same across habitats and regions, but the lack of signal likely also reflects the low sample sizes for most habitat types and some regions. Furthermore, it will be interesting to repeat the study based on a more representative global sample of species (the bias in this current analysis towards grasses alien to South Africa was simply for applied reasons).

When I compare impacts scores of alien grasses with impact scores of studies that assessed other plant taxa (Kumschick et al. 2015, Rumlerová et al. 2016), the results also show that the competition with native plant species is the most frequent mechanism through which alien grasses cause impacts. Four species from the ranking list were previously assessed in those studies (Kumschick et al. 2015, Rumlerová et al. 2016), and my results were similar to them for two of the species (*Arundo donax* and *Paspalum dilatatum*), each with a difference of less than 5 between the overall impact scores. However, I obtained higher overall impacts than Kumschick et al. (2015) and Rumlerová et al. (2016) for the other two species (*Cortaderia selloana* and *Hordeum jubatum*), each with a difference of 9 and 8 respectively. These differences can be explained by the broader search criteria applied, for example authors of the above-mentioned studies used keywords such as ‘‘invas* or exot* or weed*’’ in addition to the species name, while I only used the species name as a search term.

Although impacts of alien grasses are poorly studied when compared to other species such as birds and mammals, I was able to find impact records for more than 80% of the grass species selected for the assessment which is higher than for other species such as amphibians (41.3%) (Measey et al. 2016). The average number of papers (5.7) used to score impacts of alien grasses across the globe was also higher than the amphibians and other species (Kumschick et al. 2015, Measey et al. 2016). Similar to the mammals and other plants (Kumschick and Nentwig 2010, Kumschick et al. 2015), alien grasses were also reported to cause impact across all impact mechanisms. This might be because grasses occur across a wide range of sectors and habitats, which allows them to exert impact across all mechanisms. When prioritising management of all alien species, the ranking list can be compared to other assessments conducted for other species such as birds, amphibians, mammals, and aquatic species (Kumschick and Nentwig 2010, Laverty et al. 2015, Measey et al. 2016, Nentwig et al. 2010). However, it is important to note that impact assessments of some of those species are based on impacts recorded only in Europe and not globally, which may cause a bias to the overall impact scores. More impact studies are still needed for alien grass species, especially when it comes to species with no impact records across all introduced ranges but with taxonomic characteristics of invaders (such as *Bambusa balcooa*, Canavan et al. 2016). It will be interesting to see if the findings of Canavan et al. (2018a) that bamboos have similar impacts in their native and alien ranges are the same for other grasses or perhaps only other tall-statured grasses (Canavan et al. 2018b). However, I suspect there are qualitative differences between the impacts in the native and alien ranges for the grasses studied here, as the impacts observed are not primarily a response to human disturbance.

Two species were scored as causing very high impacts (4 or 5) outside of South Africa, but only low levels of impact (1 or 2) in South Africa. For instance, *Glyceria maxima* obtained a score of 5 because it is associated with the death of livestock through poisoning in Australia (Barton et al. 1983), but such impacts have not (yet) been recorded in South Africa. This can flag species that could potentially cause high impacts in South Africa and which should therefore be monitored, or preventative measures put in place to limit such impacts occurring in future. In most other cases the impact elsewhere was either the same or slightly higher than that recorded in South Africa, except for *Agrostis stolonifera, Hordeum murinum,* and *Nassella trichotoma* This included two species (*Nassella trichotoma* and *Hordeum murinum*) whose impacts in South Africa were one level higher than elsewhere. For example, *Nassella trichotoma* obtained a score of 5 in South Africa and 4 elsewhere (in Australia) for impacts on animal production by reducing livestock carrying capacity and pasture production (Klepeis et al. 2009). The lack of correlation between impacts found in South Africa and elsewhere should, however, be taken with caution. It is indicative of a research gap. Records of impacts are generally fewer in South Africa (with a maximum of five sources per species and an average of 1.9) and even lacking for most species. Alternatively, it could indicate that there is an impact debt (Rouget et al. 2016), i.e. species have not reached their full impact potential in South Africa (yet), as species with more information in South Africa did not show higher similarities in impact magnitudes to elsewhere. Finally, South Africa might be more resilient to grass invasions and impacts are actually lower here (Visser et al. 2017). These hypotheses warrant more research and can only be disentangled once more data become available.

2.5 Conclusion

In summary, the lack of statistically significant differences in impact magnitudes across habitats and regions for alien grasses suggests that impact in this group is not habitat or region specific as in other groups (cf. Hulme et al. 2013, Pyšek et al. 2011). As such I recommend that different habitats should be equally considered for alien grass impact management. While I recommend that impact scoring schemes such as the one used in this study should be incorporated in the decision-making processes for alien species management, I caution that these schemes indicate potential and not actual impacts.

Chapter 3 : Risk analysis of *Paspalum* species in South Africa, with a field assessment of the impacts caused by *P. quadrifarium*

Declaration: this chapter is intended for submission to the journal *ABC Bothalia*

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Contributions of each author:

KVN, VV, JRUW & SK: Planned and discussed the study design

KVN: Conducted the risk analyses, collected field data, led the writing

MDC: Provided taxonomic assistance during the field study

VV & KVN: Statistical analysis and species distribution modelling

SK, VV, & JRUW: Provided guidance, comments and edited the manuscript

Abstract

Grasses have been reported to cause impacts such as altering habitats and community structures in areas where they have been introduced. However, in South Africa, such impacts have not been frequently recorded. Here, I analysed the risk posed by six alien *Paspalum* species to the biodiversity of South Africa. A framework recently developed for the regulation of alien species to South Africa was used to conduct the analyses. The potential distributions of the alien *Paspalum* species were determined through species distribution modelling. The risk analyses indicated that three species (*P. quadrifarium, P. dilatatum,* and *P. notatum*) were high-risk species with medium management feasibility, while the others were of low risk. Three species (*P. quadrifarium, P. dilatatum,* and *P. urvillei)* had large relative occurrence rate in South Africa. I then looked for evidence of risk on the ground by studying the impact of *P. quadrifarium* in invaded, cleared, and uninvaded sites. The field study showed that *P. quadrifarium* decreased the abundance of other plant species and changed the composition of the invaded community. In cleared sites, species richness was similar to the uninvaded sites. However, cleared areas had more alien species, which indicates secondary invasion. These results are relevant for the management and prioritisation of alien grasses in South Africa, particularly *Paspalum* species.

Keywords: Risk analysis, relative occurrence rate, invasion status, *Paspalum quadrifarium*, species cover, species abundance

3.1 Introduction

Alien grasses have shown to be amongst the most damaging species in the world, transforming natural ecosystems (D'Antonio and Vitousek 1992). In places such as Australia, the USA and Hawaii, alien grasses change fire regimes and cause habitat loss for native animals (D'Antonio and Vitousek 1992, Brooks et al. 2004, Gaertner et al. 2014). When compared to those areas, South Africa has few records of widespread negative impacts due to invasive grasses. This might be because South Africa has fewer invasive grasses, or that the invasions are more recent, so the impacts have not accrued yet, that there is something fundamentally different about South Africa that limits invasions and/or their impact (Visser et al. 2016), or simply that the impacts have not yet been studied. There are several papers reporting on impacts of alien grasses in South Africa, however, these studies only briefly mention impacts and do not go into details in a structured method (Milton 2004, Musil et al. 2005, Parker-Allie et al. 2009, Rahlao et al. 2009, 2014, Sharma et al. 2010). Some South African ecosystems (grasslands and savanna) might, by their nature, be more resistant to grass invasions (Visser et al. 2016). Nevertheless, rising CO_2 levels and increasing temperatures associated with human-induced global climate change may provide competitive advantages to certain alien grasses (Milton 2004, Visser et al. 2017). It would be beneficial for South Africa to formulate and put in place a management plan for mitigating against these anticipated threats.

Reviews of alien grasses by Milton (2004) and Visser et al. (2017), have generated: (i) an inventory of grasses previously introduced in the country (256 species); (ii) knowledge on their pathways of intentional introduction; (iii) their current status based on the introduction-naturalisation-invasion-continuum by Blackburn et al. (2011); (iv) current distribution of some grass species; and (v) areas most impacted by alien grasses. This information is fundamental for the formulation of management plans and can be used to monitor the change in the invasion status of a species. However, for most alien grasses we still have poor knowledge of their abundances and there are no reports of successful alien grass eradications. We also have a paucity of knowledge on the actual environmental and socio-economic impacts, especially for species which are not widespread. This knowledge is important as it can be used to inform and alert conservation managers with regards to the species' impacts.

In South Africa, there are regulatory lists used in the prioritisation of alien species. To know which species to regulate we need to know what their risks are and if they threaten native biodiversity and the economy of the country. One solution of undertaking transparent decision making for management prioritisation is the use of risk analysis to formally collate scientific evidence. Risk analysis is a cost-effective way to approach alien species prioritisation as it collates scientific evidence necessary for the successful management of an alien species (Keller and Kumschick, 2017). It also takes into account the benefits obtained from the alien species to ensure sustainable management. This approach can be important for South Africa as it can assist the country to conform to international standards for the management of alien species (Keller and Perrings 2011).

To address the use of risk analysis for the prioritisation of alien grasses, I analyse one group of alien grasses occurring in South Africa. I selected the genus *Paspalum* (family: Poaceae, subfamily: Panicoideae, tribe: Paniceae) for this study because it contains species with different invasion status in the country. Also, *Paspalum* species generally have a broad native range, and some are found to be noxious weeds even in their native range (Panario and Bidegain 1997), which means they are likely to be successful and invasive outside of their native ranges (Goodwin et al. 1999). The genus includes around 400 species, mostly native to tropical and subtropical regions of the Americas (Adamowski et al. 2005, Martelotto et al. 2007, Speranza 2009). Nine *Paspalum* species have been recorded in South Africa, of which three are native (*P. scrobiculatum, P. distichum,* and *P. vaginatum*). In this study, I focus on alien *Paspalum* species with the aim to:

I. investigate the status of the six *Paspalum* species recorded as alien in South Africa based on the currently available knowledge;
II. determine the potential extent of invasions using species distribution modelling;
III. provide recommendations for regulation based on the risk analysis framework of alien taxa; and
IV. investigate the impacts of one species, *P. quadrifarium,* on native plant abundance and diversity.

3.2 Methods and materials

3.2.1 Species selection

Six alien *Paspalum* species are alien to South Africa and were selected for this study, namely *Paspalum dilatatum, P. notatum, P. nutans*, *P. quadrifarium, P. urvillei,* and *P. virgatum*. This group (*Paspalum* genus) was selected because it contains species with different distribution ranges, occurs in a variety of habitats, has a variety of benefits and seems to have species in varying stages of invasion status in South Africa (see Table 3.1).

3.2.2 Risk analysis framework

A framework developed to support the listing of alien taxa in South Africa was used to determine the risk posed by alien *Paspalum* species (Kumschick et al. 2018). The framework was developed as a tool to transparently provide scientific evidence for the listing of alien species under national regulations. It is divided into three main sections: risk assessment, risk management and risk communication. The risk assessment is formed by two main components which are (1) the likelihood and (2) the potential negative impacts posed by the alien species. The risk management part of the analysis looks at traits of the taxon which would make management inherently more difficult, as well as consider the species' benefits in order to assess potential conflicts and oppositions to management. Risk communications deals with communicating the finding of the risk assessment and the risk management to the relevant parties such as policymakers and it clarifies the circumstances of the analysis in the background section (see also Appendix 2).

3.2.3 Species distribution modelling

3.2.3.1 Occurrence data

The Global Biodiversity Information Facility (GBIF; www.gbif.org/species) and the Southern African Plant Invaders Atlas (SAPIA) database (both accessed January 2017) were used to obtain occurrence records of the six alien *Paspalum* species. The data were cleaned, and the potential distributions of the species were predicted using Maxent within R version 3.4.4 (R Core Team, 2018), and both the alien and native ranges of the *Paspalum* species were used to model the distributions.

3.2.3.2 Environmental variables

Climate variables were obtained from the WorldClim climate data (v. 2.0) at 10' spatial resolution (http://worldclim.org). I used five bioclimatic variables: annual mean temperature, temperature seasonality, annual precipitation, precipitation of driest month, and precipitation seasonality. I then used ENMTools in R to check collinearity between the climatic variables and a matrix format was used to identify correlated environmental variables (Figure S3). I also used a road density raster from ArcGIS (www.arcgis.com), and the population density data from the Socioeconomic Data and Applications Centre (SEDAC) archive (v. 4.10, http://sedac.ciesin.columbia.edu) both at 5' spatial resolution.

3.2.3.3 Species distribution modelling

The potential distributions, which is the relative occurrence rate (ROR) of *Paspalum* species, was predicted using maximum entropy modelling (MaxEnt) within R (Phillips et al. 2006). ROR of the species was measured across South Africa to determine its suitable range. Informative offsets which provide additional biological information (e.g the native range and other introduced range) and nuisance offsets that account for the sampling bias were used to model the species distribution as suggested by Merow et al. (2016)**.** The informative offsets were spatially incorporated into the MaxEnt model to provide a matrix of weight for all possible background points. The background points were then randomly selected by MaxEnt and were each assigned a bias weight (Merow et al. 2016), and were then modelled across the entire possible range (native and alien) as informative offsets using the selected climatic variables. The nuisance offsets were also modelled across all the ranges to account for the sampling bias using a model of target group sampling predicted by the population density and the road density in order to infer sampling probability where the target group is absent. Finally, to produce a modelled distribution for South Africa, I combined the informative offsets model and the nuisance offsets model to create a sampling intensity model which was then projected (cropped) to South African borders.

3.2.3.4 Model performance

Occurrence data for both the background and target group models were randomly split into two (50 % each) subsets in order to assess the ability of the models to predict the potential distribution of each *Paspalum* species. The random splitting was replicated five times, and the mean between the replicates was used to determine the area under the curve (AUC), omission rate and to predict the potential distribution. The performance of the models was evaluated by examining the area under the receiver operating curve (ROC) for each *Paspalum* species. I interpreted the AUC either as excellent (> 0.9), good (0.8–0.9), fair (0.7–0.8), poor (0.6–0.7) or failed (0.5–0.6) according to Swets (1988). The importance of the environmental variables and their relationship with the species' potential distribution was also assessed and determined using the shapes of the marginal response curves and the permutation importance.

3.2.4 Environmental impact case study

3.2.4.1 Case study species

P. quadrifarium (commonly known as tussock paspalum or evergreen paspalum) was selected for the impact case study for the following reasons: (1) it is expected to affect the community where it occurs due to its large stature; (2) it has been found invading a natural ecosystem; (3) it currently has a very limited distribution range in South Africa; but (4) it grows along a stream which connects to a larger body of water making it easy for the species to spread. *P. quadrifarium* originates from South America and is considered as a weed in parts of its native range (Uruguay) (Verloove and Reynders 2007). It was first reported in South Africa in 2003 (Fish et al. 2015). The reason for its introduction into South Africa is unknown and its environmental and socio-economic benefits in the country are also uncertain. *P. quadrifarium* was introduced to other countries such as the USA, Italy, and Australia as a horticultural species (Fish et al.

2015). It is a large bunch grass (1.5 m tall) that can outcompete other plants by forming dense impenetrable stands (Laterra 1997, Picone et al. 2003). It is unpalatable, has low nutritional value and does not provide suitable forage when mature (Juan et al. 2000).

3.2.4.2 Study site

The field study was conducted in the Melmoth area, Mthonjaneni Municipality, Kwa-Zulu Natal, South Africa (S28° 34.784' E31° 14.504'). The area receives 800-1150 mm of rainfall per annum and has frequent mist during summer and frost in the winter season (Bezuidenhout and Singels 2007). The area is part of the Northern Midlands Moist Mistbelt Grasslands with an elevation of 800 m above sea-level (Scott Shaw and Escott 2011). The study area is dominated by agricultural land and timber forests. It also has pockets of natural grasslands, and the grasslands are home to threated plants and wildlife such as the rare *Helichrysum woodii*, *Myosorex sclateri, Chrysospalax villosus*, *Tyto capensis*, and the critically endangered *Anhydrophryne ngongoniensis*, among others (Matthews et al. 1999, Armstrong 2001, Perera et al. 2011, Ansara-Ross et al. 2013, Rampartab and Chanel 2016).

3.2.4.3 Experimental design

Field sampling was carried out in September 2017 during the flowering season of most vascular plants in that area. Three treatments were selected in order to compare the differences in abundance of the plant species between the sites. The first treatment was the invaded area, which is a site where *P. quadrifarium* is currently present and at high density. The second treatment was the area where the species had invaded previously and has been removed by a clearing team of the South African National Biodiversity Institute (Wilson et al. 2013). This treatment represented the possible plant community after removal of *P. quadrifarium*. The last treatment was a nearby environmentally suitable area for *Paspalum quadrifarium* to grow, but not (yet) invaded, which was intended as a control site representing the plant community before the invasion by *P. quadrifarium*.

For each treatment location, I estimated the percentage cover of each species in selected quadrats. Since *P. quadrifarium* is a large tuft grass, and one adult individual can cover a 1x1 m quadrat, I used 3x3 m quadrats because they were large enough to accommodate its spatial structure and several other species. For each treatment, 35 quadrats were established (105 in total) in a random manner by using a random number table, a compass and a hand watch. I used a compass of a GPS to determine where north is and used that direction as 12 o'clock on a watch. To establish a quadrat, I took two numbers (from 1 to 10) in the random number table, the first number was to determine which direction to walk on the clock, and the second number was the number of metres to walk from the initial point. The abundance of each species within each quadrat was estimated by recording the species and assigning a percentage cover estimate to each of them.

3.2.4.4 Statistical analysis

I used Generalised Linear Latent Variable Models (GLLVMs) (Hui et al. 2015) in R version 3.4.4 (R Core Team, 2018) to determine the impacts of *P. quadrifarium* on plant community composition and abundance. GLLVMs are an extension of standard generalised linear models and allow one to account for latent (unobserved) variables. Latent variables represent the covariation among species' composition and abundance, as well as representing any missing environmental predictors. GLLVMs provide a useful and statistically more rigorous alternative to more traditional ordination methods, such as principal component analysis or non-metric multi-dimensional scaling (Hui et al. 2015, Niku et al. 2017, Warton et al. 2015).

All models were fitted with a negative binomial family because species counts are usually over-dispersed (i.e. there are many zero or large, but few low counts) (Niku et al. 2017). I did not include row effects, because this would have only considered species composition and not abundance too (Niku et al. 2017). As a first step, I fitted an unconstrained model with no covariates other than the estimated latent variables (Hui et al. 2015), I then performed a Dunn-Smyth residual analysis for the null model in order to assess the suitability of using a negative binomial family and whether all variance-explaining variables were included (Dunn and Smyth 1996). I then fitted another model with quadrat invasion status (uninvaded, invaded and cleared) as a covariate (Warton et al. 2015) and checked the fit of the second model with covariates against the pure latent model using the Akaike information criterion (AIC) (Bozdogan 1987).

I used the estimated latent variables to construct an ordination biplot from the unconstrained model to visualise the variation in species composition and patterns across the treatments (Hui et al. 2015). I then used the second model fitted with the invasion status of the quadrat as a covariate to construct an ordination biplot, which shows the covariation in species composition remaining after accounting for invasion status and therefore the effect of *P. quadrifarium* on species composition. An unconstrained and a constrained residual correlation were also constructed to determine the co-occurrences of different species.

3.3 Results

3.3.1 Status of *Paspalum* species in South Africa according to risk analysis

Of the six alien *Paspalum* species which are noted to occur in South Africa (Table 3.1), only four (*P. dilatatum, P. notatum, P. urvillei,* and *P. quadrifarium*) have fairly extensive specimen collections from within South Africa. I found no evidence of presence for *P. nutans* and *P. virgatum* in the country but have found extra-limital specimens in the SANBI Pretoria herbarium collections. Despite the uncertainty regarding the presence of two *Paspalum* species in South Africa, risk analyses were conducted for all alien *Paspalum* species*.* Three of the species (*P. dilatatum, P. notatum* and *P. quadrifarium*) obtained a high-risk score with medium management feasibility (Table 3.1), and the risk analyses recommend for their listing under the 1b category of the NEMBA A&IS Regulations. The other three (*P. urvillei, P. nutans*, and *P. virgatum*) obtained a low-risk score with medium to low management feasibility and are not recommended for listing (see Appendix 2 for the full risk analyses).

Table 3.1: Current and potential status of alien Paspalum species occurring in South Africa – summary of the area occupied, risk analysis and regulation status. The area occupied is shown by the number of quarter degree grid cells in which the species occurs and is proof of presence. The risk analysis indicates the risk assessment and risk management results from which the suggested NEMBA categorisation is based. The regulation status indicates the species' current and suggested NEMBA categorization. Species invasion status is adapted from the introduction-naturalization-invasion (INI) continuum by Blackburn et al. (2011).

Species name	Area occupied (No. of Current QDGCs)	Risk analysis		Regulation status[1]		Invasion status in South Africa[2]
		Risk assessment	Risk management	Current NEMBA category	Suggested NEMBA category	
P. dilatatum	196	High	Medium	Not listed	1b	E
P. notatum	22	High	Medium	Not listed	1b	B2
P. quadrifarium	3	High	Medium	1a	1b/1a	C3
P. nutans	0	Low	Low	Not listed	Do not list	Introduced
P. urvillei	73	Low	Medium	Not listed	Do not list	C3
P. virgatum	0	Low	Low	Not listed	Do not list	Introduced

[1]Regulation status as per the National Environmental Management: Biodiversity Act (NEMBA), 1a: alien species which are invasive, but with small distribution range must be eradicated. Category 1b: Invasive species that must be controlled and are prohibited from trade or planting.

[2]Invasion status in South Africa as per the Unified Framework for Biological Invasions (Blackburn et al. 2011, B2: Introduced species in cultivation, i.e. individuals provided with conditions suitable for them but explicit measures to prevent dispersal are limited at best. C3: Individuals surviving in the wild in location where introduced, reproduction occurring, and population self-sustaining; D1: Self-sustaining population in the wild, with individuals surviving a significant distance from the original point of introduction; E: Fully invasive species, with individuals dispersing, surviving and reproducing at multiple sites across a greater or lesser spectrum of habitats and extent of occurrence.

3.3.2 Potential species distribution modelling

3.3.2.1 Sampling bias model

Correcting for sampling bias was effective in improving the model's accuracy in predicting the ROR of each *Paspalum* species. The sampling bias model obtained an average AUC of 0.758, indicating a fair accuracy of the model (Figure S4). Road density obtained an AUC > 0.75 and population density an AUC of 0.672, both indicating the fair accuracy of the ROR predictions. However, road density contributed the most in this model.

3.3.2.2 Potential distribution of individual species

Paspalum dilatatum

A total of 4076 presence records for all six alien *Paspalum* species were found and *P. dilatatum* had the largest number of occurrence records (n=2052, see Table 3.1). The AUC values of the random and target model were both > 0.9 showing an excellent accuracy in the model's predictions (Table 3.2). The permutation importance value (40.35) and the response curves (Figure S5, Table S3) both indicate that annual mean temperature was the largest contributor in predicting the ROR of *P. dilatatum,* followed by temperature seasonality. In accordance with the response curves, the species distribution model of this species (Figure 3.1), indicates the highest ROR in areas with an annual mean temperature range of between 5 and 26 °C. Therefore, the coastal areas and the northern provinces of South Africa are more likely to experience a high infestation of *P. dilatatum.* Of the six alien *Paspalum* species studied, this species has the largest current distribution in South Africa (Fish et al. 2015) and has obtained the highest ROR for South Africa, the model was able to predict its distribution range across the country (Figure 3.1).

Paspalum notatum

P. notatum obtained a total number of 464 occurrences, and the level of accuracy for the random and target group models was good with an AUC of 0.857 and 0.86

respectively (Table 3.1). Annual mean temperature also had the largest permutation importance for predicting the ROR for this species with a range of 4 to 29 °C (Figure S6). However, this species has the smallest ROR in South Africa (Figure 3.1), with optimum ROR around the coastal areas of Eastern Cape and Kwa-Zulu Natal province. The model was able to predict most of the *P. notatum* distribution range in agreement with its current distribution as shown in Fish et al. (2015).

Paspalum nutans

P. nutans had a total number of 191 occurrences (Table 3.1), but there was no occurrence data for South Africa in the data set. The target and random group models indicated an excellent level of accuracy (AUC> 0.9) (Table 3.1). Temperature seasonality had the highest permutation importance (61.49) (Figure S7, Table S3). This species has the highest ROR along the coast of South Africa (Figure 3.1).

Paspalum quadrifarium

The number of occurrences for *P. quadrifarium* was 283, and the target and random group model both obtained an excellent AUC value > 0.9 (Table 3.1). Temperature seasonality was the most important predictor (44.60) (Figure S8, Table S3). Species distribution model indicates a high ROR of this species around northern Kwa-Zulu Natal, Mpumalanga, and two pockets in the coast of the Western Cape and Eastern Cape (Figure 3.1).

Paspalum urvillei

A total number of 694 occurrences was used to model the ROR of *P. urvillei* (Table 3.2). The two group models had an excellent level of accuracy (AUC > 0.9). The permutation importance and response curves show that annual mean temperature (63.41) is the most important predictor variable for the ROR of *P. urvillei* followed by temperature seasonality (Figure S9, Table S3). The optimum ROR of this species in South Africa is in Kwa-Zulu Natal, Mpumalanga and Limpopo where it is predominantly distributed.

Paspalum virgatum

P. virgatum obtained a good level of accuracy for both the target and random group models (AUC > 0.8). This species had a total number of 392 occurrences, with no occurrence for South Africa in the data set. Temperature seasonality is the most contributing and important environmental variable for this species (Figure S10, Table S3). This species' highest ROR in South Africa is along the coasts of Kwa-Zulu Natal and the borders of Mpumalanga and Limpopo.

Table 3.2: Number of occurrence records for each Paspalum species and the area under the receiver operating curve (AUC) mean values from five-replicated Maxent runs of the random group and the target group models. The AUC is interpreted as excellent (> 0.9), good (0.8–0.9), fair (0.7–0.8), poor (0.6–0.7) or failed (0.5–0.6) according to Swets (1988).

Species	**Number of records**	**Area under the curve (AUC)**	
		Random group model (with bias)	**Target group model (no bias)**
Paspalum dilatatum	2052	0.914	0.917
Paspalum notatum	464	0.857	0.864
Paspalum nutans	191	0.905	0.911
Paspalum quadrifarium	283	0.959	0.961
Paspalum urvillei	694	0.925	0.924
Paspalum virgatum	392	0.814	0.830

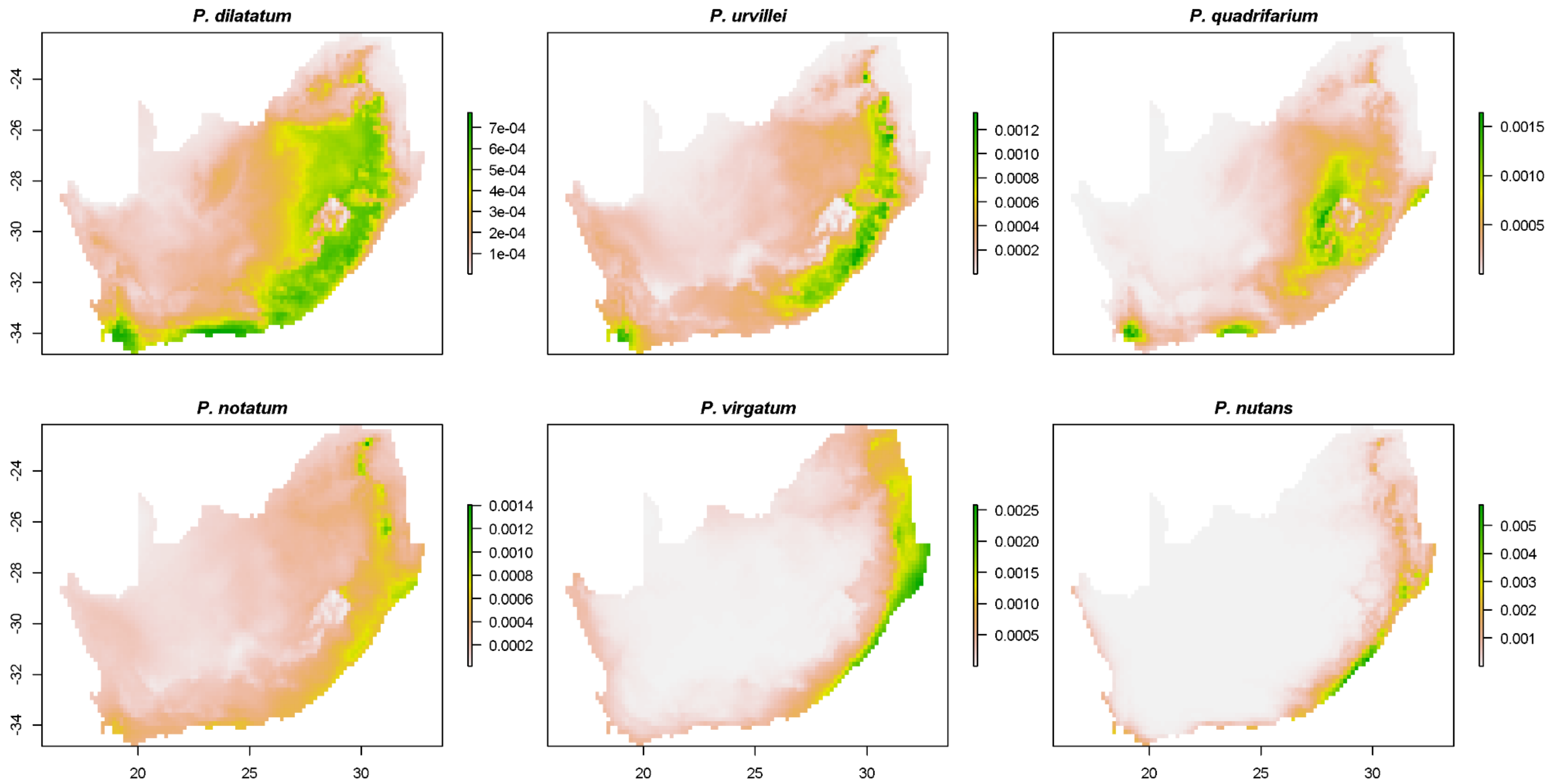

Figure 3.1: The potential distributions of alien Paspalum species in South Africa with sampling bias and informative offsets. The colours ranging from white (low) to green (high) indicates the species' relative occurrence rate which is a proxy for the probability of a particular species to be present in any give area.

3.3.3 Case study: impact of *Paspalum quadrifarium* on the native plant community

3.3.3.1 GLLVM model fit and validation

AIC values of 8557 and 7931 were obtained by the pure latent model and the model with covariates respectively. When I verified the negative binomial relationship between the residuals and variables the pure latent variable model obtained a random distribution for all residual plots (Figure S11), which indicates that the negative binomial is the best fit for the data and that all variances are well explained by the variables. Including the invasion status as covariates improved the model into better explaining the variation between the three sampling sites and the correlations between the plant species.

3.3.3.2 Impact on species abundance, composition and co-occurrence

A total of 54 plant species across all sites (including *P. quadrifarium*) were recorded, of which 14 species were alien (Table S5). I found 53, 51 and 43 plant species in the invaded, uninvaded and the cleared treatments, respectively, indicating species richness was lowest in the cleared treatment. A GLLVM with two latent variables and no predictors showed distinct clustering of invaded, uninvaded and cleared quadrats, although there was some overlap of invaded and cleared quadrats (Figure 3.2a). This indicates there are clear differences in species composition between uninvaded quadrats and both invaded and cleared quadrats, but some overlap in species composition among invaded and cleared quadrats. This was confirmed when I plotted species names onto the ordinations (Figure S12a, corresponding to Figure 3.2a), with this showing similar clustering of species along the latent variables. The invaded cluster was dominated by *P. urvillei, Dalbergia obovata,* and some tall tree species such as *Zanthoxylum capense,* and was negatively associated with the first latent variable and positively associated with the second latent variable. The uninvaded cluster was negatively associated with both latent variables and tended to contain more native than alien species (*Vachellia karroo, Vachellia sieberiana, Setaria megaphylla and Persicaria senegalensis*) (Figure S12a). Finally, the cleared cluster was dominated by short-statured species such as short grasses (*Sporobolus africanus, Agrostis stolonifera, Agrostis eriantha*), herbs (*Senecio madagascariensis*) and shrubs (*Solanum incanum*) and was positively associated with the first latent variable and negatively with the second latent variable.

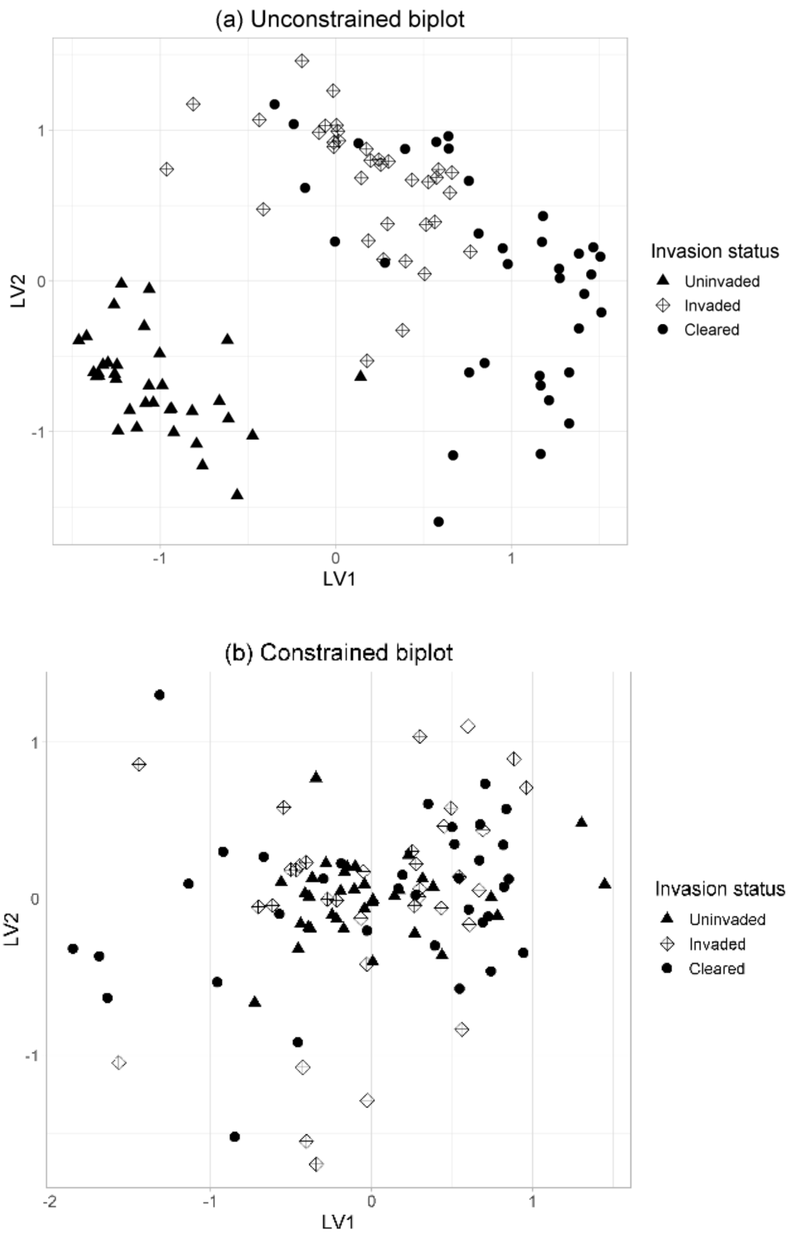

Figure 3.2: Ordination plot of n = 105 sampling quadrats for (a) the unconstrained latent variable (LV) model showing the distribution of the quadrats in the sampling area without considering their invasion status. Points (quadrats) close to each other are similar in species composition. (b) Ordination after including invasion status as a covariate, highlighting the effect of quadrat invasion status (and therefore P. quadrifarium) on species composition.

Before controlling for the quadrat's invasion status, *P. quadrifarium* seem to have strong positive correlations with *Solanum incanum*, *Centella asiatia*, *Senecio madagascariensis* and *Agrostis eriantha*. A strong negative correlation is observed between *P. quadrifarium* and the species dominating the invaded and the uninvaded cluster in Figure 3.3a (*P. urvillei, Dalbergia obovata, Zanthoxylum capense, Vachellia karroo, Vachellia sieberiana, Setaria megaphyllum, Miscanthus capensis and Persicaria senegalensis*) indicating that these species are less likely to occur with each other.

I found that the presence or absence of *P. quadrifarium* affects the plant species composition of the quadrats in the three sites (Figure 3.3b and S12b). However, several plant species diverged from the origin to form correlation clusters of their own. For example, a cluster of alien species (*Lantana camara* and *Pteridium aquilinum)* is formed in correspondence with the cleared site cluster (Figure S12b) and these are observed in Figure 3.3b to have a faint positive correlation with *P. quadrifarium*.

This is also a general trend for other species with correlations, where the co-occurrences between the species are not significant (Figure 3.3b). Most plant species do not show correlations with other species in Figure 3.3b, for example, *Zanthoxylum capensis, Sporobolus africanus, Solanum incanum, Panicum maximum, Rauvolfia caffra, P. urvillei* and *Centella asiatica.* This indicates that the presence or absence of *P. quadrifarium* in a quadrat influence the co-occurrences of the plant species and the significance of their relationship in the plant community. These results mean that *P. quadrifarium* causes moderate impact through competition which according to the framework is impact that results in a decline of population size of at least one native species (Hawkins et al. 2015, see risk analysis report in the appendices).

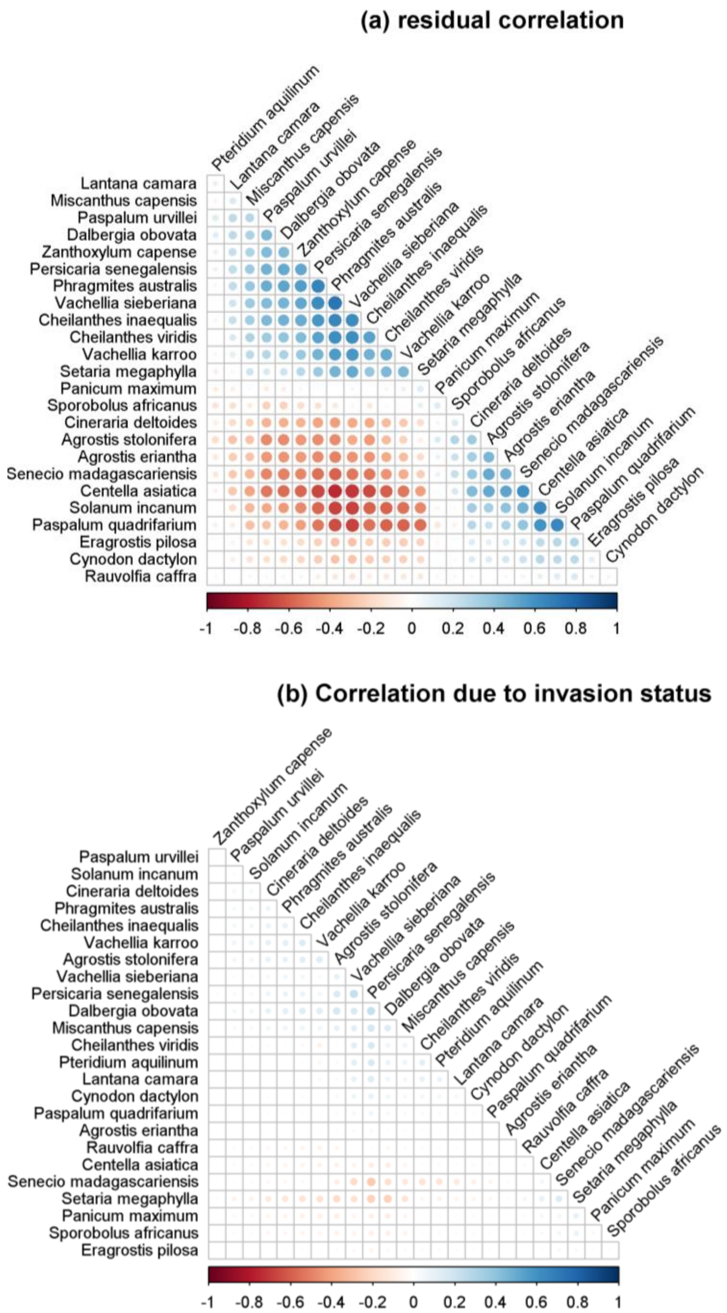

Figure 3.3: Residual correlation matrix showing correlations between species based on: (a) the unconstrained ordination, and (b) the partial ordination after controlling for Paspalum quadrifarium invasion status (invaded, uninvaded, and cleared). The difference between (a) and (b) shows that much of the correlation between species' co-occurrences is accounted for by the invasion status of P. quadrifarium, highlighting the effect this species has on community composition. Red, white and blue indicates a negative, no, or a positive correlation between species, respectively. The strength of the correlation is indicated by the size and darkness of the squares.

3.4 Discussion

The results provided an illustration on the status of alien *Paspalum* species in South Africa. I found that *P. dilatatum* and *P. urvillei* were introduced for pasture and were distributed across the country as pasture species in the 1960s (Rhind 1973). Attempts of creating a new cultivar between the two species called 'Pasadara' were also made at Cedara and Estcourt (Kwa-Zulu Natal province) pasture research stations around that time. However, the cultivar was never released due to consistently low seed yields (Rhind, 1973). In a survey conducted by the grass breeding section at Cedara in 1963, they found that *P. dilatatum* was used extensively and 15.6 % (5020 ha) of the land under artificial pastures was devoted to this species (Rhind 1973). However, it is no longer preferred for pasture due to its slow establishment rate, inconsistencies in seed quality and susceptibility to ergot fungus which may cause infertility to livestock when ingested (Tainton et al. 1990). *P. urvillei* was not successful as a pasture grass (for silage and hay) as it prefers moist soils and could not be grown extensively across the country (Tainton et al. 1990). Currently, the two species are widespread across the country in all provinces (Table 3.1).

P. notatum was introduced as pasture for sheep, but its seeds were later sold to home-owners as lawn grass by local seed companies (Rhind 1973). It was also used across the country in sports fields. But the species was not preferred for this purpose due to its hardness (Rhind 1973, Tainton et al. 1990). Currently, the species is still used for lawns and only occurs in disturbed areas outside cultivation.

The fourth species known to occur in South Africa is *P. quadrifarium*. This species was first recorded outside of cultivation in 2003 around the Melmoth area in Kwa-Zulu Natal (KZN) (Fish et al. 2015). It is said to have a small distribution, however, the extent of invasion for this species is uncertain.

With regards to the two species with unknown current distribution in South Africa, *P. nutans* was said to be cultivated in South Africa by Glen (2002), and *P. virgatum* was introduced and grown as a pasture trial species in some pasture research stations (Athole, Leeuwkuil and Prinshof) [see Appendix 4 in (Visser et al. 2017)]. The pasture stations have since been closed and I found no information on the outcome of the trials for the two species. I therefore contacted experts, research institutions, and credible databases to inquire about *P. nutans* and *P. virgatum* but found no further information on the current distributions of these two species (Table S4). Their species distribution models indicate small relative occurrence rate in South Africa, which suggests that *P. nutans* and *P. virgatum* may have not been introduced into climatically suitable environments and did not survive after introduction.

Risk analysis provides a means for making evidence-based recommendations for the management prioritisation of alien species (Keller and Kumschick, 2017). Climatic modelling can and has been, used to create a list for alien species with the potential of becoming invasive (risky) instead of the risk analysis approach (Faulkner et al. 2014, Renteria et al. 2017). The risk analyses and species potential distribution models that I conducted show that the potential distribution size of alien species alone does not always mean that species pose a risk. For instance, *P. urvillei* is widely distributed and a common weed in South Africa (Fish et al. 2015), but the results of the risk analysis indicates that it has low risk to native biodiversity because it invades disturbed areas. *P. quadrifarium* has a smaller localised distribution range in the country but the risk analysis show that it poses a higher risk than *P. urvillei* – because it invades in a more natural ecosystem. Similar to *P. urvillei*, *P. dilatatum* is also a common invader in South Africa and often occurs together with *P. urvillei* in disturbed areas across the country (Fish et al. 2015), but, the risk analysis shows a high risk for *P. dilatatum.* The higher risk of *P. quadrifarium* and *P. dilatatum* is due to the higher impact magnitudes. For instance, *P. dilatatum* can impact the economy through impacts on animal and agricultural production because it competes with agricultural crops and has been reported by Cawdell-Smith et al. (2010) to cause Stanger disease for cattle, horses and sheep in Australia. These differences in the degree of risk can only be determined by analysing all aspects of risk using a formal risk analysis approach, which would not have been apparent using species distribution modelling alone.

Knowledge about the risks posed by these *Paspalum* species in South Africa is important as it can be used as motivation for their regulation. However, it is also important to extrapolate the management feasibility of the species to ensure effectiveness. The risk management results of the risk analysis show that populations of the four *Paspalum* species with known current distribution can be easily accessible in South Africa, but their management will not be easy due to propagule persistence and detectability difficulties. For example, *P. quadrifarium* has multiple reproduction mechanisms, a short reproduction time and its seeds are of long persistence, (Vignolio et al. 2003, Verloove and Reynders 2007). Attempts to manage this species without an indication of whether management is feasible might lead to failure and misuse of resources.

The case study on the impacts of *P. quadrifarium* on the plant community found strong evidence that the species accounted for much of the change in community composition across an invasion gradient of this species. In its native range (Argentina), *P. quadrifarium* plays a major role in the structuring of native plant communities (Perelman et al. 2003). Several studies in other countries (reviewed in the previous chapter) indicated that *P. quadrifarium* can cause a decrease in size of local plant populations by forming large impenetrable stands that exclude other plant species (Laterra 1997, Picone et al. 2003, Verloove and Reynders 2007). My field study indicates that this is also the case in South Africa - herbaceous plant species decreased in the invaded site, suggesting that *P. quadrifarium* is excluding these species through competition. Moreover, these effects were long-lasting as quadrats cleared of *P. quadrifarium* were closer in species composition to invaded than uninvaded quadrats.

The field study results showed that *P. quadrifarium* co-occurs with other alien plant species more frequently than with native species. When a target species co-occurs with other aliens, it can be detrimental for management efforts as it is easier for these other alien species to occupy the area cleared of the target species (O'Loughlin and Green 2017). My results show exactly this - the site cleared of P. quadrifarium was quickly invaded by other alien plants (e.g. *Lantana camara, Psidium guajava).* This suggests that the removal of the target species did not improve the state of the local plant community. Active restoration must therefore be implemented together with management efforts in order to mitigate secondary invasions (Zavaleta et al. 2001).

Although not a major focus of my research, the field study showed there was little to no regrowth of *P. quadrifarium* in the cleared site after four years of clearing. This can mean one of three things: firstly, that the removal of the species was successful in the site. Secondly, it could be because secondary invasion occurred before *P. quadrifarium* could regrow. Lastly, it could be because fire has been excluded in the area where *P. quadrifarium* occurs (Fish et al. 2015), as fire plays a role in breaking the dormancy of this species' seeds and its survival in its native range (Vignolio et al. 2003).

One of the limitations of this case study was the presence of other alien plants across the sampling areas, which could have also contributed to the variation in plant species composition and co-occurrence. However, this did not affect the results because the invasion status of *P. quadrifarium* was the only difference across the three treatments.

3.5 Conclusion

Alien grasses have been reported to pose risk in their recipient communities around the globe. Knowledge of their risk in the local context is important for their management. However, prioritisation of one alien species over another can be complicated. This study points to the importance of risk analysis as a tool to provide scientific evidence for the management of alien species. Using this tool and species distribution modelling I found that alien *Paspalum* species pose a varied risk in South Africa. Of particular concern was *P. quadrifarium* which currently has a very limited distribution, but a large potential distribution in South Africa. Moreover, *P. quadrifarium* was found to be capable of changing local plant species composition, which could lead to changes in the structure and functioning of the local community. As such, *P. quadrifarium* should be prioritised for management in South Africa, and experimental research should be conducted to test various methods for its control and potential eradication. Other *Paspalum* species occurring in disturbed areas should also be monitored and controlled in agricultural and pasture lands.

Chapter 4 : Thesis conclusion

This thesis comprises two studies and a field case study that set out to investigate the risk posed by alien grasses in South Africa. Specifically, I wanted to understand the mechanisms through which the alien grasses cause environmental and socio-economic impacts, the magnitude of those impacts as well as the likelihood of the impacts to occur in South Africa. I was also interested in determining a way of providing evidence necessary for the prioritisation of alien grasses with different invasion status and research effort in the country. I considered it significant to also determine whether the alien grasses cause impact on the local community where they occur.

To answer the questions about the environmental and socio-economic impacts of alien grasses, I conducted a systematic review of published literature and databases on the impacts of selected alien grasses occurring in South Africa with the widest alien ranges globally. Here, I found 352 published studies reporting on the impacts of 48 alien grasses. Impact mechanism was a much stronger predictor of impact magnitude than habitat type or region impacted. Impacts magnitudes across different environmental and socio-economic impact mechanisms varied, with most species reported to cause environmental impacts on native species through competition and impacts on the ecosystems. This highlighted the ability of grass species to transform ecosystems through changing fire frequencies and rapidly resprouting to exclude native shrubs and grasses as it is observed in the Americas. I also found records of higher socio-economic impacts on agricultural production, indicating the abilities of most alien grasses to invade frequently disturbed areas. I found no significant variation in impacts of the grass species across different habitats and regions.

This is concerning for South Africa as some grasses reported to transform ecosystems, i.e. *Bromus* species in the Mojave deserts (Brooks 1999, Abella et al. 2012), have invaded South African biodiversity hotspots such as the Cape Floristic Region (Milton 2004, Musil et al. 2005). In a positive light, this also suggests that impact from other alien ranges can be used to extrapolate the impacts associated with a particular grass species in South Africa which can be useful for their management and prioritisation in the country.

Overall, Chapter 2 provides the evidence necessary for South African biodiversity managers and conservationists to become aware of the potential impacts of alien grass species in this country. However, the negative impacts of an alien species alone do not provide enough ground for the prioritisation of a species over another. This is because much more information is needed for such decisions. For example, it is equally important to know whether the species has suitable habitat and climate in an area. Also, some impact magnitudes are specific to a particular area. For example, hybridisation is only possible if both species are present in the same area. Also, single species can cause varying magnitude of impacts in certain habitats. These limitations can be avoided by using risk analyses, which in its self includes impact assessment as “likelihood of consequences”.

By extension, in chapter 3 I build on the findings from chapter 2 by providing evidence necessary for determining the risk of species in different invasion stages. To achieve this, I conducted full risk analyses focusing on six alien *Paspalum* species and modelled their potential distribution ranges in South Africa. I used the results from the analyses and the species distribution modelling to determine the likelihood of each species to cause risk and to make recommendations for their listing on the NEMBA A&IS Regulations. Here, I found that three *Paspalum* species pose a high risk and I have recommended their listing under category 1b in the NEMBA A&IS Regulations. The other three species are low risk and have a small optimum distribution range in South Africa, they should therefore not be regulated.

Furthermore, I wanted to determine the actual environmental risk posed by one alien *Paspalum* species. Thus, I conducted a field case study to compare changes in species composition across three treatments with the aim of determining the impact of *P. quadrifarium* on the plant community where it currently occurs. This species was ideal for this study not only because it obtained a high-risk score but because it is the only species occurring in a less disturbed ecosystem. It is also the only studied *Paspalum* species currently regulated in South Africa.

In this case study, I found that *P. quadrifarium* has an impact on the local plant community where it currently occurs. *P. quadrifarium* causes a change in the plant species composition as well as decrease the abundance of other plant species. Through this study, I also found that clearing the species opened an opportunity for secondary invasion by other alien plant species. This underlines the importance of active restoration when eradication of an alien species is considered. Fortunately, I found little to no regrowth on the sites where it has been cleared. This is very promising for the eradication of this species. However, in the risk analysis of this species, I recommended its listing in the NEMBA A&IS Regulation under 1b while it is already listed as a 1a species, i.e. eligible for eradication. I recommend that eradication feasibility study on this species should be conducted because it might not be as limited in distribution as it perceived.

Overall this thesis provided evidence of the impacts of alien grasses and demonstrated the importance of risk analysis for the prioritisation of alien species, especially for groups with limited local studies. The results show that impacts of alien grasses are similar across introduced ranges.

These results can be used to motivate the listing or the delisting of alien grasses occurring in South Africa, and the impact assessment results can be used to monitor species said to cause huge impacts and motivate for more local impact studies.

Further studies on this group of plants should consider looking at the following:

- Here in South Africa, there are species invading natural ecosystems (Fynbos) that have been reported to transform ecosystems elsewhere in the world, for example: *Bromus* grasses in the Mojave deserts. Risk analyses on such species should be conducted to look at their risk in those habitats, and to provide evidence for their prioritisation.

- I found very little information on the impacts of most alien grasses in South Africa. I suggest that species with major impacts through any mechanism (e.g. *Phalaris aquatica* and *Polypogon monspeliensis* on animal production) should be studied in a South Africa context as well.

- I also suggest that stakeholders who might be benefiting from high impact species such as *Cortaderia selloana* and *Arundo donax* should be engaged to determine whether the species are still used for their primary reason of introduction and whether other native species could be used instead. Such information is useful for the management planning of these species.

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Supplementary materials

Supplementary tables

Table S1: The summary table of obtained maximum environmental and socio-economic impact scores per species and mechanism (ranked alphabetically according to the species name). Reference numbers refer to the list in Appendix A.

Species	Impact magnitude	Impact mechanism	Ref No. (App A)
Agrostis stolonifera	3	1.3 Competition	143
Agrostis stolonifera	1	1.4 Diseases or parasites	211
Agrostis stolonifera	2	1.5 Hybridisation	67
Agrostis stolonifera	1	2.4 Infrastructure and administration	143
Agrostis stolonifera	2	2.6 Human social life	170
Aira caryophyllea	2	1.3 Competition	431
Aira caryophyllea	1	1.4 Diseases or parasites	259
Aira caryophyllea	1	1.6 Ecosystems	132
Aira caryophyllea	1	2.1 Agricultural production	59
Aira caryophyllea	1	2.2 Animal production	431
Aira caryophyllea	1	2.4 Infrastructure and administration	287
Arrhenatherum elatius	3	1.3 Competition	303
Arrhenatherum elatius	2	1.6 Ecosystems	401
Arrhenatherum elatius	2	2.1 Agricultural production	152
Arrhenatherum elatius	1	2.4 Infrastructure and administration	146
Arrhenatherum elatius	1	2.5 Human health	401
Arundo donax	2	1.2 Predation or parasitism or intoxication	444
Arundo donax	3	1.3 Competition	140
Arundo donax	1	1.4 Diseases or parasites	86
Arundo donax	4	1.6 Ecosystems	56

Species	Impact magnitude	Impact mechanism	Ref No. (App A)
Arundo donax	1	2.1 Agricultural production	445
Arundo donax	1	2.2 Animal production	445
Arundo donax	4	2.4 Infrastructure and administration	86
Arundo donax	1	2.6 Human social life	56
Avena barbata	1	1.1 Plants or vegetation	423
Avena barbata	3	1.3 Competition	385
Avena barbata	2	1.6 Ecosystems	360
Avena barbata	1	2.1 Agricultural production	381
Avena fatua	3	1.1 Plants or vegetation	306
Avena fatua	3	1.3 Competition	305
Avena fatua	1	1.4 Diseases or parasites	306
Avena fatua	3	1.5 Hybridisation	306
Avena fatua	4	2.1 Agricultural production	13
Avena fatua	3	2.4 Infrastructure and administration	253
Avena sterilis	3	2.1 Agricultural production	260
Bambusa vulgaris	2	1.2 Predation or parasitism or intoxication	358
Bambusa vulgaris	3	1.3 Competition	130
Bambusa vulgaris	3	1.6 Ecosystems	252
Bambusa vulgaris	3	2.2 Animal production	35
Bambusa vulgaris	2	2.5 Human health	23
Brachypodium distachyon	3	1.3 Competition	3
Brachypodium distachyon	1	1.4 Diseases or parasites	369
Brachypodium distachyon	3	1.5 Hybridisation	181
Brachypodium distachyon	2	1.6 Ecosystems	448
Brachypodium distachyon	2	2.5 Human health	305
Briza maxima	3	1.3 Competition	425
Briza maxima	3	1.6 Ecosystems	396

Species	Impact magnitude	Impact mechanism	Ref No. (App A)
Bromus catharticus	3	1.3 Competition	422
Bromus catharticus	1	1.4 Diseases or parasites	150
Bromus catharticus	2	1.5 Hybridisation	206
Bromus catharticus	1	2.1 Agricultural production	191
Bromus diandrus	3	2.1 Agricultural production	185
Bromus diandrus	3	2.2 Animal production	135
Bromus hordeaceus	3	1.3 Competition	403
Bromus madritensis	2	1.3 Competition	101
Bromus madritensis	3	1.6 Ecosystems	402
Bromus madritensis	3	2.2 Animal production	390
Bromus rigidus	2	1.4 Diseases or parasites	329
Bromus rigidus	4	2.1 Agricultural production	391
Bromus rigidus	3	2.2 Animal production	329
Bromus rubens	3	1.2 Predation or parasitism or intoxication	113
Bromus rubens	3	1.3 Competition	174
Bromus rubens	3	1.6 Ecosystems	407
Bromus rubens	3	2.2 Animal production	402
Bromus tectorum	4	1.3 Competition	192
Bromus tectorum	3	1.6 Ecosystems	97
Bromus tectorum	3	2.1 Agricultural production	418
Bromus tectorum	3	2.2 Animal production	393
Bromus tectorum	2	2.4 Infrastructure and administration	393
Cenchrus spinifex	1	1.3 Competition	377
Cenchrus spinifex	1	1.4 Diseases or parasites	398
Cenchrus spinifex	2	2.2 Animal production	122
Cortaderia jubata	3	1.3 Competition	445
Cortaderia jubata	4	1.6 Ecosystems	198
Cortaderia jubata	2	2.3 Forestry production	105
Cortaderia jubata	3	2.4 Infrastructure and administration	160
Cortaderia jubata	1	2.5 Human health	445
Cortaderia jubata	2	2.6 Human social life	445
Cortaderia selloana	2	1.3 Competition	409

Species	Impact magnitude	Impact mechanism	Ref No. (App A)
Cortaderia selloana	1	1.4 Diseases or parasites	220
Cortaderia selloana	2	1.5 Hybridisation	80
Cortaderia selloana	2	1.6 Ecosystems	108
Cortaderia selloana	2	2.1 Agricultural production	417
Cortaderia selloana	2	2.3 Forestry production	160
Cortaderia selloana	3	2.4 Infrastructure and administration	160
Cortaderia selloana	2	2.5 Human health	426
Cortaderia selloana	2	2.6 Human social life	397
Cynosurus echinatus	2	1.3 Competition	379
Cynosurus echinatus	2	1.4 Diseases or parasites	26
Dactylis glomerata	3	1.3 Competition	441
Dactylis glomerata	3	2.1 Agricultural production	340
Dactylis glomerata	3	2.5 Human health	147
Digitaria sanguinalis	3	1.3 Competition	433
Digitaria sanguinalis	3	2.1 Agricultural production	370
Elymus repens	3	1.1 Plants or vegetation	438
Elymus repens	3	1.3 Competition	51
Elymus repens	2	1.4 Diseases or parasites	123
Elymus repens	2	1.5 Hybridisation	27
Elymus repens	3	2.1 Agricultural production	164
Elymus repens	2	2.3 Forestry production	311
Elymus repens	2	2.5 Human health	321
Festuca arundinacea	2	1.3 Competition	437
Festuca arundinacea	2	1.4 Diseases or parasites	196
Festuca arundinacea	2	1.5 Hybridisation	193
Festuca arundinacea	2	1.6 Ecosystems	36

Species	Impact magnitude	Impact mechanism	Ref No. (App A)
Festuca arundinacea	3	2.1 Agricultural production	99
Festuca arundinacea	4	2.2 Animal production	64
Festuca arundinacea	2	2.5 Human health	442
Glyceria maxima	2	1.3 Competition	430
Glyceria maxima	2	1.6 Ecosystems	241
Glyceria maxima	5	2.2 Animal production	38
Glyceria maxima	3	2.6 Human social life	436
Holcus lanatus	3	1.3 Competition	45
Holcus lanatus	1	1.4 Diseases or parasites	282
Holcus lanatus	3	1.6 Ecosystems	39
Holcus lanatus	1	2.2 Animal production	432
Holcus lanatus	2	2.5 Human health	299
Hordeum jubatum	2	1.4 Diseases or parasites	307
Hordeum jubatum	2	1.5 Hybridisation	266
Hordeum jubatum	2	2.1 Agricultural production	109
Hordeum jubatum	3	2.2 Animal production	49
Hordeum murinum	1	1.3 Competition	447
Hordeum murinum	2	1.4 Diseases or parasites	178
Hordeum murinum	2	1.5 Hybridisation	323
Hordeum murinum	2	1.6 Ecosystems	335
Hordeum murinum	3	2.2 Animal production	447
Lolium multiflorum	2	1.4 Diseases or parasites	327
Lolium multiflorum	2	1.5 Hybridisation	194
Lolium multiflorum	2	2.1 Agricultural production	301
Lolium multiflorum	2	2.5 Human health	102
Lolium perenne	2	1.5 Hybridisation	434
Lolium perenne	3	2.2 Animal production	203
Lolium perenne	2	2.5 Human health	19
Lolium temulentum	1	1.3 Competition	435
Lolium temulentum	1	1.5 Hybridisation	359

Species	Impact magnitude	Impact mechanism	Ref No. (App A)
Lolium temulentum	2	2.1 Agricultural production	435
Lolium temulentum	2	2.5 Human health	435
Nassella trichotoma	3	1.3 Competition	142
Nassella trichotoma	3	1.6 Ecosystems	412
Nassella trichotoma	1	2.1 Agricultural production	61
Nassella trichotoma	5	2.2 Animal production	412
Nassella trichotoma	3	2.4 Infrastructure and administration	345
Oryza sativa	1	1.4 Diseases or parasites	368
Oryza sativa	1	1.5 Hybridisation	184
Panicum miliaceum	2	2.1 Agricultural production	317
Paspalum dilatatum	1	1.4 Diseases or parasites	98
Paspalum dilatatum	1	1.5 Hybridisation	300
Paspalum dilatatum	3	2.2 Animal production	75
Paspalum dilatatum	3	2.4 Infrastructure and administration	248
Paspalum dilatatum	2	2.6 Human social life	168
Paspalum notatum	3	1.6 Ecosystems	429
Paspalum notatum	3	2.1 Agricultural production	314
Paspalum notatum	1	2.2 Animal production	246
Paspalum notatum	3	2.5 Human health	95
Paspalum notatum	3	2.6 Human social life	92
Paspalum quadrifarium	2	1.3 Competition	346
Paspalum quadrifarium	1	1.6 Ecosystems	405
Paspalum quadrifarium	1	2.2 Animal production	202
Paspalum urvillei	2	1.3 Competition	394
Paspalum urvillei	2	1.5 Hybridisation	318
Paspalum urvillei	1	2.1 Agricultural production	250
Paspalum urvillei	1	2.5 Human health	394
Pennisetum setaceum	3	1.3 Competition	324

Species	Impact magnitude	Impact mechanism	Ref No. (App A)
Pennisetum setaceum	2	1.6 Ecosystems	354
Pennisetum setaceum	1	2.4 Infrastructure and administration	447
Pennisetum villosum	1	1.3 Competition	411
Pennisetum villosum	1	2.2 Animal production	376
Phalaris aquatica	5	1.2 Predation or parasitism or intoxication	28
Phalaris aquatica	5	2.2 Animal production	64
Poa annua	2	1.3 Competition	70
Poa annua	1	1.4 Diseases or parasites	127
Poa annua	2	1.6 Ecosystems	235
Poa annua	2	2.1 Agricultural production	228
Poa annua	2	2.6 Human social life	230
Poa pratensis	2	1.3 Competition	383
Poa pratensis	1	1.5 Hybridisation	91
Poa pratensis	2	1.6 Ecosystems	153
Poa pratensis	2	2.2 Animal production	161
Polypogon monspeliensis	2	1.5 Hybridisation	315
Polypogon monspeliensis	2	2.1 Agricultural production	283
Polypogon monspeliensis	5	2.2 Animal production	219
Sorghum halepense	1	1.3 Competition	116
Sorghum halepense	3	1.5 Hybridisation	24
Sorghum halepense	2	1.6 Ecosystems	290
Sorghum halepense	5	2.1 Agricultural production	18
Sorghum halepense	3	2.2 Animal production	380
Vulpia bromoides	2	1.3 Competition	336
Vulpia bromoides	1	1.4 Diseases or parasites	365
Vulpia bromoides	2	1.6 Ecosystems	34
Vulpia bromoides	2	2.1 Agricultural production	112

Species	Impact magnitude	Impact mechanism	Ref No. (App A)
Vulpia bromoides	2	2.2 Animal production	334
Vulpia myuros	2	1.3 Competition	335
Vulpia myuros	3	2.1 Agricultural production	14
Vulpia myuros	3	2.2 Animal production	14
Vulpia myuros	3	2.3 Forestry production	438

Table S2: The random effects model selection indicating the number of random parameters (K), the Akaike's Information Criterion (AIC), log-likelihood (LL), and likelihood ratio statistic (L). Species identity and mechanism nested within mechanism type (environmental or socio-economic) were individually excluded and tested against the full model including both random effects. Only species identity was found to significantly improve model fit. m1 represents a cumulative link mixed effects model estimating the effect of habitat, region and impact mechanism on overall impact magnitude of the studied alien grasses.

Model	K	AIC	LL	L	P
m1	34	2202.70	-1067.40	59.978	0.001
m2	33	2200.70	-1067.40	4e-04	0.9837
M3	33	2345.80	-1139.90	144.36	< 0.001
M4	32	1313.40	-624.72	-885.98	1

m1 = clmm (Impact.magnitude ~ Habitat + Region + Mechanism + (1|Species.name) + (1|Impact ..type..Environmental.Socio.economic..:Mechanism), data = dat, Hess = T)

m2 = clmm (Impact.magnitude ~ Habitat + Region + Mechanism + (1|Species.name), data = dat, Hess = T)

m3 = clmm (Impact.magnitude ~ Habitat + Region + Mechanism + (1|Impact ..type..Environmental.Socio.economic..:Mechanism), data = dat, Hess = T)

m4= clm(Impact.magnitude ~ Habitat + Region + Mechanism,

data=dat, Hess=T)

Table S3: The permutation importance values of alien six *Paspalum* occurring indicating the contributions of climatic environmental variables used to model the relative occurrence rate in South Africa.

Variables	Paspalum_dilatatum (average)		Paspalum_notatum (average)		Paspalum_nutans (average)		Paspalum_quadrifarium (average)		Paspalum_urvillei (average)		Paspalum_virgatum (average)	
	Contribution	Permutation importance	Contribution	Permutation importance	Contribution	Permutation importance	Contribution	Permutation importance	Contribution	Permutation importance	Contribution	Permutation importance
Annual mean temperature	40.35	49.69	20.95	35.46	11.24	13.72	21.87	13.28	34.92	63.41	13.21	14.82
Temperature seasonality	31.41	12.95	45.97	19.42	61.49	51.45	40.51	44.60	38.11	19.04	66.56	60.09
Annual precipitation	13.45	22.91	16.94	22.45	2.55	6.29	11.26	27.39	6.15	5.79	5.74	17.76
Precipitation of driest month	7.12	8.24	6.85	14.59	13.10	19.94	5.23	11.93	5.22	4.67	5.85	1.23
Precipitation seasonality	7.65	6.19	9.26	8.05	11.60	8.58	21.10	2.77	15.57	7.06	8.62	6.08

Table S4: Methodology followed when investigating the presence and current distribution of *P. nutans* and *P. virgatum* in S.A.

Sources	**Action**	**Correspondent**	**Results**	**Dates**	**Notes**
Literature	What did you do? Google? Search databases?				- None
SANBI Herbarium: DBN	-Visited to familiarise myself with grass species and to help digitize specimen for BRAHMS during internship	Mkhipheni Ngwenya	No specimen for *P. nutans* and *P. virgatum*	08/ 2015	- Not found
SANBI Herbarium: PTA	-Email communication -Phone call follow- up	Caroline Mashau	- No record of specimen collected in SA - Scanned and emailed back specimen under extra Africa collection	07/ 09/ 2016	-only have specimen from extra-Africa for both species
GBIF	Data base search	http://www.gbif.org	- No occurrence in South Africa (both species recorded in Madagascar)	07/ 10/ 2016	No record in SA
GSSA	-Email communication	Sigrun Ammann	-Refers me to the KZN Mistbelt. -suggest a visit to Bews Herbarium	22/ 08/ 2016	- species not known

			-Provides contacts for ARC-API Roodeplaat		
ISPOT	Created project	Public participation	71 reads No comment or response	28/ 09/ 2016	No response from ISPOT project
ARC-API Roodeplaat	-Email communication -Phone call follow- up	Marike Trytsman	- Correspondent search their data base, no specimen found. - only small quantities of seeds of other Paspalum species -Never heard of *P. nutans* and *P. virgatum*	19/ 10/ 2016	-Never heard of the species
SAPIA	-Data base was not online -Email communication	Lesley Henderson	-Emailed back records of Paspalum species in SA. - No record for P. nutans and P. virgatum -Refers me to BRAHMS	11/ 10/ 2016	Not recorded in SAPIA
BRAHMS	Data base search	http://newposa.sanbi.org/sanbi/Explore	No record of specimen	11/10/2016	Not found

Bews herbarium PMB,UKZN	- Visited As referred by GSSA correspondent	Christina Potgieter	No specie men found *P. nutans* and *P. virgatum*	22/ 11/ 2016	-No record
Pasture research station / Pasture scientist	-Email communication -Phone call follow- up -Visit	Dave Goodenough Mr Kent Alistair	-Never head of *P. nutans* and *P. virgatum* - Record of *Papalums* (and other grass species) introduced in SA lost during relocations -Surveyed the pasture station, and outside along the roads for escapes - Suggest study sites - taught me how to identify *Paspalum* in the field using live specimen -Points out some of the impacts caused by other Paspalum species in the station	23/ 11/ 2016	- species not known not record of introduction

			-Provided other contacts for future reference (as one correspondent was going for retirement).		
Alien Grass Working Group	Email follow up after working group meeting	Tim O'Connor	- provided contacts for a pasture scientist who previously worked on *Paspalum* species	12/ 09/ 2016	- Suggested pasture scientist

Table S5: List of species found in the tree sampling areas, their botanical family, life form and whether they are native or alien. The species are ranked according to the species name in alphabetical order.

Species name	Botanical family	Lifeform	Native or alien
Agrostis eriantha	Poaceae	Graminoid	Native
Agrostis stolonifera	Poaceae	Graminoid	Alien
Asparagus virgatus	Asparagaceae	Herb	Native
Bare ground	-	-	-
Berkheya bipinnatifida	Asteraceae	Herb	Native
Bidens pilosa	Asteraceae	Herb	Alien
Canthium inerme	Rubiaceae	Tree	Native
Centella asiatica	Apiaceae	Herb	Native
Cheilanthes inaequalis	Sinopteridaceae	Pteridophyte	Native
Cheilanthes viridis	Sinopteridaceae	Pteridophyte	Native
Cineraria deltoids	Asteraceae	Shrub	Native
Cirsium vulgare	Asteraceae	Herb	Alien
Clausena anisata	Rutaceae	Tree	Native
Clerodendrum glabrum	Lamiaceae	Tree	Native
Conostomium natalense	Rubiaceae	Herb	Native
Croton sp	Euphorbiaceae	Tree	Native
Cussonia spicata	Araliaceae	Tree	Native
Cynodon dactylon	Poaceae	Graminoid	Native
Dalbergia obovate	Fabaceae	Tree	Native
Eragrostis pilosa	Poaceae	Graminoid	Native
Euclea divinorum	Ebenaceae	Tree	Native
Ficus sur	Moraceae	Tree	Native
Gomphocarpus physocarpus	Asclepiadaceae	Herb	Native
Halleria lucida	Scrophulariaceae	Tree	Native
Lantana camara	Verbenaceae	Shrub	Alien
Laportea sp	Urticaceae	Herb	Native
Lepidium africanum	Brassicaceae	Herb	Native
Lippia javanica	Verbenaceae	Shrub	Native

Species name	**Botanical family**	**Lifeform**	**Native or alien**
Maesa lanceolate	Maesaceae	Tree	Native
Melia azedarach	Meliaceae	Tree	Alien
Miscanthus capensis	Poaceae	Graminoid	Native
Oxalis corniculate	Oxalidaceae	herb	Alien
Panicum maximum	Poaceae	Graminoid	Native
Paspalum quadrifarium	Poaceae	Graminoid	Alien
Paspalum urvillei	Poaceae	Graminoid	Alien
Persicaria senegalensis	Polygonaceae	Herb	Native
Phragmites australis	Poaceae	Graminoid	Native
Plectranthus sp	Lamiaceae	Herb	Native
Psidium guajava	Myrtales	Tree	Alien
Pteridium aquilinum	Dennstaedtiaceae	Herb	Native
Ranunculus multifidus	Ranuculaceae	Herb	Native
Rauvolfia caffra	Apocynaceae	Tree	Native
Rock	-	-	-
Senecio madagascariensis	Asteraceae	Herb	Native
Setaria megaphylla	Poaceae	Graminoid	Native
Smilax anceps	Smilacaceae	Climber	Native
Solanum incanum	Solanaceae	Shrub	Native
Sporobolus africanus	Poaceae	graminoid	Native
Spp A	-	Tree	Native
Spp B	-	Tree	Native
Spp X	-	Shrub	Native
Syzygium cordatum	Myrtales	Tree	Native
Vachellia karroo	Fabaceae	Tree	Native
Vachellia sieberiana	Fabaceae	Tree	Native
Zanthoxylum capense	Rutaceae	Tree	Native
Ziziphus mucronata	Rhamnaceae	Tree	Native

Supplementary figures

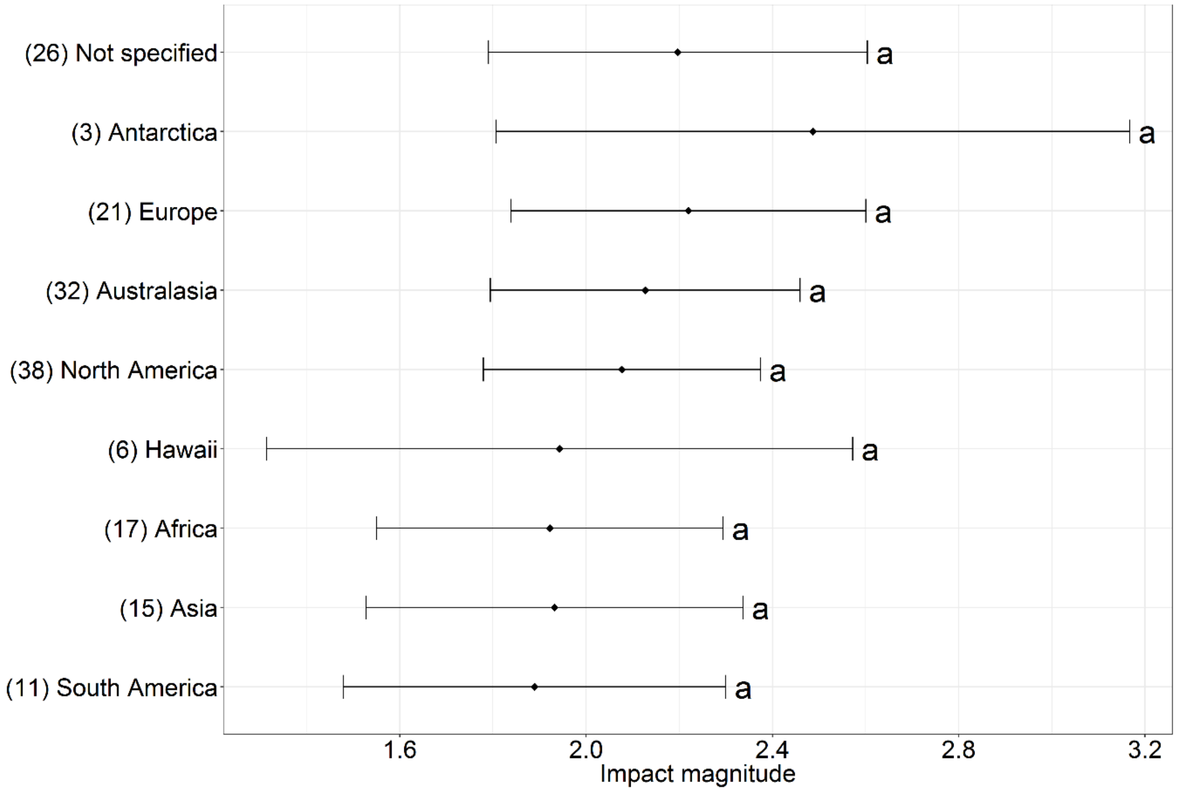

Figure S1: The impact magnitude of 48 studied alien grasses across different regions. The impact magnitudes on the x-axis are the least-square means of the impact scores as derived from a cumulative link mixed effects model. On the y-axis are the introduced regions and in brackets is the number of species with records in that region. The points represent the impact magnitudes and the error bars represent 95 % confidence intervals. Letters on the right side of the confidence intervals are level groupings indicating that impacts across regions are not significantly different. Comparisons are Tukey adjusted.

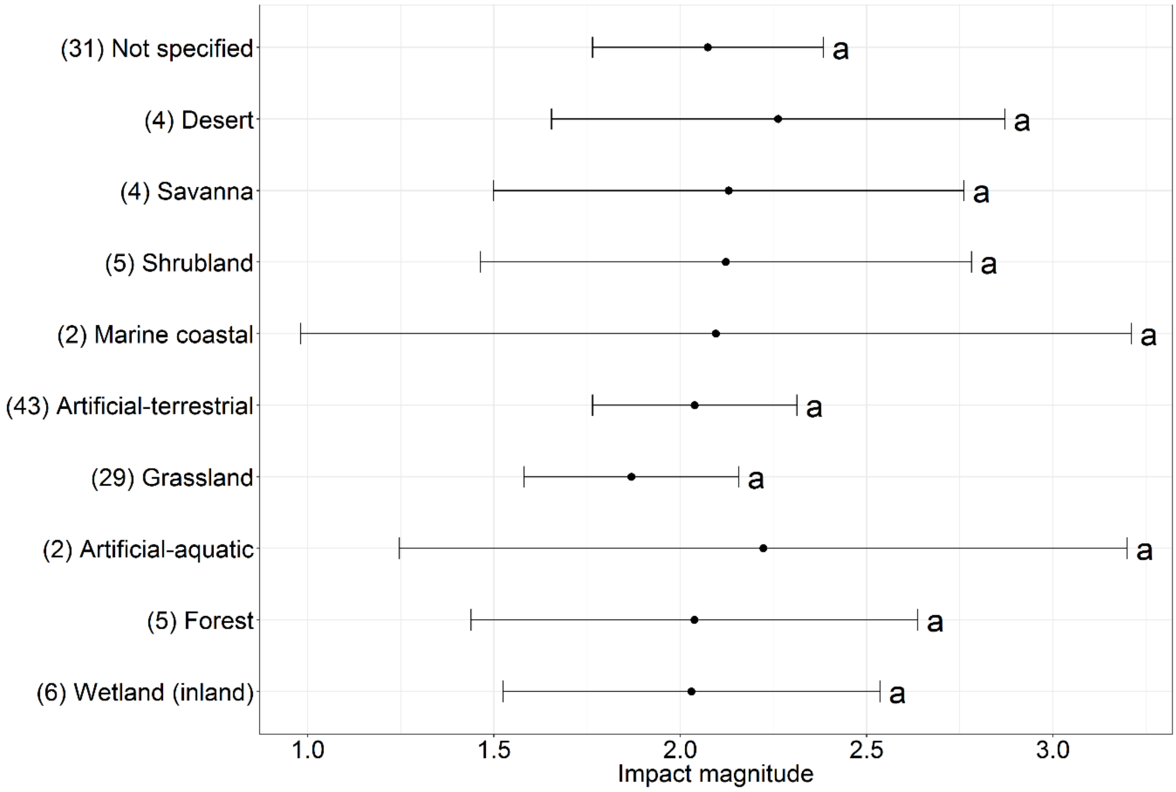

Figure S2: The impact magnitude of the 48 studied alien grasses across different habitats. The impact magnitudes on the x-axis are the least-square means of the impact scores as derived from a cumulative link mixed effects model. On the y-axis are the habitat types impacted by alien grasses and in brackets is the number of species with records in that habitat. The points represent the impact magnitudes and the error bars represent 95 % confidence intervals. Letters on the right side of the confidence intervals are level groupings indicating no significant differences among the habits. Comparisons are Tukey adjusted.

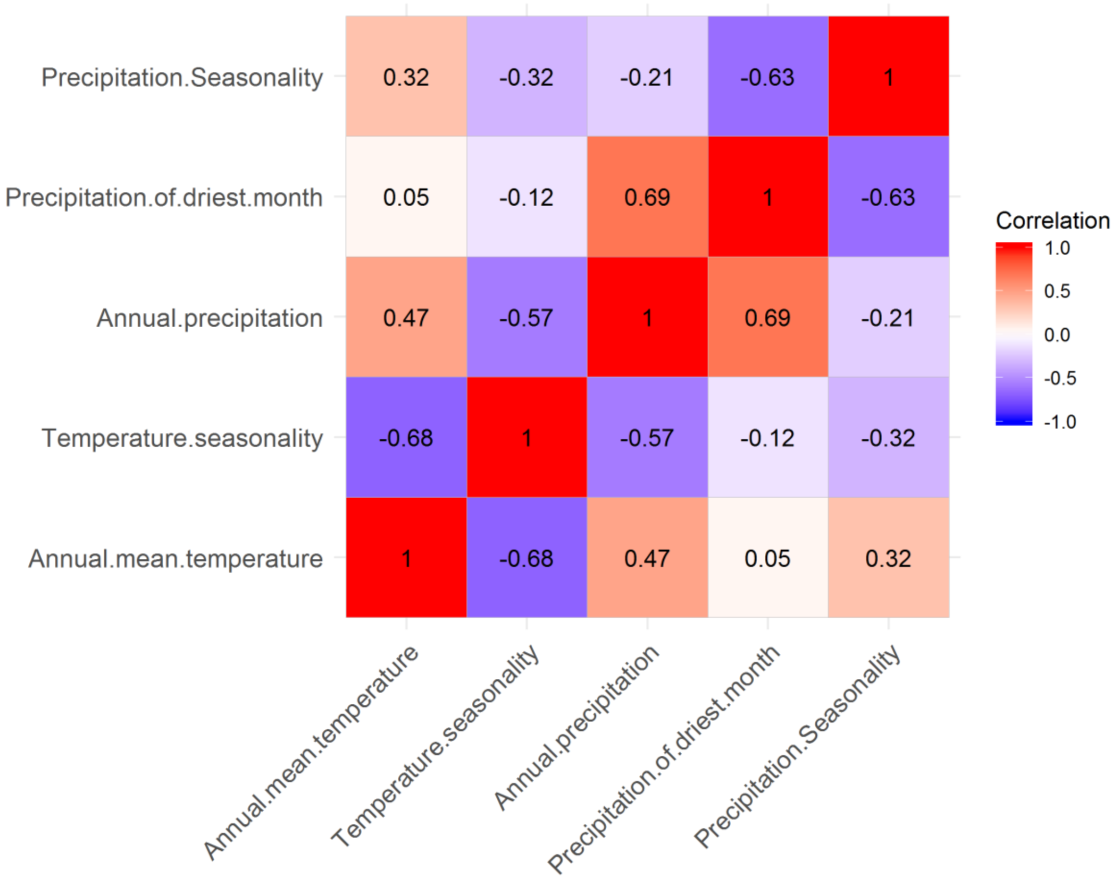

Figure S3: Collinearity matrix of the five selected environmental variables. The yellow shade indicates high collinearity between the variables and the dark blue shades show low collinearity.

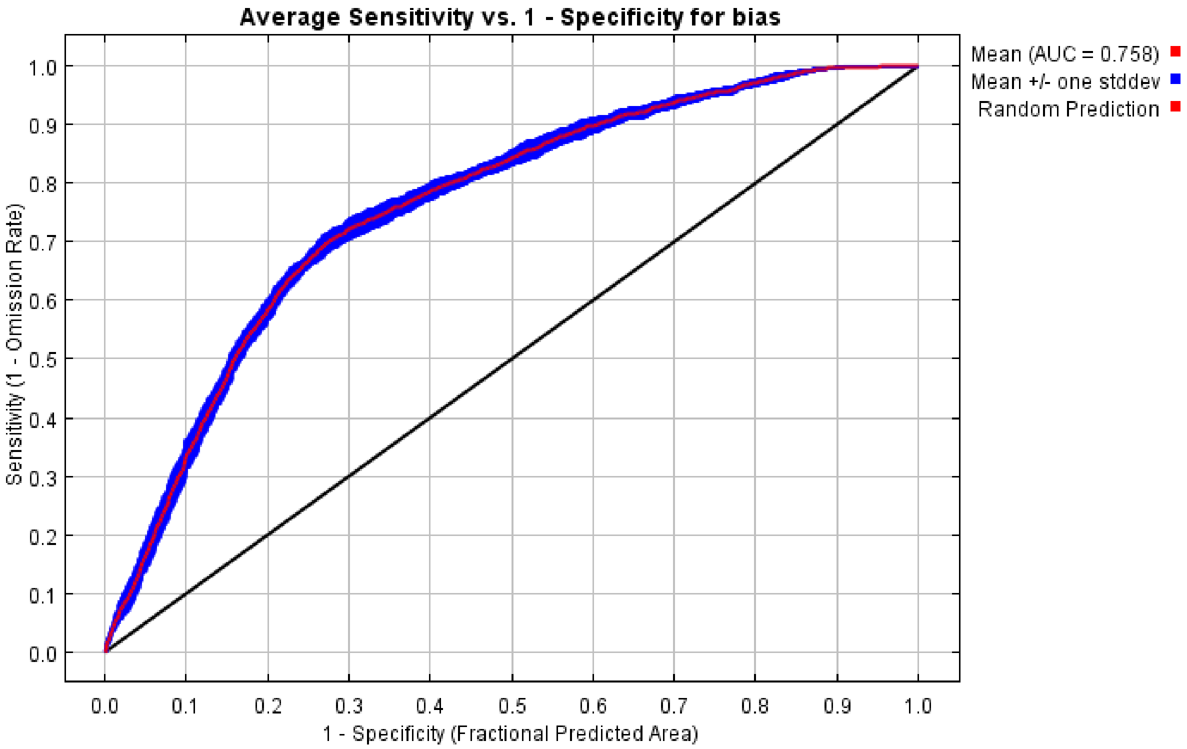

Figure S4: The receiver operating curve (ROC) of the sampling bias model. The mean AUC value of 0.758 yielded a fair level of accuracy.

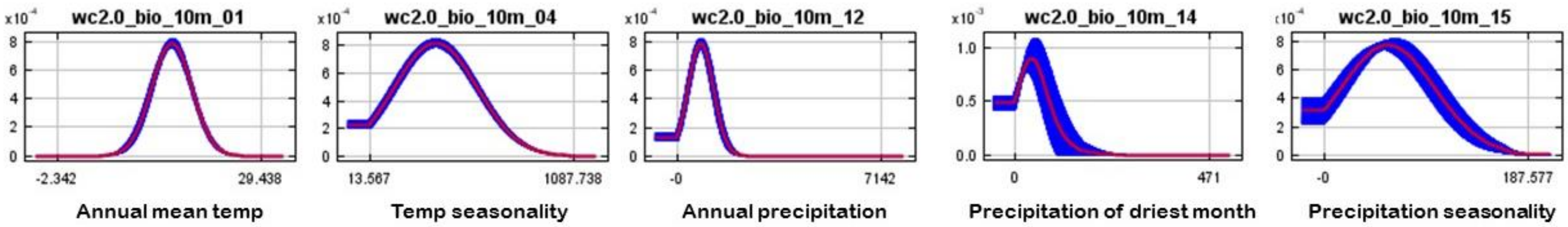

Figure S5: Response curves depicting the relationship between each selected environmental variable and the probability of determining *Paspalum dilatatum* potential distribution. The response curves are means of five replications of the testing. On the x-axis is the range of values of the variable and on the y-axis is the relative occurrence rate (a measure of the probability of occurrence). The blue shading represents the 95 % confidence interval.

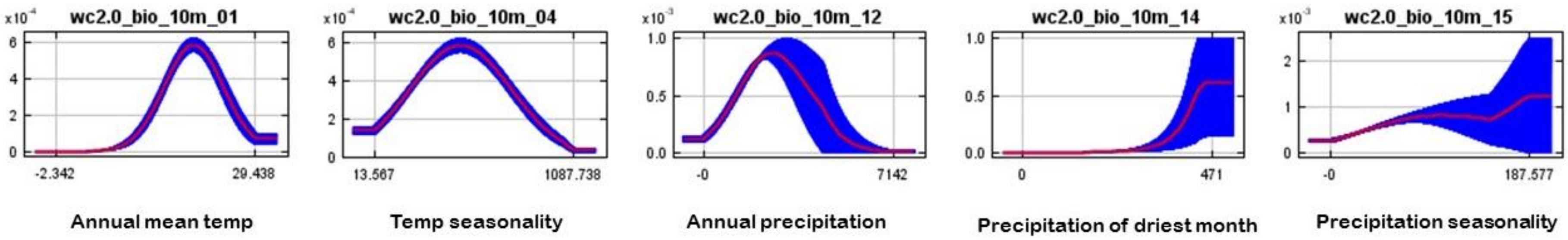

Figure S6: Response curves depicting the relationship between each selected environmental variable and the probability of determining *Paspalum notatum* potential distribution. The response curves are means of five replications of the testing. on the x-axis is the range of values of the variable and on the y-axis is the relative occurrence rate (a measure of the probability of occurrence). The blue shading represents the 95 % confidence interval.

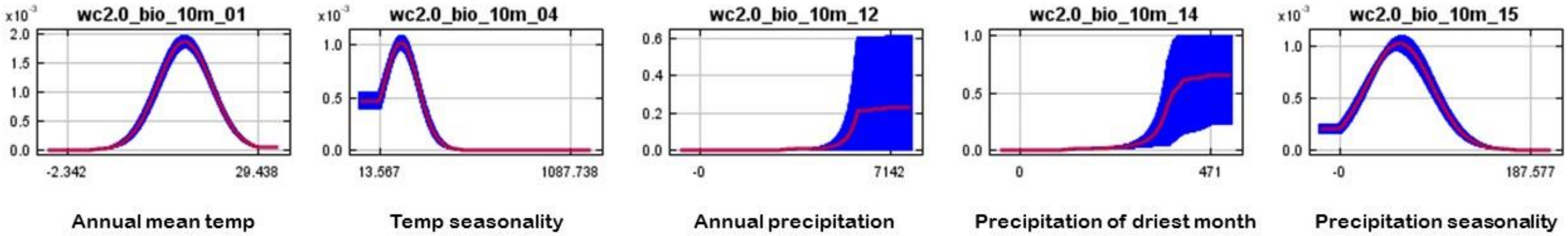

Figure S7: Response curves depicting the relationship between each selected environmental variable and the probability of determining *Paspalum nutans* potential distribution. The response curves are means of five replications of the testing. on the x-axis is the range of values of the variable and on the y-axis is the relative occurrence rate (a measure of the probability of occurrence). The blue shading represents the 95 % confidence interval.

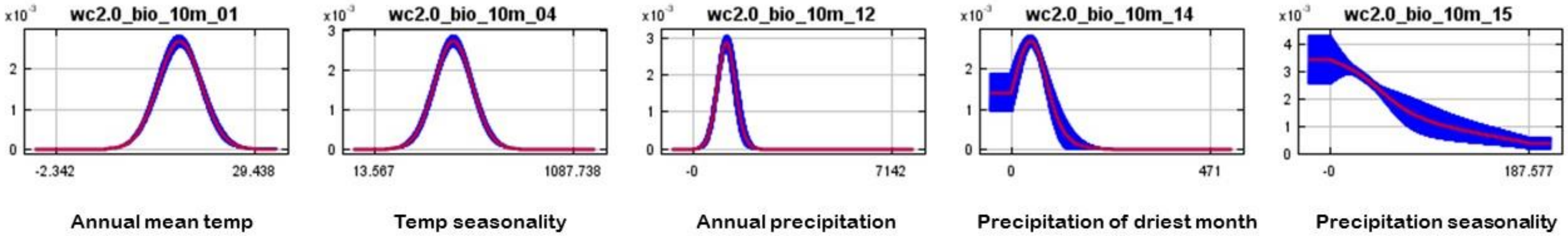

Figure S8: Response curves depicting the relationship between each selected environmental variable and the probability of determining *Paspalum quadrifarium* potential distribution. The response curves are means of five replications of the testing. on the x-axis is the range of values of the variable and on the y-axis is the relative occurrence rate (a measure of the probability of occurrence). The blue shading represents the 95 % confidence interval.

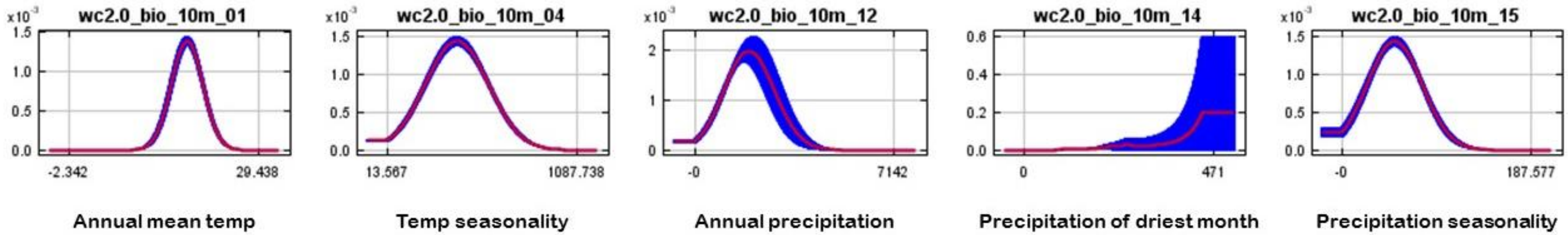

Figure S9: Response curves depicting the relationship between each selected environmental variable and the probability of determining *Paspalum urvillei* potential distribution. The response curves are means of five replications of the testing. on the x-axis is the range of values of the variable and on the y-axis is the relative occurrence rate (a measure of the probability of occurrence). The blue shading represents the 95 % confidence interval.

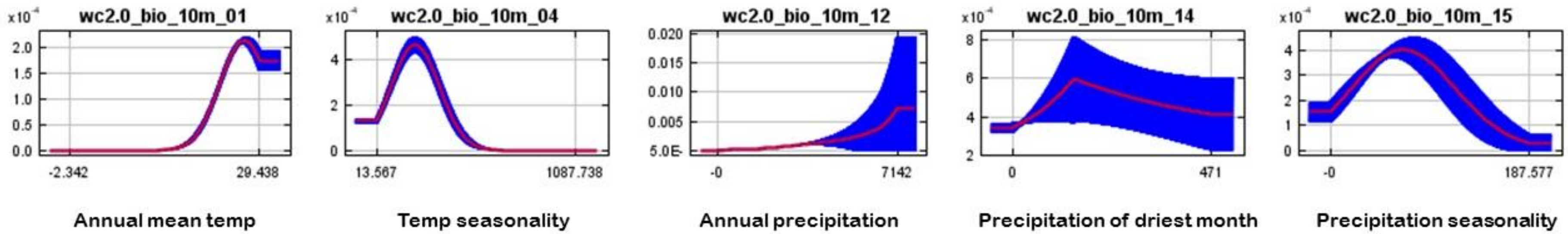

Figure S10: Response curves depicting the relationship between each selected environmental variable and the probability of determining *Paspalum virgatum* potential distribution. The response curves are means of five replications of the testing. on the x-axis is the range of values of the variable and on the y-axis is the relative occurrence rate (a measure of the probability of occurrence). The blue shading represents the 95 % confidence interval.

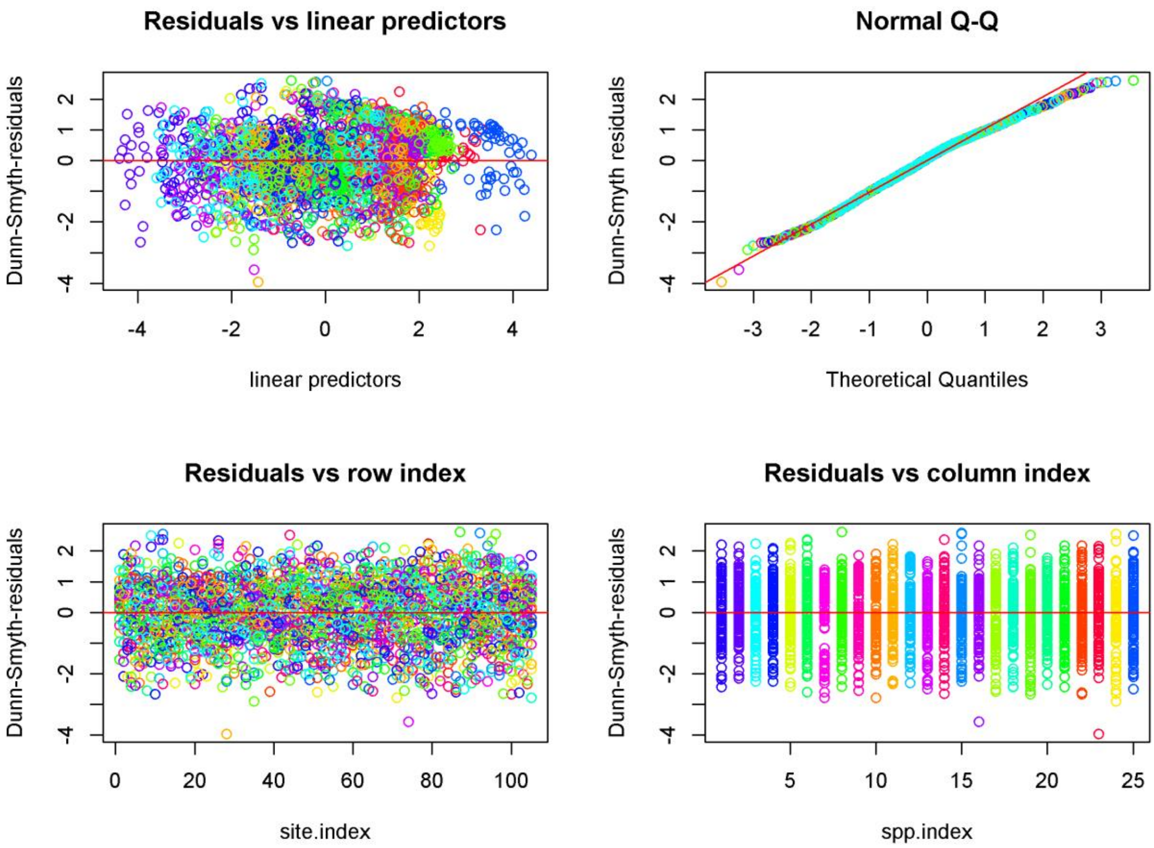

Figure S11: Dunn-Smyth residuals plots without covariates (assuming negative binomial counts) assessing the assumptions made when constructing the pure latent model. The colours in the plots represent different plant species. All three residual plots show a random scatter of the points without a pattern or shape indicating that the assumed relationship (negative binomial) between the plant community and the invasion status of the sites is correct.

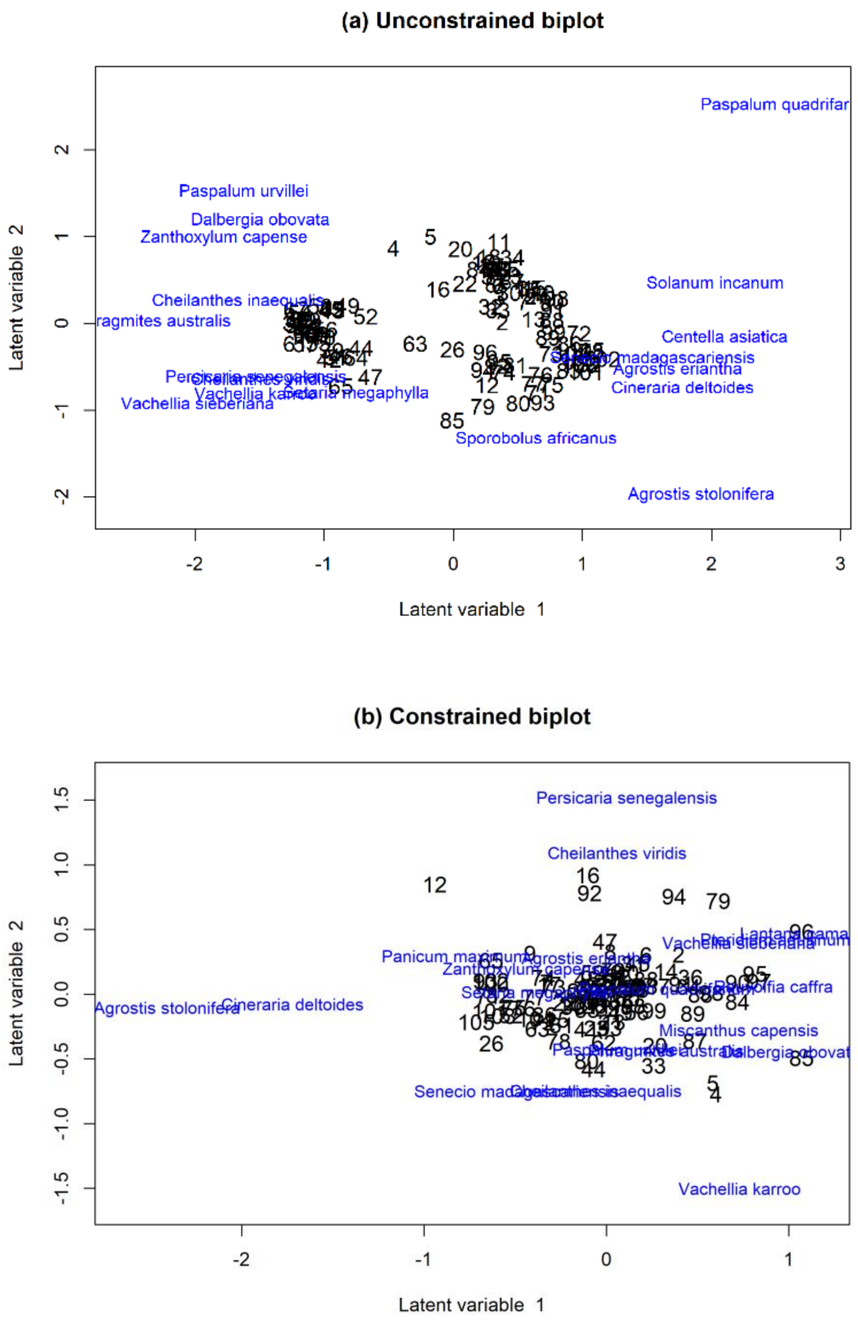

Figure S12: Ordination biplots of n = 105 sampling quadrats and 20 plant species with the largest factor loading form the origin for (a) the unconstrained latent variable model without covariates and (b) after including invasion status as covariates showing the effect of *P. quadrifarium* on species composition. The quadrats in ordination are labelled in row number. Quadrats and species far away from the origin and going towards the same direction are correlated with each other.

Appendices

Appendix A: Literature, websites, and databases used to score environmental and socio-economic impacts of 58 alien grass species according to the GISS.

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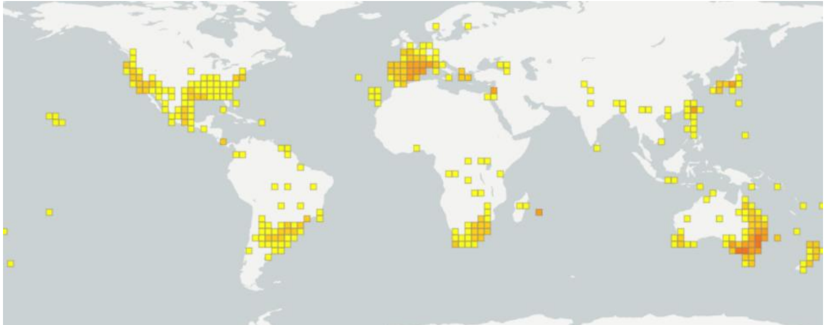
Appendix B: Risk analysis reports of six alien grasses occurring in South Africa.

Risk Analysis Report*:* *Paspalum dilatatum* Poir

Summary sheet

***Taxon*:** *Paspalum dilatatum* Poir	***Area*:** South Africa
Compiled by: Khensani Vulani NKUNA	**Approved by:**
Picture of *Taxon*  https://extension.umass.edu/landscape/weeds/paspalum-dilatatum	**Global distribution map**  (https://www.gbif.org/species/2705565)
Risk Assessment summary: *Paspalum dilatatum* Poir is already in South Africa, and is wide spread. Species distribution modelling show that this species has a relative occurrence rate of almost 50% in South Africa. The likelihood of entry, establishment, and spread is therefore probable. *P. dilatatum* has the potential to cause moderate environmental and socio-economic impacts, and these include invading managed turfs and pasture lands. It is also a reservoir of a fungus pathogen which can be toxic to livestock. The likelihood and consequences results indicate that *P. dilatatum* is a high-risk species.	**Risk score:** **High**
Management options summary: Management feasibility of *P. dilatatum* in South Africa is medium. Its populations are fairly accessible. However, it is prolific with about 50 seeds per raceme or up to 500 seeds per flowering stem, and the propagules are long, persistent with dormancy during winter. The species also reproduces vegetatively through rhizomes which makes it less easy to manage. *P. dilatatum* also occurs in our neighbouring countries and control efforts may be diminished by re-introduction from the neighbouring countries. *P. dilatatum* can be used as pasture grass for livestock or as grazing tolerant fodder plant, however, other sources indicate that it is not preferred by livestock as it is not palatable. Environmentally, the species is used for erosion control and to stabilize mine dumps, but these benefits can be fulfilled by other	**Ease of management:** **Medium**

native grass species. An eradication feasibility study has not been done on this species.	
Recommendations: I recommend that *P. dilatatum* Poir should be listed under category 1b in the NEMBA regulations as it is wide spread and has low benefits. I also recommend that a national management plan should be developed for the control of the populations occurring near natural areas. Due to the species' beneficial uses, I also recommend stakeholder engagements before the listing of the species, and during the development of the management plan.	**Listing category:** **1b**

1. Background

BAC1 Name of assessor(s)	
Name of lead assessor	Khensani Vulani Nkuna
BAC2 Contact details of assessor (s)	
Lead assessor	Organisational affiliation: South African National Biodiversity Institute, Kirstenbosch Research Centre, Cape Town, South Africa
	Email: khensani.vulani@gmail.com
	Phone: 0825946710
BAC3 Name(s) and contact details of expert(s) consulted	
Expert (1)	Name: Lesley Henderson
	Expertise: Weed Scientist (Southern Africa Plant Invader Atlas)
	Email: HendersonL@arc.agric.za
	Phone: + 27 33 335 9190
Expert (2)	Name: Sigrun Ammann
	Expertise: Grassland Society of Southern Africa president
	Email: SigrunA@elsenburg.com
	Phone: +27 44 803 3726
Expert (3)	Name: Dave Gooodenough
	Expertise: Pasture scientist at the Agricultural Research Council
	Email: GoodenoughD@arc.agric.za
	Phone: + 27 33 335 9190
Comments: I acknowledge the Alien Grass Working Group for referring me to the experts: Lesley Henderson, Sigrun Ammann, and Dave Goodenough during a discussion in 2016. Lesley Henderson: provided knowledge on unaided pathways Sigrun Ammann: provided knowledge on habitat suitability Dave Goodenough: provided knowledge of introduction and spread pathways	

<table>
<tr><td colspan="2">BAC4 Scientific name of Taxon under assessment</td></tr>
<tr><td>Taxon name: Paspalum dilatatum</td><td>Authority: Poir (J.B.AM de Lamark 1804)</td></tr>
<tr><td colspan="2">Comments:
Species level</td></tr>
<tr><td colspan="2">References:
Roskov Y., Abucay L., Orrell T., Nicolson D., Bailly N., Kirk P.M., Bourgoin T., DeWalt R.E., Decock W., De Wever A., Nieukerken E. van, Zarucchi J., Penev L., eds. (2018). Species 2000 & ITIS Catalogue of Life, 28th March 2018. Digital resource at www.catalogueoflife.org/col. Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-8858.</td></tr>
<tr><td colspan="2">BAC5 Synonym(s) considered</td></tr>
<tr><td colspan="2">Synonyms:
Digitaria dilatata (Poir.) Coste (synonym); Panicum platense (Spreng.) Kuntze (synonym); Paspalum dilatatum var. decumbens Vasey (synonym); Paspalum dilatatum subsp. Flavescens Roseng., B.R.Arrill. & Izag. (synonym); Paspalum dilatatum f. paucispica Hack., nom. nud. (synonym); Paspalum dilatatum var. sacchariferum Arechav. (synonym); Paspalum eriophorum Schult. & Schult.f. (synonym); Paspalum lanatum Spreng., nom. illeg. (synonym); Paspalum moluccanum Huber, nom. superfl. (synonym); Paspalum ovatum Nees ex Trin., nom. superfl. (synonym); Paspalum ovatum var. grandiflorum Nees (synonym); Paspalum pedunculare J.Presl (synonym); Paspalum platense Spreng. (synonym); Paspalum selloi Spreng. ex Nees, pro syn. (synonym)</td></tr>
<tr><td colspan="2">Comments:
Species level</td></tr>
<tr><td colspan="2">References:
Roskov Y., Abucay L., Orrell T., Nicolson D., Bailly N., Kirk P.M., Bourgoin T., DeWalt R.E., Decock W., De Wever A., Nieukerken E. van, Zarucchi J., Penev L., eds. (2018). Species 2000 & ITIS Catalogue of Life, 28th March 2018. Digital resource at www.catalogueoflife.org/col. Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-8858.</td></tr>
<tr><td colspan="2">BAC6 Common name(s) considered</td></tr>
<tr><td colspan="2">Common names:
English: Dallis grass, Water grass, Dallas grass, Dallisgrass; French: Herbe de miel , Herbe sirop, Hiku nua, Palpalum dilate; Spanish: grama de agua, pasto miel, pasto dallis, pasto chato, zacate dallis, hierba dallis, hierba de australia</td></tr>
<tr><td colspan="2">Comments:</td></tr>
<tr><td colspan="2">References:
http://www.itis.gov.</td></tr>
<tr><td colspan="2">BAC7 What is the native range of the Taxon? (map in Appendix BAC7)</td></tr>
<tr><td>Response:
Native to South America (i.e. Brazil, Bolivia, Argentina, Chile, Paraguay and Uruguay).</td><td>Confidence: High</td></tr>
<tr><td colspan="2">Comments:</td></tr>
</table>

Confidence high because all sources confirm each other
References: Heuzé V., Tran G., Sauvant D. (2015). *Dallis grass (Paspalum dilatatum)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/404. *Last updated on May 11, 2015, 14:30* http://www.tropicalforages.info/key/forages/Media/Html/entities/*paspalum_dilatatum*.htm. http://www.herbiguide.com.au/Descriptions/hg_*Paspalum*.htm.
BAC8 What is the global alien range of the *Taxon*? (map in Appendix BAC8)
Response: Austalia, Spain, Subtropics of USA, France, Japan, Brazil, South Africa, Argentina, New Zealand, Taiwan, Portugal, Spain, Azores, Italy, Austria, Germany, Iran, Turkey, India. Swaziland, Lesotho, and Zimbabwe — Confidence: High
Comments:
References: *Paspalum dilatatum* Poir. stdterms.in GBIF Secretariat (2017). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei http://www.tropicalforages.info/key/forages/Media/Html/entities/*paspalum_dilatatum*.htm.
BAC9 Geographic scope = the *Area* under consideration
Area of assessment: South Africa
Comments:
BAC10 Is the *Taxon* present in the *Area*?
Response: Yes — Confidence: High
Comments: *P. dilatatum* is wide spread in the Area
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria South African National Biodiversity Institute. 2016. Botanical Database of Southern Africa (BODATSA) [dataset]. doi: to be assigned.
BAC11 Availability of physical specimen
Response: Yes — Confidence in ID: High
Herbarium or museum accession number: Herbarium or museum accession number: 30117 (Brahm's code) Live species also available in the Area
References: South African National Biodiversity Institute. (2016). Botanical Database of Southern Africa (BODATSA) [dataset]. doi: to be assigned.
BAC12 Is the *Taxon* native to the *Area* or part of the *Area*?

The *Taxon* is native to (part of) the *Area*.	No	Confidence: High
The *Taxon* is alien in (part of) the *Area*.	Yes	Confidence: High
Comments: *P. dilatatum* is alien across the whole area		
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria		
BAC13 What is the *Taxon*'s introduction status in the *Area*?		
The *Taxon* is in cultivation/containment.	No	Confidence: Low
The *Taxon* is present in the wild.	Yes	Confidence: High
The *Taxon* has established/naturalised.	Yes	Confidence: High
The *Taxon* is invasive.	Yes	Confidence: High
Comments: *P. dilatatum* was initially introduced via pasture research station (was cultivated in containment), but it is now widely distributed, it is not cultivated in the stations anymore. However, it still occurs as a problematic weed in one of the stations and has also become invasive and undesirable.		
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria Expert 3: Dave Goodenough		
BAC14 Primary (introduction) pathways		
Release	No	Confidence: Low
Escape	Yes	Confidence: Medium
Contaminant	No	Confidence: Low
Stowaway	Yes	Confidence: Low
Corridor	No	Confidence: Low
Unaided	No	Confidence: Low
Comments: Introduced into South Africa via pasture research stations (Cedara, Estcourt, Leeuwkuil, and Prinshof) as a trial species for pasture		
References: Expert 3: Dave Goodenough Visser, V., Wilson, J.R., Fish, L., Brown, C., Cook, G.D. and Richardson, D.M. (2016). Much more give than take: South Africa as a major donor but infrequent recipient of invasive non-native grasses. Global Ecology and Biogeography, 25(6), pp.679-692.		

Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria

2. Likelihood

LIK1 Likelihood of entry via unaided primary pathways	
Response: Probable	Confidence: High
Rationale: *P. dilatatum* is already in the country and has naturalised (Personal observation, 2017), however, it is unlikely for the species to be introduced into the country unaided “Naturalised from South America.” Fish et al (2015) The confidence level is high because there is direct relevant observational evidence to support the assessment.	
References: Personal observation Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria Expert 1: Lesley Henderson	

LIK2 Likelihood of entry via human-aided primary pathways	
Response: Probable	Confidence: Low
Rationale: *P. dilatatum* is present in neighbouring countries, may come into South Africa via connected water ways Confidence low because there is no direct observation to support the assessment	
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria. Visser, V., Wilson, J.R., Fish, L., Brown, C., Cook, G.D. and Richardson, D.M. (2016). Much more give than take: South Africa as a major donor but infrequent recipient of invasive non-native grasses. Global Ecology and Biogeography, 25(6), pp.679-692. *Paspalum dilatatum* Poir. stdterms.in GBIF Secretariat (2017). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2018-06-10.	

LIK3 Habitat suitability	
Response: Probable	Confidence: High
Rationale: Species is already wide spread in South Africa. It grows from sea level up to an altitude of 2300 m. Optimal growth conditions are average day temperatures ranging from 23°C to 30°C, annual rainfall within 900-1300 mm or where irrigation is available, on heavy, moist, alluvial and basaltic clay soils or red loams with high fertility and a soil pH from 5.5 to 7.0. Dallis grass is very adaptive and can grow where annual rainfall is less than 750 mm, on soils in the 4.5-8 pH range. Dallis grass is remarkably	

tolerant of drought because of its thick rhizomes. It is mildly frost tolerant and its deep root allows it to regrow after frost The confidence level is high because there is direct relevant observational evidence to support the assessment.
References: Heuzé V., Tran G., Sauvant D. (2015). *Dallis grass (Paspalum dilatatum)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/404 *Last updated on May 11, 2015, 14:30* Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria. Expert 2: Sigrun Ammann

LIK4 Climate suitability	
Response: Probable	Confidence: High
Rationale: Species is already widely distributed across the Area (Fish et al. 2015). Species distribution modelling shows that *P. dilatatum* has a large relative occurrence rate in South Africa (see Figure LIK 4 in appendix of this report) The confidence level is high because there is direct relevant observational evidence to support the assessment.	
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria.	

LIK5 Unaided secondary (dispersal) pathways	
Response: Fairly probable	Confidence: Low
Rationale: Can float via water ways and spread by birds during nest constructions Grass used by birds to build nest Confidence low because there is no direct observation to support the assessment	
References: Expert 3: Dave Goodenough Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria.	

LIK6 Human aided secondary (dispersal) pathways	
Response: Probable	Confidence: Medium
Rationale: It is possible for the taxon to be carried by human as it grows along disturbed areas on pathways such as hiking trails and along the roads. Livestock such as cattle may also carry propagules of the taxon when they feed on it. Used as hey for livestock “Widely used as fodder and leys” (Fish et al. 2015).	

Confidence medium because there is some direct observation to support the assessment, but some information is inferred
References: Expert 3: Dave Goodenough Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria.

3. Consequences

IMP1 Environmental impact (Table 3)	
Response: MC	Confidence: Medium
Rationale: Based on transmission of disease and hybridisation	
References: See below	
IMP1a: Competition	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1b: Predation	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1c: Hybridisation	
Response: MC	Confidence: Medium
Rationale: “However, aposporous embryo sacs were present in ovules of the *P. pubiflorum* & Uruguayan dallisgrass hybrid, indicating that the genes controlling apomixis were from the apomictic Uruguayan dallisgrass.” (Actkinson et al. 1999). “Interspecific hybridisation and backcrossing were used in an attempt to transfer the ergot resistance of *Paspalum urvillei* (vaseygrass) into a sexual biotype of *P. dilatatum* (dallisgrass).” Schrauf et al. 2003 Confidence level is Medium as there is some direct observational evidence to support the assessment, but some information is inferred, and Impacts are recorded at a spatial scale which may not be relevant to the scale over which original native communities can be characterized, but extrapolation or downscaling of the data to relevant scales is considered reliable, or to embrace little uncertainty	
References: Actkinson, J.M. and Burson, B.L. (1999). Cytogenetic Relationships between *Paspalum pubiflorum* and Three South American *Paspalum* Species 1. International journal of plant sciences, 160(4), pp.775-781. Schrauf, G.E., Blanco, M.A., Cornaglia, P.S., Deregibus, V.A., Madia, M., Pacheco, M.G., Padilla, J., García, A.M. and Quarín, C. (2003). Ergot resistance in plants of Paspalum dilatum incorporated by hybridisation with *Paspalum urvillei*. Tropical Grasslands, 37(3), pp.182-186.	

IMP1d: Transmission of disease	
Response: MC	Confidence: Low
Rationale: "The plant-pathogenic fungus *Claviceps paspali* infects florets of the dallisgrass *Paspalum dilatatum* and induces the plant to produce honeydew (containing massive amounts of conidia), which in turn attracts insects for dispersal of the fungal spores. In Japan, the association between *C. paspali* and its host plant is common, although both *P. dilatatum* and *C. paspali* are introduced species." Sugiura and Yamazaki (2007). "A serious problem with the grass is its susceptibility to ergot (*Claviceps paspali*)." Davies and Cohen 1(992). Confidence level is low because in the sources referenced the species is only a host of a pathogen (*C. paspali*) however there is no direct observation of the species transmitting the pathogen to native species.	
References: Sugiura, S. and Yamazaki, K. (2007). Migratory moths as dispersal vectors of an introduced plant-pathogenic fungus in Japan. Biological Invasions, 9(2), pp.101-106. Davies, L.J. and Cohen, D. (1992). Phenotypic variation in somaclones of *Paspalum dilatatum* and their seedling offspring. Canadian Journal of Plant Science, 72(3), pp.773-784.	
IMP1e: Parasitism	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1f: Poisoning/toxicity	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1g: Bio-fouling	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1h: Grazing/herbivory/browsing	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1i: Chemical, physical or structural impact on ecosystem	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1k: Interaction with other alien species	
Response: DD	Confidence: Low
Rationale:	
References:	

IMP2 Socio-economic impact (Table 3)	
Response: MO	Confidence: High
Rationale: Based on Infrastructure and administration and impacts on animal production	
References: See below	
IMP2a: Agriculture	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2b: Animal production	
Response: MO	Confidence: High
Rationale: "During the last decade *Paspalum dilatatum* Poir. has attained considerable prominence as a forage grass in various parts of the South. One serious objection to its use, however, is that forage poisoning frequently results among cattle feeding on it." Brown (1916) "Outbreaks of staggers following ingestion of paspalum *(Paspalum dilatatum*) containing the sclerotium of C. paspali have been recorded in cattle, horses and sheep on the east coast of Australia for 100 years. The first intoxication occurred near Scone, NSW in March 2002. Three Australian Stockhorse foals, 2–3 months of age, were affected. In the second occurrence of intoxication, near Forbes, NSW, eight mature Standardbred mares and geldings, 4–10 years of age, had been grazing in an irrigation channel for 2 days to reduce overgrowth that was predominantly paspalum. On the morning of the third day, two of the horses developed hindquarter paresis and had great difficulty using their hindlegs." Cawdell-Smith et al. (2010) Confidence is high because there is direct relevant observational evidence to support the assessment, and there are reliable/good quality data sources on impacts of the taxa.	
References: Brown, H.B. (1916). Life history and poisonous properties of Claviceps paspali. J Agric Res, 7(9), pp.401-407. Cawdell-Smith, A.J., Scrivener, C.J. and Bryden, W.L. (2010). Staggers in horses grazing *Paspalum* infected with Claviceps paspali. Australian veterinary journal, 88(10), pp.393-395.	
IMP2c: Mariculture /aquaculture	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2d: Forestry	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2e: Infrastructure and administration	
Response: MO	Confidence: Medium

Rationale: "Dallisgrass (*Paspalum dilatatum* Poir.) grows in water conveyance canals and reduces water velocity and discharges in these canals. Consequently, dallisgrass causes problems in operation and maintenance of irrigation and drainage canals. Dallisgrass affects water velocity in irrigation canals and furrows." Nasseri (2016) Confidence level is medium because there is some direct observational evidence to support the assessment, but some information is inferred.
References: Nasseri, A. (2016). Canal Geometry, Flow Velocity, Dallisgrass (*Paspalum dilatatum* Poir.) Density and Soil Phosphorous Effects on Hydraulic Resistance of Vegetated Canals. Tarım Bilimleri Dergisi, 22(2), pp.187-195.

IMP2f: Human health	
Response: DD	Confidence: Low
Rationale:	
References:	

IMP2g: Human social life	
Response: MN	Confidence: Medium
Rationale: "Dallisgrass is one of the most troublesome perennial weed species invading managed turfgrass systems in North Carolina. The presence of dallisgrass negatively affects the appearance, texture, and playability of desired turfgrass species in home lawns, golf courses, and athletic fields (Turgeon 2008)" (Henry et al. 2008). "Dallisgrass (*Paspalum dilatatum* Poir.) is a problematic rhizomatous perennial grass weed of managed turfgrass stands throughout the southern United States" (Johnston and Henry 2016). Confidence level: Medium because there is some direct observational evidence to support the assessment, but some information is inferred, and some of the information is not from the primary source.	
References: Johnston, C.R. and Henry, G.M. (2016). Dallisgrass (*Paspalum dilatatum*) Control with Thiencarbazone-methyl, Foramsulfuron, and Halosulfuron-methyl in Bermudagrass Turf. HortScience, 51(6), pp.754-756. Henry, G., Burton, J., Richardson, R. and Yelverton, F. (2008). Absorption and translocation of foramsulfuron in dallisgrass (*Paspalum dilatatum*) following preapplication of MSMA. Weed science, 56(6), pp.785-788.	

IMP3 Closely related species' environmental impact	
Response: N/A	Confidence:
Rationale:	
References:	

IMP4 Closely related species' socio-economic impact	
Response: N/A	Confidence:
Rationale:	

References:

IMP5 Potential impact	
Response: MO	Confidence: Low
Rationale: Competition: *Paspalum dilatatum* has the potential to compete with native desirable and palatable grasses, for nutrients, and space. Agricultural production: the species is a reservoir for a fungal pathogen has the potential to transmit the pathogen to agricultural crops, thereby decreasing their yield and overall quality. Human social life/ infrastructure: *Paspalum dilatatum* has the potential to decrease the aesthetic appeal of manage turfs by causing unevenness of the turfs thereby increasing management costs. Confidence level is low because there is no direct observation to support the assessment and all information is inferred based on the traits of the species.	
References:	

4. Management

MAN1 What is the feasibility to stop future immigration?	
Response: Low	Confidence: High
Rationale: The species occurs in neighbouring countries (Swaziland, Zimbabwe, Lesotho, Mozambique and Namibia), therefore, re-introduction of the species into South Africa is highly possible and regulating all pathways such as through waterways corridors, stowaway or as contaminant can be difficult. The spikelets of *P. dilatatum* are also hairy which enables them to attach to clothing and livestock hides. Confidence is high because there is direct relevant observational evidence to support the assessment, and there are reliable/good quality data sources on impacts of the taxa.	
References: https://keyserver.lucidcentral.org/weeds/data/media/Html/*paspalum_dilatatum*.htm	

MAN2 Benefits of the Taxon	
MAN2a Socio-economic benefits of the Taxon	
Response: Medium	Confidence: Medium
Rationale: *P. dilatatum* has very little socio-economic benefits, it was initially introduced into South Africa for pasture, it is also used as pasture for livestock in its native country, however other sources have indicated that the species is not palatable and therefore not preferred by livestock. (keyserver.lucidcentral.org) It is no longer preferable for pasture in South Africa due to its slow establishment rate, inconsistencies in seed quality and ergot fungus susceptibility (Taiton et al. 1990).	

"Used as a grazing tolerant fodder plant producing a good quantity of high quality, palatable forage if grazed to prevent it becoming rank. Used in irrigated pastures. Frost sensitive but recovers quickly from rootstock." (Heuzé et al 2015). Confidence level is medium because there is some direct observational evidence to support the assessment, but some information is inferred.
References: https://keyserver.lucidcentral.org/weeds/data/media/Html/*paspalum_dilatatum*.htm Heuzé V., Tran G., Sauvant D. (2015). *Dallis grass (Paspalum dilatatum)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/404 *Last updated on May 11, 2015, 14:30* Tainton N., Bransby D., dev Booysen P (1990) Common veld and pasture grasses of Natal. Pietermaritzburg: Shuter and Shooter. 198 pp.

MAN2b Environmental benefits of the Taxon	
Response: Low	Confidence: Medium
rationale: Its vigorous growth and deep rooting make dallis grass a very valuable plant for erosion control. It is used to stabilize mine dumps in South Africa (FAO, 2010). Confidence level is medium because there is some direct observational evidence to support the assessment, but some information is inferred.	
References: Heuzé V., Tran G., Sauvant D. (2015). *Dallis grass (Paspalum dilatatum)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/404 *Last updated on May 11, 2015, 14:30*	

MAN3 Ease of management (Table 4)	
Response: Medium	Confidence: Low
Rationale: Ease of management is medium because some aspects make it difficult to manage For example: *P. dilatatum* is already wide spread in South Africa, the seeds can stay dormant during winter and can persist for five years, produces are about 50 seeds per raceme or up to 500 seeds per flowering stem and can also reproduce through rhizomes. It is drought and waterlogging tolerant. However, *P. dilatatum* populations in South Africa, are fairly accessible and time for first reproduction is not short. Also see below	
References: See below	
MAN3a How accessible are populations?	
Response:1	Confidence: Medium
Rationale: 1 = Moderately accessible Most population of *P. dilatatum* are easily accessible grows in disturbed area and along roadsides, however, *P. dilatatum* can also grows from sea level up to an altitude of 2300 m. Confidence level is medium because there is some direct observational evidence to support the assessment, but some information is inferred.	
References:	

Heuzé V., Tran G., Sauvant D. (2015). *Dallis grass (Paspalum dilatatum)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/404 *Last updated on May 11, 2015, 14:30*	
MAN3b Is detectability critically time-dependent?	
Response: 2	Confidence: Medium
Rationale: 2 = Yes, detectability is critically time-dependent. Without seeds the species looks similar to other *Paspalum* species such as *P. urvillei.* "Resembles *P. urvillei*, which has more racemes and smaller spikelets" (Fist et al. 2015). Confidence level is medium because there is some direct observational evidence to support the assessment, but some information is inferred.	
References: Heuzé V., Tran G., Sauvant D. (2015). *Dallis grass (Paspalum dilatatum)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/404 *Last updated on May 11, 2015, 14:30* Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria.	
MAN3c Time to reproduction	
Response: 1	Confidence: Medium
Rationale: 1 = takes 1 to 3 years to reach reproduction stage Seeds germinate in moist warm months and seedling growth is slow, often taking 2-3 years to reach their first flowering (www.herbiguide.com.au). Flowering: October to May in South Africa (Fish et al. 2015). Confidence level is medium because there is some direct observational evidence to support the assessment, but some information is inferred.	
References: http://www.herbiguide.com.au/Descriptions/hg_Paspalum.htm Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015) identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria.	
MAN3d Propagule persistence	
Response: 1	Confidence: Low
Rationale: 1 = propagules persist for 1 to 5 years Seed dormancy during winter. Mature plants can produce more than 250,000 seeds. A fungus often destroys many seeds in other Confidence is low because there is no direct observation from the source to support the assessment	
References: http://www.herbiguide.com.au/Descriptions/hg_Paspalum.htm	

MAN4 Has the feasibility of eradication been evaluated?

Response: No	Confidence: Low
Rationale:	
References:	

5. Calculations

Likelihood = Probable

Parameter	Likelihood	Stages	Final assessment
LIK1	Probable	P(entry) = Probable	P (invasion) = Probable
LIK2	Probable		
LIK3	Probable	P(establishment) = Probable	
LIK4	Probable		
LIK5	Fairly probable	P (spread) = Probable	
LIK6	Probable		

Consequence = MO

Parameter	Mechanism/sector	Response
IMP1a	Competition	DD
IMP1b	Predation	DD
IMP1c	Hybridisation	MC
IMP1d	Disease transmission	MC
IMP1e	Parasitism	DD
IMP1f	Poisoning/toxicity	DD
IMP1g	Bio-fouling	DD
IMP1h	Grazing/herbivory/browsing	DD
IMP1i	Chemical, physical, structural impact	DD
IMP1k	Interaction with other aliens	DD
IMP2a	Agriculture	DD
IMP2b	Animal production	MO
IMP2c	Mariculture/aquaculture	DD
IMP2d	Forestry	DD
IMP2e	Infrastructure	MO
IMP2f	Human health	DD
IMP2g	Human social life	MN

Risk = High

		Consequences				
		MC	MN	MO	MR	MV
Likelihood	Extremely unlikely	low	low	low	medium	medium
	Very unlikely	low	low	low	medium	high
	Unlikely	low	low	medium	high	high
	Fairly probable	medium	medium	high	high	high
	Probable	medium	high	high	high	high

Ease of management = Medium

Parameter	Question	Response
MAN3a	How accessible are populations?	1
MAN3b	Is detectability critically time-dependent?	2
MAN3c	Time to reproduction	1
MAN3d	Propagule persistence	1
MAN3	**SUM**	**5**

Supplementary to add to answer sheet

Appendix BAC7: Provide here a map of the native range, if possible. If the map is available in a file, please insert a low res copy (<1MB) and provide the file name and (if possible) a link to a higher resolution copy below.

https://www.gbif.org/species/2705565

Appendix BAC8: Provide here a map of the global alien range, including the range within the *Area*, if possible. If the map is available in a file, please insert a low-res copy (<1MB) and provide the file name and (if possible) a link to a higher resolution copy below.

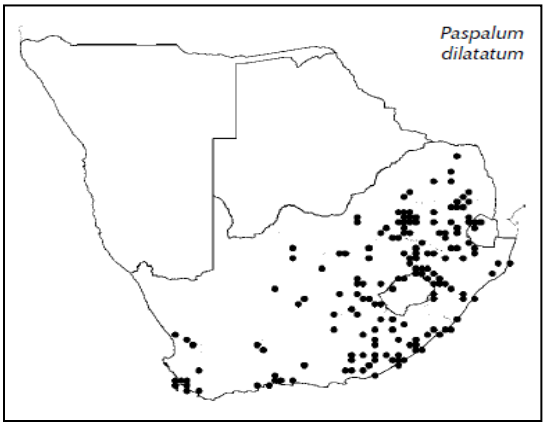


Figure BAC8a: Current distribution of *P. dilatatum* in South Africa (Fish et al. 2015)

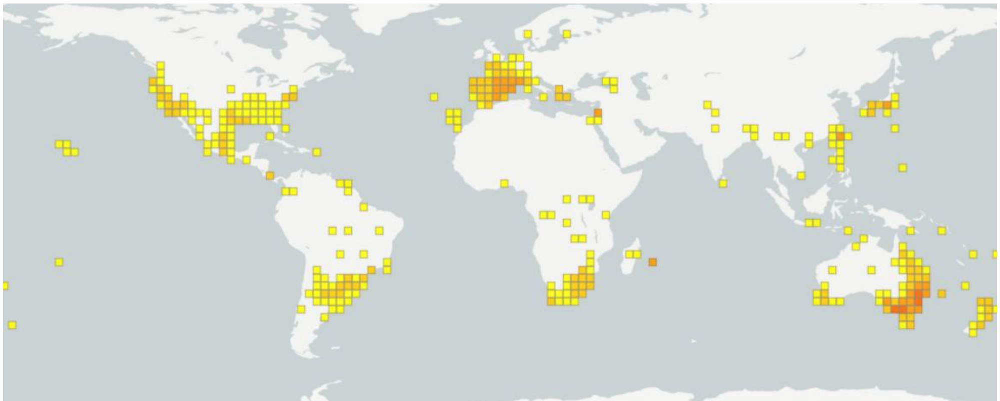


Figure BAC8b: Global distribution of *P. dilatatum* (alien and native) (https://www.gbif.org/species/2705565)

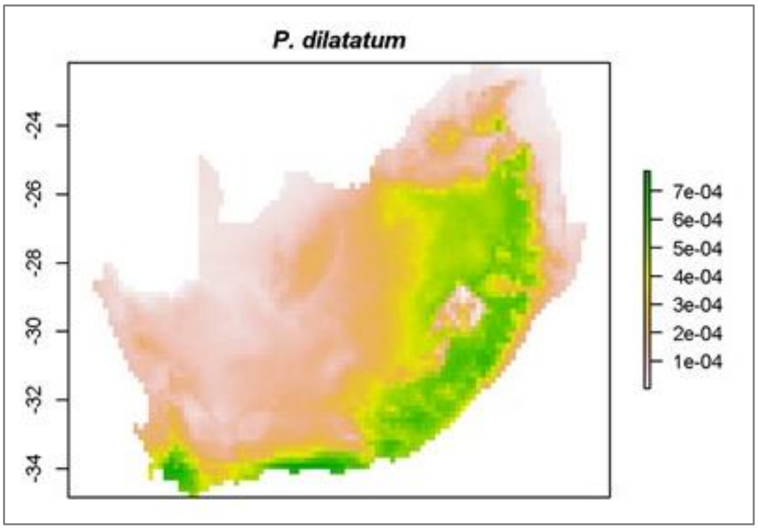
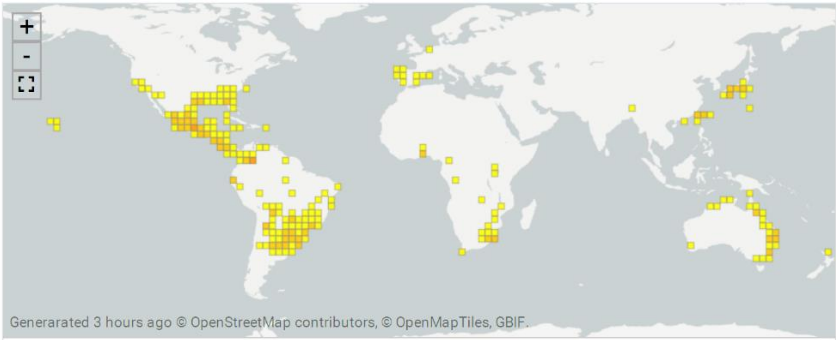


Figure LIK4: Relative occurrence rate of *P. dilatatum* in South Africa (in correspondence with LIK4 Climate suitability of this report).

Risk Analysis Report: *Paspalum notatum* Flugge

Summary sheet

***Taxon*:** *Paspalum notatum* Flugge (1810)	***Area*:** South Africa
Compiled by: Khensani Vulani NKUNA	**Approved by:**
Picture of *Taxon*  **www.zambiaflora.com/**	**Alien distribution map** (BAC8)  **https://www.gbif.org/species/2705621**

Risk Assessment summary: *Paspalum notatum* occurs in most provinces in South Africa, therefore, likelihood of entry is probable. However, it is mostly found in disturbed areas such as cultivated areas (gardens, irrigated pasture lands), roadsides and hiking trails. Climate suitability of P. notatum is < 5 % in South Africa. There is no clear record of this species causing impact in natural ecosystems. *P. notatum* can cause moderate skin allergies affecting human health, it can invade managed turfs such as Golf courses and reduce their aesthetic value buy causing unevenness. This species is a high-risk species in South Africa because its overall consequences are moderate (MO) and the likelihood is of entry, establishment, and spread if fairy probable.	**Risk score:** **High**
Management options summary: *P. notatum* reproduces by seeds and rhizomes, the seeds are long living in the seed bank due to dormancy and can stay viable even after ingestion by livestock. The taxon also occurs in South African neighbouring countries which can lower eradication feasibility due to the likelihood of reintroduction. Overall management feasibility is medium. Here in South Africa *P. notatum* is still used as lawn grass in Mpumalanga, Gauteng, Kwa-Zulu Natal and Limpopo. Environmentally, it can be used to stabilise soil and for phytoremediation. It can also be used as hey but is no	**Ease of management:** **Medium**

longer cultivated for that purpose. Its benefits can be fulfilled by other native species.	
Recommendations: I recommend that this taxon should be listed under category 1b in the NEMBA regulations because it is already wide spread due to its beneficial (low) uses as lawn grass. Also, I recommend that Stakeholders should be engaged, and a management plan should be developed to address the populations occurring escaping the gardens and into other disturbed areas.	**Listing category:** **1b**

1. Background

BAC1 Name of assessor(s)	
Name of lead assessor	Khensani Vulani Nkuna
BAC2 Contact details of assessor (s)	
Lead assessor	Organisational affiliation: South African National Biodiversity Institute, Kirstenbosch Research Centre, Cape Town, South Africa
	Email: khensani.vulani@gmail.com
	Phone: 0825946710
BAC3 Name(s) and contact details of expert(s) consulted	
Expert (1)	Name: Lesley Henderson
	Expertise: Weed Scientist (SAPIA)
	Email: HendersonL@arc.agric.za
	Phone: + 27 33 335 9190
Expert (2)	Name: Sigrun Ammann
	Expertise: GSSA president
	Email: SigrunA@elsenburg.com
	Phone: +27 44 803 3726
Expert (3)	Name: Dave Gooodenough
	Expertise: Pasture scientist (ARC)
	Email: GoodenoughD@arc.agric.za
	Phone: + 27 33 335 9190
Comments: Acknowledgements to the Alien Grass Working Group who referred to me the above experts: Lesley Henderson (provided knowledge on potential impact), Sigrun Ammann (knowledge population accessibility), and Dave Goodenough (provided knowledge on dispersal pathway and the species' future immigration).	
BAC4 Scientific name of Taxon under assessment	
Taxon name: *Paspalum notatum*	Authority: Flugge (1810)

Comments: Species level	
References: Roskov Y., Abucay L., Orrell T., Nicolson D., Bailly N., Kirk P.M., Bourgoin T., DeWalt R.E., Decock W., De Wever A., Nieukerken E. van, Zarucchi J., Penev L., eds. (2018). Species 2000 & ITIS Catalogue of Life, 28th March 2018. Digital resource at www.catalogueoflife.org/col. Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-8858.	
BAC5 Synonym(s) considered	
Synonyms: *Paspalum distachyon* Willd. ex Döll, pro syn. (synonym), *Paspalum notatum* var. latiflorum Doll (synonym), *Paspalum notatum* var. typicum Parodi, nom. inval. (synonym), *Paspalum saltense* Arechav. (synonym), *Paspalum taphrophyllum* Steud. (synonym), *Paspalum uruguayense* Arechav. (synonym)	
Comments: Species level	
References: Roskov Y., Abucay L., Orrell T., Nicolson D., Bailly N., Kirk P.M., Bourgoin T., DeWalt R.E., Decock W., De Wever A., Nieukerken E. van, Zarucchi J., Penev L., eds. (2018). Species 2000 & ITIS Catalogue of Life, 28th March 2018. Digital resource at www.catalogueoflife.org/col. Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-8858.	
BAC6 Common name(s) considered	
Common names: English: Bahia grass, Common bahai, Lawn Paspalum; Spanish: Gramilla blanca; Gramilla brava; Hierba de Bahia; Hierba tejana; Pasto bahia; French: Herbe de Bahia; Portuguese: Grama-batateis	
Comments:	
References: https://www.cabi.org/isc/abstract/20153048098	
BAC7 What is the native range of the *Taxon*? (add map in Appendix BAC7)	
Response: Mexico, USA, the Caribbean (Antigua and Barbuda, Cuba, Dominica, Grenada, Guadeloupe, Jamaica, Martinique, Montserrat, Puerto Rico, St Lucia, St Vincent and Grenadines), South America (Argentina, Bolivia, Brazil, Paraguay, Peru, Uruguay), and central America (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico (east), Nicaragua, Panama).	Confidence: High
Comments: “It is a neophyte native to America, known for applications in phytoremediation.” Stinca et al. (2016) “Probably the most widespread native grass species in South and Central America, found on open ground, savannas, and pastures.” www.tropicalforages.info Confidence level is high because the information is not contradictory.	

References: Stinca, A., Galasso, G. and Banfi, E. (2016). First Italian record of Paspalum notatum Flüggé (Poaceae) and its typification. Acta Botanica Croatica, 75(1), pp.153-156. Heuzé V., Tran G. (2016). *Bahia grass (Paspalum notatum)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/402 *Last updated on March 23, 2016, 16:46* www.tropicalforages.info/key/forauges	
BAC8 What is the global alien range of the *Taxon*? (add map in Appendix BAC8)	
Response: Australia, North America, Asia (Indonesia, Thailand, and Vietnam), Brazil, Mexico, Cuba, Argentina, Italy, USA (Alabama, Arkansas, California, Florida, Georgia, Louisiana, Missouri, New Jersey, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, Puerto Rico and the Virgin Islands), Japan, Colombia, Paraguay, Taiwan, South Africa, Swaziland, Lesotho, Mozambique, Zimbabwe	Confidence: High
Comments: Confidence level is high because sources confirm each other.	
References: Paspalum notatum Fluegge stdterms.in GBIF Secretariat (2017). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2018-06-11. Stinca, A., Galasso, G. and Banfi, E. (2016). First Italian record of *Paspalum notatum* Flüggé (Poaceae) and its typification. Acta Botanica Croatica, 75(1), pp.153-156. Heuzé V., Tran G. (2016). *Bahia grass (Paspalum notatum)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/402 *Last updated on March 23, 2016, 16:46* Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015) Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria http://www.bugwood.org	
BAC9 Geographic scope = the *Area* under consideration	
Area of assessment: South Africa	
Comments:	
BAC10 Is the *Taxon* present in the *Area*?	
Response: Yes	Confidence: High
Comments: *P. notatum* has naturalised and is wide spread here in South Africa (Fish et al 2015). GPS coordinate of site: S28° 34m 40.1s' E31° 14 m 24.9s'	
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015) identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria South African National Biodiversity Institute. (2016). Botanical Database of Southern Africa (BODATSA) [dataset]. doi: to be assigned.	

<table>
<tr><td colspan="3">BAC11 Availability of physical specimen</td></tr>
<tr><td colspan="2">Response: Yes</td><td>Confidence in ID: High</td></tr>
<tr><td colspan="3">Herbarium or museum accession number: 30119 (Brahm's code)
Naturalised in Gauteng, Limpopo, Freestate, Kwa-Zulu Natal, Mpumalanga and the Western Cape (Fish et al. 2015)</td></tr>
<tr><td colspan="3">References:
South African National Biodiversity Institute. (2016). Botanical Database of Southern Africa (BODATSA) [dataset]. doi: to be assigned.
Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria
Personal observation (2016)</td></tr>
<tr><td colspan="3">BAC12 Is the Taxon native to the Area or part of the Area?</td></tr>
<tr><td>The Taxon is native to (part of) the Area.</td><td>No</td><td>Confidence: High</td></tr>
<tr><td>The Taxon is alien in (part of) the Area.</td><td>Yes</td><td>Confidence: High</td></tr>
<tr><td colspan="3">Comments:</td></tr>
<tr><td colspan="3">References:
South African National Biodiversity Institute. (2016). Botanical Database of Southern Africa (BODATSA) [dataset]. doi: to be assigned.
Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria</td></tr>
<tr><td colspan="3">BAC13 What is the Taxon's introduction status in the Area?</td></tr>
<tr><td>The Taxon is in cultivation/containment.</td><td>Yes</td><td>Confidence: High</td></tr>
<tr><td>The Taxon is present in the wild.</td><td>Yes</td><td>Confidence: High</td></tr>
<tr><td>The Taxon has established/naturalised.</td><td>Yes</td><td>Confidence: High</td></tr>
<tr><td>The Taxon is invasive.</td><td>No</td><td>Confidence: Low</td></tr>
<tr><td colspan="3">Comments: P. notatum is cultivated in South Africa as lawn grass. Outside cultivation, P. notatum is naturalised in disturbed areas and invades agricultural lands.</td></tr>
<tr><td colspan="3">References:
Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015) identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria
Personal observation (2016)
Expect 3: Dave Goodenough</td></tr>
<tr><td colspan="3">BAC14 Primary (introduction) pathways</td></tr>
<tr><td>Release</td><td>No</td><td>Confidence: Low</td></tr>
<tr><td>Escape</td><td>Yes</td><td>Confidence: Medium</td></tr>
<tr><td>Contaminant</td><td>No</td><td>Confidence: Low</td></tr>
</table>

Stowaway	No	Confidence: Low
Corridor	No	Confidence: Low
Unaided	No	Confidence: Low
Comments: *P. notatum* escapes gardens by spreading into the surrounding disturbed areas (i.e. along the roads, managed other turfs, pasture lands, etc		
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria Expect 3: Dave Goodenough		

2. Likelihood

LIK1 Likelihood of entry via unaided primary pathways	
Response: Probable	Confidence: High
Rationale: *P. notatum* already occurs in South Africa and used for lawn. “Frequency in southern Africa: infrequent.” Fish et al (2015) The confidence level is high because there is direct relevant observational evidence to support the assessment.	
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015) identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria.	

LIK2 Likelihood of entry via human-aided primary pathways	
Response: Fairly probable	Confidence: Medium
Rationale: The likelihood of entry is fairly probable because there are several human aided pathways of introduction such as pasture but not regularly used as the species is not palatable. *P. notatum* can enter South Africa from the neighbouring countries as a contaminant of soil or can be attached to livestock although these are not the primary pathways of introduction in to the country (Expert 3). “Pasture though not extensively cultivated as it is less productive and palatable than most other cultivated pastures.” Fish et al (2015) Confidence level is medium because there is some direct observational evidence to support the assessment, but some information is inferred.	
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria. Expert 3: Dave Goodenough	

LIK3 Habitat suitability	
Response: Fairy probable	Confidence: Medium

Rationale: Habitat suitability is fairy probable because key conditions for the suitable habitat of *P. notatum* are met only in a marginal part of the country because the species prefers high rain falls and sandy to clay soils. “Rainfall in its native habitat mostly ranges from 700-1,500 mm year. It is generally sown in areas with a well distributed annual rainfall from about 900-1,500 mm, but can be used at up to 2,500 mm. It is very tolerant to drought and to a lesser extent to salinity when well stablished. It is known to survive 20 to 36 days of flooding. It also occurs from sea level to over 2,300 m asl (Bolivia and Mexico), representing an average annual temperature range of about 17-25ºC. Frosts occur over a significant part of its range. Optimum temperature for germination is 30-35°C, for growth 25-30°C, and for tillering, 20-25°C. Little growth occurs in the cooler months. Tops are burnt off by frost and are killed when temperatures fall below -10° to -12°C.” Heuze and Tran (2016) “Occurs in high rainfall areas on sandy or clay soil; often in disturbed places and cultivation. Frequency in southern Africa: Infrequent” Fish et al (2015) “It is adapted to both upland and lowland areas, and has been found on open ground, savannas, and pastures from elevations at sea level to 2000 m in Central and South America. *P. notatum* easily invades disturbed pastures, roadsides, and rights-of-way, but does not appear to invade intact, undisturbed, native systems.” www.bugwood.org Confidence level medium because there is some direct evidence to support the assessment, but some information is inferred.
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria. Heuzé V., Tran G. (2016). *Bahia grass (Paspalum notatum)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/402 *Last updated on March 23, 2016, 16:46* http://www.bugwood.org

LIK4 Climate suitability	
Response: Unlikely	Confidence: High
Rationale: Species has suitable climate in South Africa (see Figure LIK 4 in appendix of this report), but it is very little (relative occurrence rate < 5%). “It grows from sea level to an altitude of 2000 m, and in regions with annual rainfall from 750 mm to 2000 mm. Optimal mean temperature is 20°C.” Heuze and Tran (2016) The confidence level is high because there is direct relevant observational evidence to support the assessment.	
References: Heuzé V., Tran G. (2016). *Bahia grass (Paspalum notatum)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/402 *Last updated on March 23, 2016, 16:46*	

LIK5 Unaided secondary (dispersal) pathways	
Response: Unlikely	Confidence: Medium

Rationale: Unaided dispersal pathway of *P. notatum* is unlikely because this species is sessile, however its dispersal capabilities are slow and short distanced (< 50 km in 10 years). *P. notatum* spreads slowly but surely. Poor seedling competitiveness limits spread, but once plants are established, they spread strongly by virtue of the stout ground-appressed stolons, and strong root system.” Heuzé and Tran (2016) Spreading by means of long, fibrous, rhizome-like stolons that root at the nodes to form new growth, the plant can form a dense mat of growth, especially when cut regularly as in a lawn (tropical.theferns.info.) Confidence level is medium because it is a taxonomic trait for the species to spread using rhizomes but the rate of spread in the sources above is inferred.
References: Heuzé V., Tran G. (2016). *Bahia grass (Paspalum notatum)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/402 *Last updated on March 23, 2016, 16:46* Tropical Plants Database, Ken Fern. tropical.theferns.info. 2018-05-13. <tropical.theferns.info/viewtropical.php?id=*Paspalum+notatum*> Expert 1: Lesly Henderson

LIK6 Human aided secondary (dispersal) pathways	
Response: Probable	Confidence: High
Rationale: Used (spread) here in South Africa as a lawn grass for home gardens and for managed turfs, also planted on airports and national road/ highways sides (in KZN) as soil stabilizers to reduce soil erosion (Expert 3; Fish et al. 2015). Viable seeds are spread through dissemination in faeces of livestock (tropical.theferns.info). Viable seed is spread readily in animal dung.” Heuzé and Tran (2016) Confidence level is high because the information is not controversial or contradictory as it is common knowledge that *P. notatum* is a lawn grass and sometimes used for pasture.	
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria. Heuzé V., Tran G. (2016). *Bahia grass (Paspalum notatum)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/402 *Last updated on March 23, 2016, 16:46* Tropical Plants Database, Ken Fern. tropical.theferns.info. 2018-05-13. <tropical.theferns.info/viewtropical.php?id=*Paspalum+notatum*> Expert 3: Dave Goodenough	

3. Consequences

IMP1 Environmental impact (Figure 3)	
Response: MO	Confidence: Low
Rationale: Based on physical impacts on ecosystem	

References: See below	
IMP1a: Competition	
Response: MN	Confidence: Low
Rationale: *P. notatum* can invade pastures and disturbed rights-of-way, it can impede the growth and survival of native species by the formation of dense mats of vegetation. *P. notatum* can dominate the habitat, and its stands can resist invasion by other plant species. It has not, however, been documented to invade intact native systems (wiki.bugwood.org). Impact magnitude is minor (MN) because the competition with native species occurs in disturbed areas and not natural ecosystems. Confidence level is low because the information source is considered to be of low quality.	
References: https://wiki.bugwood.org	
IMP1b: Predation	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1c: Hybridisation	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1d: Transmission of disease	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1e: Parasitism	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1f: Poisoning/toxicity	
Response: DD	Confidence: Medium
Rationale: "No major toxicity has been reported. Levels of HCN in the DM of 28 ppm have been measured, but this is unlikely to cause problems, which usually occur when levels in the green matter exceed 200 ppm. There is the potential for ergotism caused by Claviceps in the seed head, but no problem has been documented." www.tropicalforages.info Confidence level is medium because there is some observational evidence to support the assessment, but some information is inferred	
References: http://www.tropicalforages.info/key/forages/Media/Html/entities/paspalum_notatum.htm	
IMP1g: Bio-fouling	
Response: DD	Confidence: Low
Rationale:	

References:	
IMP1h: Grazing/herbivory/browsing	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1i: Chemical, physical or structural impact on ecosystem	
Response: MO	Confidence: Low
Rationale: Physical impact on ecosystem: *P. notatum* has altered the natural fire regime in many areas within the south Eastern U.S. Since the 1940s, cattle ranchers have used winter burns to stimulate the growth of forage species, including *P. notatum*. In addition to changes to fire regimes, the installation of *P. notatum* pastures has also resulted in changes to hydrological regimes. Ditches and canals constructed to establish and maintain these pasture grasses alter historic drainage patterns and water levels. These changes can negatively affect neighbouring wetlands. (wiki.bugwood.org) Confidence level is low because the information source is considered to be of low quality and the information is contradictory with the knowledge that *P. notatum* invaded disturbed areas.	
References: https://wiki.bugwood.org	
IMP1k: Interaction with other alien species	
Response: DD	Confidence: Low
Rationale:	
References:	

IMP2 Socio-economic impact (Figure 3)	
Response: MO	Confidence: Medium
Rationale: Based in impacts on human health	
References: See below	
IMP2a: Agriculture	
Response: MO	Confidence: Medium
Rationale: “Because of its prolific growth rate and prostrate growth pattern, bahiagrass invades 'Coastal' bermudagrass [*Cynodon dactylon* (L.) Pers.] hayfields, crowding out the bermudagrass and resulting in lower hay production. Therefore, bahiagrass can be a costly weed in Coastal bermudagrass hayfields.” Smith 1983 Confidence level is medium because there is some direct observational evidence to support the assessment, but some information is inferred	
References: Smith, A.E., 1983. Differential bahiagrass (*Paspalum notatum*) cultivar response to atrazine. Weed Science, pp.88-92.	
IMP2b: Animal production	
Response: MC	Confidence: Medium

Rationale: "Typically, bahiagrass lacks the nutritional quality for good animal performance for many classes of livestock with high nutrient demand, but it is persistent, productive with low inputs under hot and humid conditions, and well suited for cow-calf operations (Ball, Hoveland, and Lacefield 1998; Coleman, Moore, and Wilson 2004)" Myer et al. (2011) Confidence level is medium because there is some direct observational evidence to support the assessment, but some information is inferred, and some of the information is not from the primary source	
References: Myer, R., Blount, A., Coleman, S. and Carter, J. (2011). Forage Nutritional Quality Evaluation of Bahiagrass Selections during Autumn in Florida. Communications in soil science and plant analysis, 42(2), pp.167-172.	
IMP2c: Mariculture/aquaculture	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2d: Forestry	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2e: Infrastructure and administration	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2f: Human health	
Response: Mo	Confidence: Medium
Rationale: "Patients with grass pollen allergy from a subtropical region showed higher skin prick diameters with subtropical Bahia grass and Bermuda grass pollens than with Johnson grass and Ryegrass pollens. IgE reactivity was higher with pollen of Bahia grass than Bermuda grass, Johnson grass and Ryegrass." Davies et al. (2012) "Twenty-nine of 34 (85%) consecutive patients presenting with grass pollen allergy were skin prick test positive to Bahia grass pollen." Davies et al. (2008) Patients from subtropical regions of the world show higher allergic sensitivity to grass pollens of Chloridoideae and Panicoideae grasses, than to temperate grass pollens." Davies et al. (2014) "Bahia grass, *Paspalum notatum*, flowers late into summer and could account for allergic rhinitis at this time. Our data shows there is also a high frequency of serum IgE reactivity with Bahia grass in grass pollen allergic patients with seasonal rhinitis." Davies et al. (2005) "The subtropical Bahia grass, *Paspalum notatum*, of the Panicoideae subfamily of grasses is a clinically important source of pollen allergens." Timbrell et al (2014) Confidence level is medium because impacts are recorded at a spatial scale which may not be relevant to the scale over which original native communities can be characterized, but extrapolation or downscaling of the data to relevant scales is considered reliable, or to embrace little uncertainty	

References: Davies, J.M., Li, H., Green, M., Towers, M. and Upham, J.W. (2012). Subtropical grass pollen allergens are important for allergic respiratory diseases in subtropical regions. Clinical and translational allergy, 2(1), p.4. Davies, J.M., Mittag, D., Dang, T.D., Symons, K., Voskamp, A., Rolland, J.M. and O'Hehir, R.E. (2008). Molecular cloning, expression and immunological characterisation of Pas n 1, the major allergen of Bahia grass *Paspalum notatum pollen*. Molecular immunology, 46(2), pp.286-293. Davies, J.M., 2014. Grass pollen allergens globally: the contribution of subtropical grasses to burden of allergic respiratory diseases. Clinical & Experimental Allergy, 44(6), pp.790-801. Davies, J.M., Bright, M.L., Rolland, J.M. and O'hehir, R.E. (2005). Bahia grass pollen specific IgE is common in seasonal rhinitis patients but has limited cross-reactivity with Ryegrass. Allergy, 60(2), pp.251-255. Timbrell, V.L., Riebelt, L., Simmonds, C., Solley, G., Smith, W.B., Mclean-Tooke, A., Van Nunen, S., Smith, P.K., Upham, J.W., Langguth, D. and Davies, J.M. (2014). An immunodiagnostic assay for quantitation of specific IgE to the major pollen allergen component, Pas n 1, of the subtropical Bahia grass. International archives of allergy and immunology, 165(4), pp.219-228.

IMP2g: Human social life	
Response: MN	Confidence: High
Rationale: "Bahiagrass and common lespedeza often infest centipede- grass lawns and result in a poor-quality turf." Johnson (1979) "In North Carolina, dallisgrass (*Paspalum dilatatum* Poir.) and bahiagrass (*Paspalum notatum* Fluegge) are two of the most prevalent and difficult to control weed species in turf. They are both rhizomatous, perennial grass species that readily invade golf course fairways and roughs." Henry et al (2009) Confidence is high because there is direct relevant observational evidence to support the assessment, and there are reliable/good quality data sources on impacts of the taxa.	
References: Johnson, B.J. (1979). Bahiagrass (*Paspalum notatum*) and common lespedeza (*Lespedeza striata*) control with herbicides in centipedegrass (*Eremochloa ophiuroides*). Weed Science, pp.346-348. Henry, G.M., Burton, M.G. and Yelverton, F.H., 2009. Heterogeneous distribution of weedy Paspalum species and edaphic variables in turfgrass. HortScience, 44(2), pp.447-451.	

IMP3 Closely related species' environmental impact	
Response: N/A	Confidence: Low
Rationale:	
References:	

IMP4 Closely related species' socio-economic impact	
Response: N/A	Confidence:
Rationale:	

References:

IMP5 Potential impact	
Response: MN	Confidence: Low
Rationale: Potential structural impact on ecosystem: because *P. notatum* is a rhizomatous spreading “lawn” grass, it has the potential to spread by forming mats and gradually transforming the ecosystem and impending the growth of native species through competition for space (Expert 3, Expert 2) Potential impact on human infrastructure and administration: *P notatum* can grow in between the cracks of pavements and has a deep rhizomatous root system, which may increase the cracks on the pavements (Expert 1)	
References: Expert 1: Lesly Henderson Expert 2: Sigrun Ammann Expert 3: Dave Goodenough	

4. Management

MAN1 What is the feasibility to stop future immigration?	
Response: Low	Confidence: Medium
Rationale: The feasibility to stop future immigration is low because the species occurs in our neighbouring countries which increases the possibilities of reintroduction through human aided pathways (as lawn, pasture, transport stowaways or contaminant) In most countries *P. notatum* invades disturbed areas such as hiking trails and roadsides, this increases the risk of its introduction in to South Africa as its propagules can be transported into South Africa as a contaminant or a stowaway “Also, seeds of this species can stay viable after ingestion by livestock, there is therefore the possibility of introducing the species into the country through that channel” (Expert 3) Confidence level is medium because there is some direct observational evidence to support the assessment, but some information is inferred.	
References: Expert 3: Dave Goodenough Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria.	

MAN2 Benefits of the Taxon	
MAN2a Socio-economic benefits of the *Taxon*	
Response: Low	Confidence: Medium
Rationale: Socio-economic benefits of *P. notatum* are low because the species is not preferred for some of the benefits such as pasture due to low productivity and unpalatability. Benefits offered by *P. notatum* can be found from other grass specie.	

"Used as permanent forage for intensively grazed pastures and as a stable drought-resistant, ground cover/soil binder, particularly in traffic and shaded areas. It is Suitable for agroforestry And is recommended more for beef than for milk production. If well fertilized and vigorous it can make useful hay. It is used as a ley in four-year rotations to reduce nematode damage to tomatoes (*Lycopersicon esculentum*) and peanuts (*Arachis hypogaea*)." (Heuze and Tran 2016; tropical.theferns.info.) "Pasture though not extensively cultivated as it is less productive and palatable than most other cultivated pastures, improved strains are used as fodder for sheep." Fish et al (2015) Confidence level is medium because there is some direct observational evidence to support the assessment, but some of the above-mentioned Socio- economic benefits are information is inferred.
References: Heuzé V., Tran G. (2016). *Bahia grass (Paspalum notatum)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/402 *Last updated on March 23, 2016, 16:46* Tropical Plants Database, Ken Fern. tropical.theferns.info. 2018-07-13. <tropical.theferns.info/viewtropical.php?id=Paspalum+notatum>

MAN2b Environmental benefits of the *Taxon*	
Response: Medium	Confidence: Medium
rationale: *"Paspalum notatum* Flugge has been widely utilized for the purpose of ecological restoration of degraded land in the tropics and subtropics, where soil active aluminium (Al) is usually high as a result of acidification. *Paspalum notatum* was therefore much higher than the other three species with regard to Al translocation efficiency and therefore *P. notatum* may be regarded as both an effective Al hyper-accumulator and a potential Al hyper-remover." Huang (2009) As erosion control such as binding soil on terraces…" Fish et al (2015) Confidence level is medium because there is some direct observational evidence to support the assessment, but some information is inferred.	
References: Huang, J., Xia, H., Li, Z.A., Xiong, Y., Kong, G. and Huang, J. (2009). Soil aluminium uptake and accumulation by Paspalum notatum. *Waste Management & Research*, *27*(7), pp.668-675. Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria.	

MAN3 Ease of management (Table 4)	
Response: Medium	Confidence: Medium
Rationale: Ease of management is medium because some aspects make it difficult to manage *P. notatum* can be planted vegetatively or from seeds. It is readily established from stolon pieces or from turfs/sods and the seeds are long persistent due to dormancy. Populations of the species in South Africa only occurs in disturbed areas which can mostly be easily accessible. And its spread can be regulated as it seems as if the spread is human mediated.	

Management options: "Can be controlled using metsulfuron methyl at 10 g /ha a.i., in association with a non-ionic surfactant in 200 L water. Small seedlings are sensitive to phenoxy herbicides and thus mowing must be used to control weeds until the plants are 10-12 cm tall and well established at which time a phenoxy herbicide can be used to control broadleaf weeds. Hexazinone and triclopyr can be used for weed control in mature stands." Heuzé and Tran (2016) Also see below	
References: Heuzé V., Tran G. (2016). *Bahia grass (Paspalum notatum)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/402 *Last updated on March 23, 2016, 16:46* Also see below	
MAN3a How accessible are populations?	
Response: 1	Confidence: Medium
Rationale: Most populations of *P. notatum* in South Africa are fairly accessible as this species only occurs in disturbed areas where humans and livestock have cause disturbances for example: along the roads and cultivated areas *P. notatum* is mostly used as lawn grass in the country. Confidence level Medium because there is some direct observational evidence to support the assessment, but some information is inferred.	
References: Personal observation (2016) Expert 2: Sigrun Ammann Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria.	
MAN3b Is detectability critically time-dependent?	
Response: 2	Confidence: High
Rationale: Detectability is time-dependent because in the absence of the flower head it could be mistaken for other Paspalum species. "Similar to *P. scrobiculatum*, which has a smaller spikelet, 2.0-2.5 mm long, a flat, almost leaf-like rachis and no horizontally creeping rhizome" Fish et al. (2015) Confidence level is high because the information is not controversial or contradictory, and there are reliable/ good quality data source on impacts of taxa	
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria.	
MAN3c Time to reproduction	
Response: 1	Confidence: Low
Rationale: Don't know Confidence level is low because of data deficiency	

References:	
MAN3d Propagule persistence	
Response: 1	Confidence: Medium
Rationale: Seed - freshly harvested seed mostly has a high level of dormancy that breaks down over a period of up to 3 years (tropical.theferns.info). Flowers 9stay in flower) for 6 of the warmest months here in South Africa “Flowering: November to April” Fish et al (2015) Confidence level Medium because there is some direct observational evidence to support the assessment, but some information is inferred.	
References: Tropical Plants Database, Ken Fern. tropical.theferns.info. 2018-05-13. <tropical.theferns.info/viewtropical.php?id=*Paspalum+notatum*> Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria.	

MAN4 Has the feasibility of eradication been evaluated?	
Response: No	Confidence: Low
Rationale:	
References:	

5. Calculations

Likelihood = Fairly probable

<table>
<tr><th>Parameter</th><th>Likelihood</th><th>Stages</th><th>Final assessment</th></tr>
<tr><td>LIK1</td><td>Probable</td><td rowspan="2">P(entry) = Fairly probable</td><td rowspan="6">P (invasion) = Fairly probable</td></tr>
<tr><td>LIK2</td><td>Fairly probable</td></tr>
<tr><td>LIK3</td><td>Fairly probable</td><td rowspan="2">P(establishment) = Fairly probable</td></tr>
<tr><td>LIK4</td><td>Unlikely</td></tr>
<tr><td>LIK5</td><td>Unlikely</td><td rowspan="2">P (spread) = Probable</td></tr>
<tr><td>LIK6</td><td>Probable</td></tr>
</table>

Consequence = MO

Parameter	Mechanism/sector	Response
IMP1a	Competition	MN
IMP1b	Predation	DD
IMP1c	Hybridisation	DD
IMP1d	Disease transmission	DD
IMP1e	Parasitism	DD
IMP1f	Poisoning/toxicity	DD
IMP1g	Bio-fouling	DD
IMP1h	Grazing/herbivory/browsing	DD

IMP1i	Chemical, physical, structural impact	MO
IMP1k	Interaction with other aliens	DD
IMP2a	Agriculture	MO
IMP2b	Animal production	MC
IMP2c	Mariculture/aquaculture	DD
IMP2d	Forestry	DD
IMP2e	Infrastructure	DD
IMP2f	Human health	MO
IMP2g	Human social life	MN

Risk = High

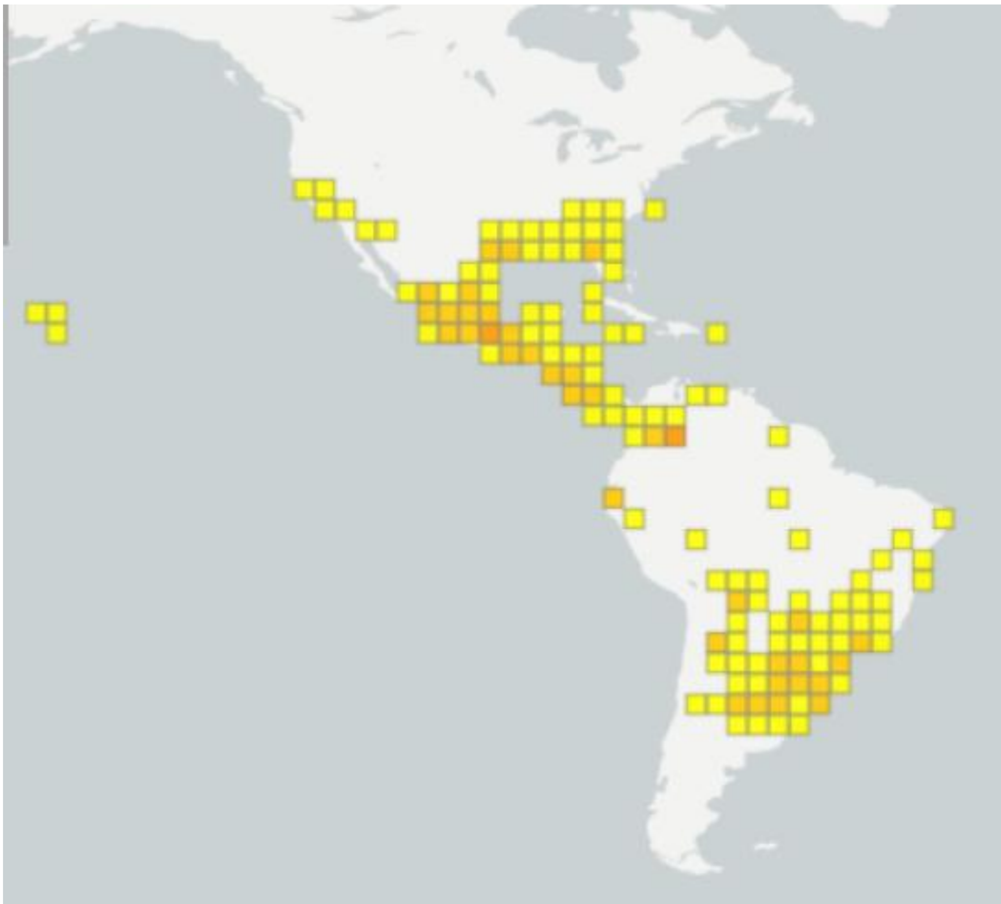
		Consequences				
		MC	MN	MO	MR	MV
Likelihood	Extremely unlikely	low	low	low	medium	medium
	Very unlikely	low	low	low	medium	high
	Unlikely	low	low	medium	high	high
	Fairly probable	medium	medium	high	high	high
	Probable	medium	high	High	high	high

Ease of management = Medium

Parameter	**Question**	**Response**
MAN3a	How accessible are populations?	1
MAN3b	Is detectability critically time-dependent?	2
MAN3c	Time to reproduction	1
MAN3d	Propagule persistence	1
MAN3	**SUM**	5

Supplementary to add to answer sheet

Appendix BAC7: Provide here a map of the native range, if possible. If the map is available in a file, please insert a low-res copy (<1MB) and provide the file name and (if possible) a link to a higher resolution copy below.



https://www.gbif.org/species/2705621

Appendix BAC8: Provide here a map of the global alien range, including the range within the *Area*, if possible. If the map is available in a file, please insert a low res copy (<1MB) and provide the file name and (if possible) a link to a higher resolution copy below.

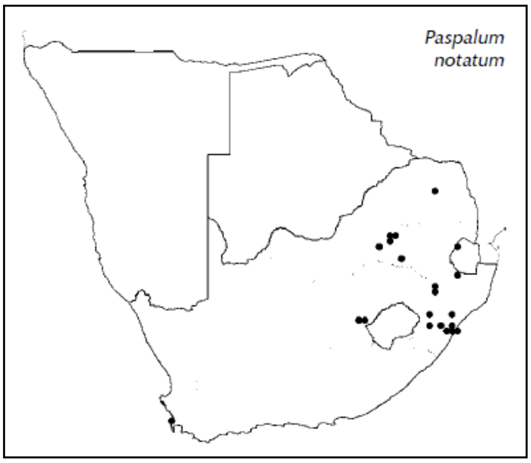


Figure 1: Current distribution of *P. notatum* in South Africa (Fish et al. 2015)

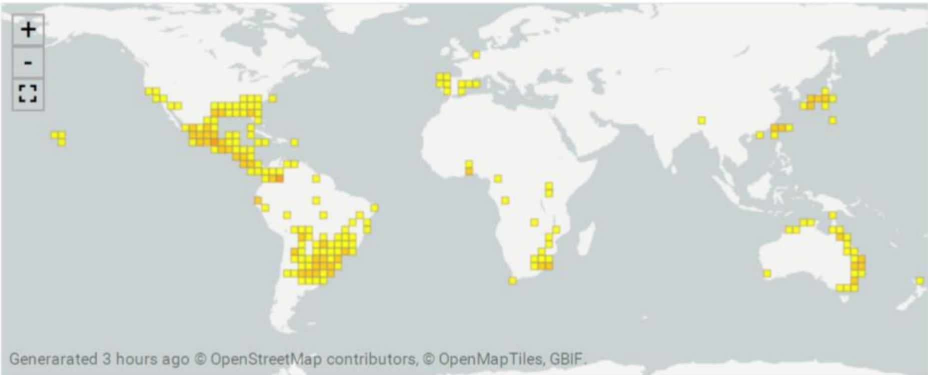


Figure 2: Global distribution of *P. notatum* (alien and native) (**https://www.gbif.org/species/2705621**)

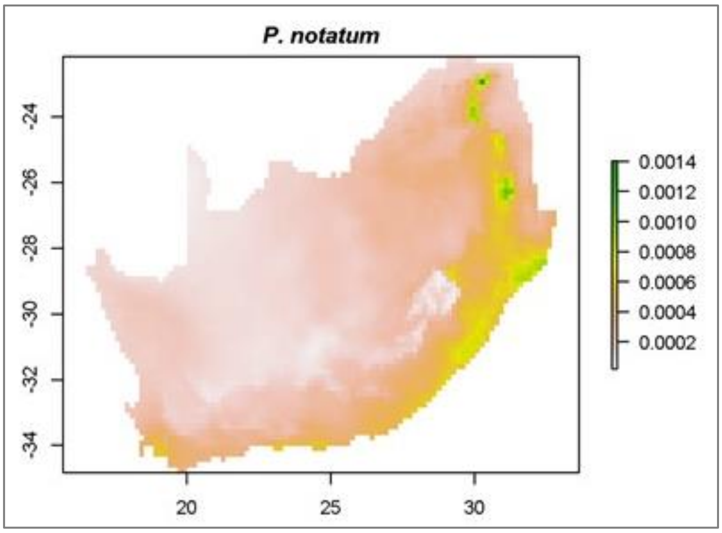
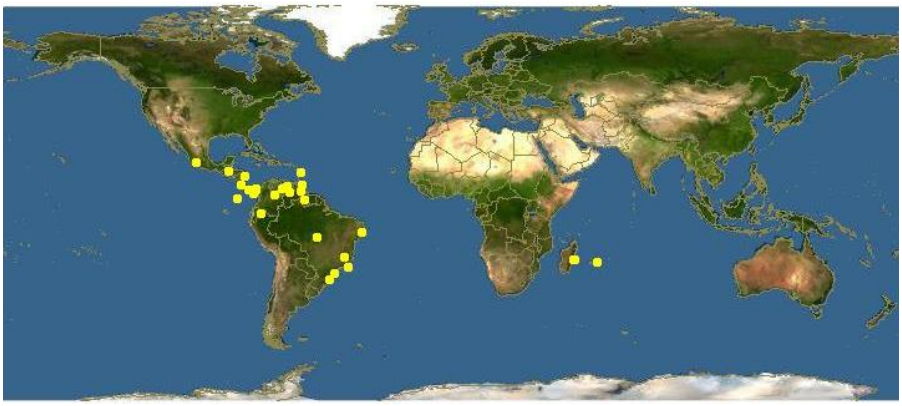


Figure LIK4: Relative occurrence rate of *P. notatum* in South Africa

Risk Analysis Report: *Paspalum nutans*

Summary sheet

<table>
<tr><td>Taxon:
Paspalum nutans (Lam 1791)</td><td colspan="2">Area:
South Africa</td></tr>
<tr><td>Compiled by:
Khensani Vulani NKUNA</td><td colspan="2">Approved by:</td></tr>
<tr><td>Picture of Taxon

sites.google.com</td><td colspan="2">Alien distribution map (BAC8)

https://www.gbif.org/species/4106554</td></tr>
<tr><td colspan="2">Risk Assessment summary:
Likelihood of entry, spread and establishment for Paspalum nutans in South Africa is very unlikely, because P. nutans is sessile and it is habitat specific. Species distribution indicates a very small relative occurrence rate of less than 5 % in south Africa. I also found no evidence on the environmental and socio-economic impacts of P. nutans. Its closely related species (Paspalum decumbens) also has no record of causing impacts.
P. nutans pose low risk in South Africa.</td><td>Risk score:

Low</td></tr>
<tr><td colspan="2">Management options summary:
It is also difficult to plan for the management of a species with no known populations in the country or knowledge on its reproduction mechanisms. I did not find reliable information necessary estimation to determine the species' management feasibility.
Management of P. nutans in South Africa is made difficult because of the lake of information on this species.</td><td>Ease of management:

Difficult</td></tr>
<tr><td colspan="2">Recommendations:
I recommend that P. nutans should not be listed in the NEMBA regulations because of its low risk score.</td><td>Listing category:

Do not list</td></tr>
</table>

Field experiment studied on the environmental and socioeconomic impacts of *P. nutans* should be conducted in places where it was introduced successfully.	

1. Background

BAC1 Name of assessor(s)	
Name of lead assessor	**Khensani Vulani NKUNA**
BAC2 Contact details of assessor (s)	
Lead assessor	Organisational affiliation: South African National Biodiversity Institute, Kirstenbosch Research Centre, Cape Town, South Africa
	email: khensani.vulani@gmail.com
	Phone: 0825946710
BAC3 Name(s) and contact details of expert(s) consulted	
Expert (1)	Name: Lesley Henderson
	Expertise: Weed Scientist (SAPIA)
	Email: HendersonL@arc.agric.za
	Phone: + 27 33 335 9190
Expert (2)	Name: Caroline Mashau
	Expertise: Poaceae herbarium curator at the South African National Biodiversity Institute (Pretoria)
	Email: c.mashau@sanbi.org.za
	Phone: 0847916363
Expert (3)	Name: Marike Trytsman
	Expertise: curator Forage Genebank at ARC-API Roodeplaat
	Email: MTrytsman@arc.agric.za
	Phone: 0128088000
Expert (4)	Name: Dave Gooodenough
	Expertise: Pasture scientist at the Agricultural Research Council
	Email: GoodenoughD@arc.agric.za
	Phone: + 27 33 335 9190

Comments: I acknowledge the Alien Grass Working Group for referring me to expert 1 and 2 (Lesley Henderson and Caroline Mashau), and Sigrun Ammann for referring me to expert 3 and 4 (Marike Trytsman and Dave Gooodenough). Lesley Henderson: provided information on potential impacts, future immigration, benefits and the species' detectability Caroline Mashau: provided information on the herbarium specimen availability Marike Trytsman: provided information on specimen availability in the GenBank Dave Goodenough: provided information on the introduction and dispersal pathways, benefits, and reproduction of the species	
BAC4 Scientific name of *Taxon* under assessment	
Taxon name: *Paspalum nutans*	Authority: Lam (1791)
Comments: Species level	
References: Roskov Y., Abucay L., Orrell T., Nicolson D., Bailly N., Kirk P.M., Bourgoin T., DeWalt R.E., Decock W., De Wever A., Nieukerken E. van, Zarucchi J., Penev L., eds. (2018). Species 2000 & ITIS Catalogue of Life, 28th March 2018. Digital resource at www.catalogueoflife.org/col. Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-8858.	
BAC5 Synonym(s) considered	
Synonyms: *Paspalum boivinii* Steud. (synonym); *Paspalum curvistachyum* Raddi (synonym); *Paspalum heteropodium* Steud. (synonym); *Paspalum lloydii* Nash (synonym); *Paspalum protensum* Trin. (synonym); *Paspalum singulare* Link (synonym); *Paspalum supinum* Steud., pro syn. (synonym)	
Comments: Species level	
References: Roskov Y., Abucay L., Orrell T., Nicolson D., Bailly N., Kirk P.M., Bourgoin T., DeWalt R.E., Decock W., De Wever A., Nieukerken E. van, Zarucchi J., Penev L., eds. (2018). Species 2000 & ITIS Catalogue of Life, 28th March 2018. Digital resource at www.catalogueoflife.org/col. Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-8858.	
BAC6 Common name(s) considered	
Common names: Paspalum penché (French)	
Comments:	
References: Encyclopaedia of Life. Available from http://www.eol.org.	
BAC7 What is the native range of the *Taxon*? (map in Appendix BAC7)	
Response: Native to tropical America (Dominica, Grenada, Martinique, St. Kitts, St. Lucia, St. Vincent), Ecuador	Confidence: Medium

Comments:
Confidence is low because of the nature of the sources but they do not contradict each other

References:
http://saintlucianplants.com/floweringplants/poaceae/paspnuta/paspnuta.html
http://www.biodiversityexplorer.org/plants/poaceae/paspalum.htm

BAC8 What is the global alien range of the *Taxon*? (map in Appendix BAC8)

Response: El salvavodor, Madagascar, Guyana, Mexico, Honduras, Columbia, Nicaragua, Mauritius, Reunion, Trinidad and Tobago	Confidence: Low

Comments:
Confidence level is low because the distributions are not confirmed

References:
Roskov Y., Abucay L., Orrell T., Nicolson D., Bailly N., Kirk P.M., Bourgoin T., DeWalt R.E., Decock W., De Wever A., Nieukerken E. van, Zarucchi J., Penev L., eds. (2018). Species 2000 & ITIS Catalogue of Life, 28th March 2018. Digital resource at www.catalogueoflife.org/col. Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-8858.

BAC9 Geographic scope = the *Area* under consideration

Area of assessment: South Africa

Comments:
Current distribution in the South Africa unknown, no map available

BAC10 Is the *Taxon* present in the *Area*?

Response: I don’t know	Confidence: Low

Comments:
No live or herbarium specimen collected from South Africa, there are only extralimital herbarium species collected from elsewhere

References: Expert 2: Caroline Mashau

BAC11 Availability of physical specimen

Response: Yes	Confidence in ID: Medium

Herbarium or museum accession number: PRE0963793
Specimen encoded for SABONET project (extra- Africa collections) (Expert 2).
Specimen collected from Panama (Province of Colon)
No record of collection in the genebank Forage Genebank at ARC-API Roodeplaat (Expert 3).

References:
Expert 2: Caroline Mashau
Expert 3: Marike Trytsman

BAC12 Is the *Taxon* native to the *Area* or part of the *Area*?

The *Taxon* is native to (part of) the *Area*.	No	Confidence: High

<table>
<tr><td>The Taxon is alien in (part of) the Area.</td><td colspan="2">Yes</td><td>Confidence: High</td></tr>
<tr><td colspan="4">Comments:
P. nutans is cited as being cultivated in Southern Africa by Glen (2002).
Confidence low because there is no other record of this species presence in South Africa</td></tr>
<tr><td colspan="4">References:
Glen, H. F. (2002). Cultivated plants of southern Africa: botanical names, common names, origins, literature. Johannesburg, Jacana.</td></tr>
<tr><td colspan="4">BAC13 What is the Taxon's introduction status in the Area?</td></tr>
<tr><td>The Taxon is in cultivation/containment.</td><td colspan="2">Yes</td><td>Confidence: Low</td></tr>
<tr><td>The Taxon is present in the wild.</td><td colspan="2">Don't know</td><td>Confidence: Low</td></tr>
<tr><td>The Taxon has established/naturalised.</td><td colspan="2">Don't know</td><td>Confidence: Low</td></tr>
<tr><td>The Taxon is invasive.</td><td colspan="2">Don't know</td><td>Confidence: Low</td></tr>
<tr><td colspan="4">Comments: Confidence level is low because the source is not specific and there is no other source to support it.</td></tr>
<tr><td colspan="4">References:
Glen, H. F. (2002). Cultivated plants of southern Africa: botanical names, common names, origins, literature. Johannesburg, Jacana.</td></tr>
<tr><td colspan="4">BAC14 Primary (introduction) pathways</td></tr>
<tr><td>Release</td><td colspan="2">No</td><td>Confidence: Low</td></tr>
<tr><td>Escape</td><td colspan="2">No</td><td>Confidence: Low</td></tr>
<tr><td>Contaminant</td><td colspan="2">Yes</td><td>Confidence: Low</td></tr>
<tr><td>Stowaway</td><td colspan="2">No</td><td>Confidence: Low</td></tr>
<tr><td>Corridor</td><td colspan="2">No</td><td>Confidence: Low</td></tr>
<tr><td>Unaided</td><td colspan="2">No</td><td>Confidence: Low</td></tr>
<tr><td colspan="4">Comments:
Recorded in Glen 2002 as cultivated in South Africa
Confidence level is low because the source (Glen 2002) does not provide enough to support the assessment and there is no other source.</td></tr>
<tr><td colspan="4">References:
Glen, H. F. (2002). Cultivated plants of southern Africa: botanical names, common names, origins, literature. Johannesburg, Jacana.</td></tr>
</table>

2. Likelihood

<table>
<tr><td colspan="2">LIK1 Likelihood of entry via unaided primary pathways</td></tr>
<tr><td>Response: Very unlikely</td><td>Confidence: Low</td></tr>
<tr><td colspan="2">Rationale:
P. nutans is not native in South Africa but there is no record on its pathway of introduction.</td></tr>
</table>

However, P. nutans is a plant, it is therefore sessile, and dispersal is not long distanced because it prefers shaded areas it will be very difficult for the species to disperse into South Africa unaided. Confidence is low because there is only one source reporting on the presence of the species in South Africa and there is no other to provide more information, also because some of the information is inferred.
References: Glen, H. F. (2002). Cultivated plants of southern Africa: botanical names, common names, origins, literature. Johannesburg, Jacana. http://www.biodiversityexplorer.org/plants/poaceae/index.htm http://www.saintlucianplants.com/floweringplants/poaceae/paspnuta/paspnuta.html

LIK2 Likelihood of entry via human aided primary pathways	
Response: Very unlikely	Confidence: Low
Rationale: "If *P. nutans* was cultivated in the country, it was probably for pasture, it might have been one of those pasture trial species that failed to adapt" (Expert 4) According to Glen (2002) *P. nutans* is cultivated meaning there was/is human aided pathway. However, the species seem to be highly sensitive, i.e. grows in shaded areas. Introduction of *P. nutans* in South Africa is probably not frequent (Expert 4) Confidence level is low because there is no observation to support the assessment and the information is inferred	
References: Expert 4: Dave Gooodenough Glen, H. F. (2002). Cultivated plants of southern Africa: botanical names, common names, origins, literature. Johannesburg, Jacana.	

LIK3 Habitat suitability	
Response: Unlikely	Confidence: Medium
Rationale: In native range *P. nutans* prefers shady moist spots, often by forest tracks Confidence is medium because the sources do not contradict each other but the nature of the source is not good quality	
References: http://www.biodiversityexplorer.org/plants/poaceae/index.htm http://www.saintlucianplants.com/floweringplants/poaceae/paspnuta/paspnuta.html	

LIK4 Climate suitability	
Response: Very unlikely	Confidence: High
Rationale: Species distribution indicate suitable climate for P. nutans in South Africa, but the relative occurrence is < 5% (see Figure LIK4 in the appendix of this report). *P. nutans* climate suitability is therefore very unlikely. Grows well in tropical climate (www.biodiversityexplorer.org) Confidence level is high because the is direct observation to support the assessment	

References: http://www.biodiversityexplorer.org/plants/poaceae/index.htm

LIK5 Unaided secondary (dispersal) pathways	
Response: Unlikely	Confidence: Low
Rationale: "This species probably spreads the same way as other paspalum, either from seeds or rhizomes or even both" (Expert 4) *P. nutans* is sessile and probably disperse slowly (< 50 km in 10 years) Confidence level is low because the information is inferred	
References: Expert 4: Dave Goodenough	

LIK6 Human aided secondary (dispersal) pathways	
Response: Unlikely	Confidence: Low
Rationale: "The species is probably spread by planting" (Expert 3) Listed as cultivated in Glen (2002) Confidence level is low because the information is inferred	
References: Expert 4: Dave Gooodenough Glen, H. F. (2002). Cultivated plants of southern Africa: botanical names, common names, origins, literature. Johannesburg, Jacana.	

3. Consequences

IMP1 Environmental impact (Figure 3)	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1a: Competition	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1b: Predation	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1c: Hybridisation	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1d: Transmission of disease	
Response: DD	Confidence: Low

Rationale:	
References:	
IMP1e: Parasitism	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1f: Poisoning/toxicity	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1g: Bio-fouling	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1h: Grazing/herbivory/browsing	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1i: Chemical, physical or structural impact on ecosystem	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1k: Interaction with other alien species	
Response: DD	Confidence: Low
Rationale:	
References:	

IMP2 Socio-economic impact (Figure 3)	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2a: Agriculture	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2b: Animal production	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2c: Mariculture/aquaculture	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2d: Forestry	

Response: DD	Confidence: Low
Rationale:	
References:	
IMP2e: Infrastructure and administration	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2f: Human health	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2g: Human social life	
Response: DD	Confidence: Low
Rationale:	
References:	

IMP3 Closely related species' environmental impact	
Response: DD	Confidence: Low
Rationale: *Paspalum decumbens* Sw (1788) No record for environmental impact even for the closest related species	
References: Roskov Y., Abucay L., Orrell T., Nicolson D., Bailly N., Kirk P.M., Bourgoin T., DeWalt R.E., Decock W., De Wever A., Nieukerken E. van, Zarucchi J., Penev L., eds. (2018). Species 2000 & ITIS Catalogue of Life, 28th March 2018. Digital resource at www.catalogueoflife.org/col. Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-8858.	

IMP4 Closely related species' socio-economic impact	
Response: DD	Confidence: Low
Rationale: *Paspalum decumbens* Sw (1788) Socio-economic impact record for the related species as well	
References: Roskov Y., Abucay L., Orrell T., Nicolson D., Bailly N., Kirk P.M., Bourgoin T., DeWalt R.E., Decock W., De Wever A., Nieukerken E. van, Zarucchi J., Penev L., eds. (2018). Species 2000 & ITIS Catalogue of Life, 28th March 2018. Digital resource at www.catalogueoflife.org/col. Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-8858.	

IMP5 Potential impact	
Response: MC	Confidence: Low
Rationale: There is generally very little to no literatures on *P. nutans* and it is rare even in its native range	

“Indigenous quite rare herb of shady moist spots, often by forest tracks” (www.saintlucianplants.com) “maybe it invades disturbed habitats just like other species” (Expert 1) There is only one record of its introduction through a pasture station as a pasture test species, the station has since been closed. Confidence level is low because the information is inferred
References: Expert 1: Lesley Henderson http://www.saintlucianplants.com/floweringplants/poaceae/paspnuta/paspnuta.html

4. Management

MAN1 What is the feasibility to stop future immigration?	
Response: High	Confidence: low
Rationale: “it should be possible to regulate its intentional introduction, more especially if it is in large quantities” (Expert 1) The closest place to South Africa where *P. nutans* occurs is Madagascar, and does not occur in other neighbouring countries, possibility of unintentional introduction is low. Confidence is low because information is inferred	
References: Expert 1: Lesley Henderson	

MAN2 Benefits of the Taxon	
MAN2a Socio-economic benefits of the *Taxon*	
Response: Low	Confidence: Low
Rationale: *P. nutans* was probably planted or trialled for pasture but did not adapt to South Africa (Expert 1 and 4). I Could not find information on the socio-economic benefits of this species Confidence is low because information is inferred	
References: Expert 1: Lesley Henderson Expert 4: Dave Goodenough Glen, H. F. (2002). Cultivated plants of southern Africa: botanical names, common names, origins, literature. Johannesburg, Jacana.	
MAN2b Environmental benefits of the *Taxon*	
Response: Low	Confidence: Low
Rationale: “If it has very strong root system it could be used to bind soils, and prevent soil erosion” (Expert 4) Confidence is low because information is inferred	
References: Expert 4: Dave Goodenough	

MAN3 Ease of management (Table 4)

Response: Difficult (6)	Confidence:
Rationale: Ease of management for *P. nutans* will be difficult in South Africa because of the information paucity on this species. See also below	
References: See below	
MAN3a How accessible are populations?	
Response: Don't know (2)	Confidence: Low
Rationale: In its native range, it grows by forest tracks (www.saintlucianplants.com) I don't know about the accessibility of *P. nutans* populations, however, if it was cultivated in the country, it was probably in an accessible area Confidence is low because information is inferred	
References: http://www.saintlucianplants.com/floweringplants/poaceae/paspnuta/paspnuta.html Glen, H. F. (2002). Cultivated plants of southern Africa: botanical names, common names, origins, literature. Johannesburg, Jacana.	
MAN3b Is detectability critically time-dependent?	
Response: Don't know (2)	Confidence: Low
Rationale: "From the herbarium specimen images, I do not see any distinct feature, one might need to carefully analyse the specimen to know which *Paspalum* it is" (Expert 1). It seems like without seed heads *P. nutans* may be difficult to identify in the field Confidence is low because information is inferred	
References: Expert 1: Lesley Henderson	
MAN3c Time to reproduction	
Response: Don't know (1)	Confidence: Low
Rationale: "Depending on whether this *Paspalum* spreads by the roots, it can start covering the ground in a year or two" (Expert 4) Confidence is low because information is inferred	
References: Expert 4: Dave Goodenough	
MAN3d Propagule persistence	
Response: Don't know (1)	Confidence: Low
Rationale: "I don't know how long the seeds last on the ground some can last long, but seeds from other *Paspalum* species like Dallas grass get attacked by fungi" (Expert 4) Confidence is low because information is inferred	
References: Expert 4: Dave Goodenough	

MAN4 Has the feasibility of eradication been evaluated?

Response: No	Confidence: Low
Rationale:	
References:	

Supplementary to add to answer sheet

Appendix BAC7: Provide here a map of the native range, if possible. If the map is available in a file, please insert a low res copy (<1MB) and provide the file name and (if possible) a link to a higher resolution copy below.

Encyclopedia of Life. Available from http://www.eol.org

Appendix BAC8: Provide here a map of the global alien range, including the range within the *Area*, if possible. If the map is available in a file, please insert a low-res copy (<1MB) and provide the file name and (if possible) a link to a higher resolution copy below.

- Map not available for distribution of the taxon in the Area

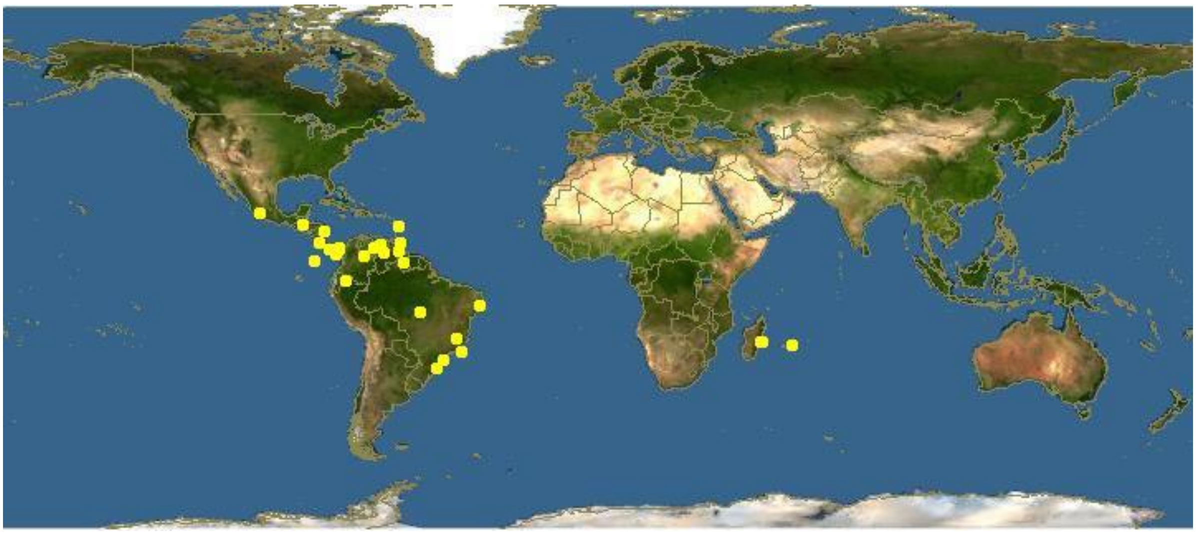


Figure 1: Global distribution of *P. nutans* (alien and native) (https://www.gbif.org/species/4106554)

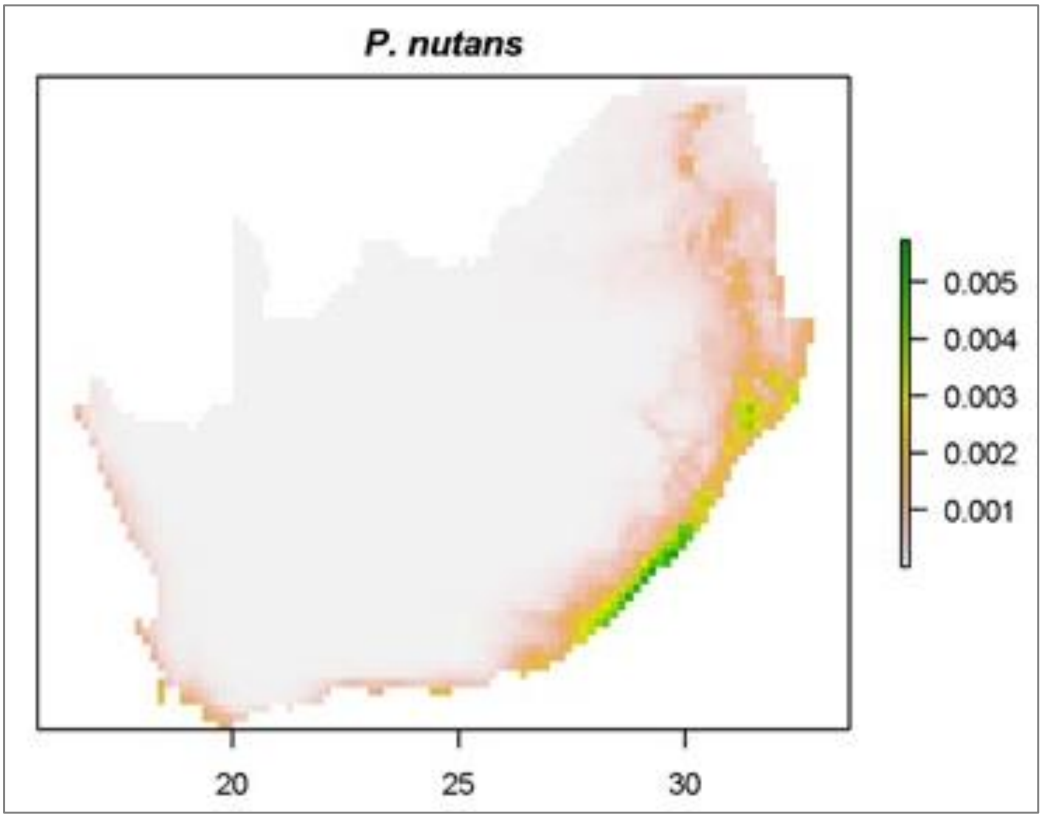


Figure LIK4: Relative occurrence rate of *P. nutans* in South Africa

Risk Analysis Report: *Paspalum quadrifarium*
Summary sheet

***Taxon*:** *Paspalum quadrifarium* L. (Lam 1791)	***Area*:** South Africa
Compiled by: Khensani Vulani NKUNA	**Approved by:**
Picture of *Taxon*  David J. https://www.invasive.org/browse/subthumb.cfm?sub=14214	**Global distribution map**  https://www.gbif.org/species/4154990

Risk Assessment summary: In South Africa, *P. quadrifarium* occurs in similar habitats as in the native range which is along the bank of a stream. However, studies have found that the species has low establishment risk (< 5 %) in the country. The overall likelihood of entry, spread, and the establishment is fairly probable because the species is sessile, and the available human aided pathways are infrequently used. *P. quadrifarium* can cause moderate impacts with the potential of outcompeting native species and physically transforming the ecosystem by forming large and tall impenetrable dense stands. It poses risk of causing fire and ultimately changing fire regimes as it is highly combustible whether dead or alive.	**Risk score:** **High**
Management options summary: *P. quadrifarium* is accessible where it currently occurs and is easily distinguishable among small grasses because of its large stature and seed heads which are produced all year round (flowers twice a year for six months). The management feasibility is medium because the seeds are long-lived, very prolific. Reproduction starts at the juvenile stage, and it can also reproduce vegetatively through rhizomes. Currently, *P. quadrifarium* has no positive environment or socio-economic impacts in South Africa. It is valued as a horticultural species in other countries because of its large attractive stature, but there is no clear record for such use here in South Africa.	**Risk management:** **Medium**

Recommendations:	**Listing category:**
I recommend that the species should be listed as a category 1b species under the NEM: BA regulations. This recommendation is based on the facts that the species has little to no benefit in South Africa and there is uncertainty about the extent of its spread. The listing can later be changed to category 1a pending a detailed assessment of costs and available management options of eradication. Stakeholders with previous and current interest in the species should be identified in order to avoid conflicts and a national management plan should be developed.	**1b**

1. Background

BAC1 Name of assessor(s)		
Name of lead assessor	**Khensani Vulani NKUNA**	
BAC2 Contact details of assessor (s)		
Lead assessor	Organisational affiliation: South African National Biodiversity Institute, Kirstenbosch Research Centre, Cape Town, South Africa	
	email: khensani.vulani@gmail.com	
	Phone: 0825946710	
BAC3 Name(s) and contact details of expert(s) consulted		
Expert (1)	Name: Lesley Henderson	
	Expertise: Weed Scientist (Southern Africa Plant Invader Atlas)	
	Email: HendersonL@arc.agric.za	
	Phone: + 27 33 335 9190	
Comments: I acknowledge the Alien Grass Working Group for referring me to the expert: Lesley Henderson, during a discussion in 2016, who provided knowledge on the introduction pathways of *Paspalum qadrifarium.*		
BAC4 Scientific name of *Taxon* under assessment		
Taxon name: *Paspalum qadrifarium L.*		Authority: Lam (1791)
Comments: Species level		
References: Roskov Y., Abucay L., Orrell T., Nicolson D., Bailly N., Kirk P.M., Bourgoin T., DeWalt R.E., Decock W., De Wever A., Nieukerken E. van, Zarucchi J., Penev L., eds. (2018). Species 2000 & ITIS Catalogue of Life, 28th March 2018. Digital resource at www.catalogueoflife.org/col. Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-8858. Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria.		
BAC5 Synonym(s) considered		

Synonyms: *Paspalum variegatum* Link (synonym); *Paspalum quadrifarium* var. ferrugineum (Trin.) Herter (synonym); *Panicum lagascae* var. quadrifarium (Lam.) Kuntze (synonym); *Paspalum eruciferum* Trin. ex Steud., pro syn. (synonym); *Paspalum ferrugineum* Trin. (synonym); *Paspalum quadrifarium* var. majus Döll (synonym); *Paspalum quadrifarium* var. minus Döll (synonym);	
Comments: Species level	
References: Roskov Y., Abucay L., Orrell T., Nicolson D., Bailly N., Kirk P.M., Bourgoin T., DeWalt R.E., Decock W., De Wever A., Nieukerken E. van, Zarucchi J., Penev L., eds. (2018). Species 2000 & ITIS Catalogue of Life, 28th March 2018. Digital resource at www.catalogueoflife.org/col. Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-8858.	
BAC6 Common name(s) considered	
Common names: Tussuck Paspalum (English), Crown grass (English), Golden-top grass (English), or evergreen Paspalum (English), Paja colorada (Spanish), Paja manse (Spanish)	
Comments: The most common English name is Tussochk paspalum Has a few in Spanish based on the region	
References: South African National Biodiversity Institute. (2016). Botanical Database of Southern Africa (BODATSA) [dataset]. doi: to be assigned. *Paspalum quadrifarium* Lam. in Wiersema J H (2018). GRIN Taxonomy. US National Plant Germplasm System. Checklist Dataset https://doi.org/10.15468/ao14pp accessed via GBIF.org on 2018-05-14.	
BAC7 What is the native range of the *Taxon*? (map in Appendix BAC7)	
Response: The species is native to the southern South American countries: Brazil, Argentina, Paraguay, Uruguay	Confidence: High
Comments: Some of the native range is not shown in the map although there are known populations in the native range Map based on preserved/ herbarium specimen *Paspalum quadrifarium* is considered a weed in some parts of its native range (in Uruguay)	
References: *Paspalum quadrifarium* Lam. in Wiersema J H (2018). GRIN Taxonomy. US National Plant Germplasm System. Checklist Dataset https://doi.org/10.15468/ao14pp accessed via GBIF.org on 2018-05-14. Verloove, F. and Reynders, M. (2007). Studies in the genus *Paspalum* (Paniceae, Poaceae) in Europe—2. The Quadrifaria group. Willdenowia, 37(2), pp.423-430.	
BAC8 What is the global alien range of the *Taxon*? (map in Appendix BAC8)	
Response: Australia, USA, Benin, Italy, South Africa	Confidence: High
Comments:	

<table>
<tr><td colspan="3">References:
Verloove, F. and Reynders, M. (2007). Studies in the genus Paspalum (Paniceae, Poaceae) in Europe—2. The Quadrifaria group. Willdenowia, 37(2), pp.423-430.
Paspalum quadrifarium Lam. in Wiersema J H. (2018). GRIN Taxonomy. US National Plant Germplasm System. Checklist Dataset https://doi.org/10.15468/ao14pp accessed via GBIF.org on 2018-05-14.
Panario, D. and Bidegain, M. (1997). Climate change effects on grasslands in Uruguay. Climate Research, pp.37-40.</td></tr>
<tr><td colspan="3">BAC9 Geographic scope = the Area under consideration</td></tr>
<tr><td colspan="3">Area of assessment: South Africa</td></tr>
<tr><td colspan="3">Comments:</td></tr>
<tr><td colspan="3">BAC10 Is the Taxon present in the Area?</td></tr>
<tr><td colspan="2">Response: Yes</td><td>Confidence: High</td></tr>
<tr><td colspan="3">Comments:
Paspalum quadrifarium has only been recorded in KwaZulu-Natal around the Melmoth area and along the N2 towards Kokstad and Port Shepstone. It is suspected that it was introduced in South Africa from South America as a horticultural ornamental grass around 2003/2004. It is a naturalised weed in South Africa and it grows in large impenetrable stands.
S28° 34.698' E31° 14.370'</td></tr>
<tr><td colspan="3">References:
Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015) identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria.
South African National Biodiversity Institute. (2016). Botanical Database of Southern Africa (BODATSA) [dataset]. doi: to be assigned.</td></tr>
<tr><td colspan="3">BAC11 Availability of physical specimen</td></tr>
<tr><td colspan="2">Response: Yes</td><td>Confidence in ID: High</td></tr>
<tr><td colspan="3">Herbarium or museum accession number:
PRE0867648-0</td></tr>
<tr><td colspan="3">References:
South African National Biodiversity Institute. (2016). Botanical Database of Southern Africa (BODATSA) [dataset]. doi: to be assigned.</td></tr>
<tr><td colspan="3">BAC12 Is the Taxon native to the Area or part of the Area?</td></tr>
<tr><td>The Taxon is native to (part of) the Area.</td><td>No</td><td>Confidence: High</td></tr>
<tr><td>The Taxon is alien in (part of) the Area.</td><td>Yes</td><td>Confidence: High</td></tr>
<tr><td colspan="3">Comments: P. quadrifarium is alien across South Africa including the islands.</td></tr>
<tr><td colspan="3">References:
Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015) identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria.
South African National Biodiversity Institute. (2016). Botanical Database of Southern Africa (BODATSA) [dataset]. doi: to be assigned.</td></tr>
</table>

BAC13 What is the *Taxon*'s introduction status in the *Area*?		
The *Taxon* is in cultivation/containment.	Yes	Confidence: Low
The *Taxon* is present outside of captivity/cultivation.	Yes	Confidence: High
The *Taxon* has established/naturalised.	Yes	Confidence: High
The *Taxon* is invasive.	Yes	Confidence: High
Comments: *Paspalum quadrifarium* has a self-sustaining naturalised population within a timber forest and between the forest and a grassland. It is not cultivated or in containment, the population occurs outside cultivation where it spread along a network of a small stream. It is not known, however, if the species is still in a garden as an ornamental somewhere, but it presumably was at some stage (so the response is yes with low confidence).		
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria. Expert 1: Lesley Henderson		

BAC14 Primary (introduction) pathways		
Release	No	Confidence: Low
Escape	Yes	Confidence: Medium
Contaminant	No	Confidence: Low
Stowaway	Yes	Confidence: Low
Corridor	No	Confidence: Low
Unaided	No	Confidence: Low
Comments: It is suspected that *Paspalum quadrifarium* was introduced in to the area as a garden plant, or as a stowaway of the machinery equipment and tracks used in the timber forest. It has the potential to spread and be introduced to new areas via interconnected waterways as it grows along a network of small streams which connect to a bigger river.		
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015) identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria. Expert 1: Lesley Henderson		

2. Likelihood

LIK1 Likelihood of entry via unaided primary pathways	
Response: Probable	Confidence: High
Rationale: It is unlikely for *P. qadrifarium* to be introduced in to the country unaided However, *P. quadrifarium* occurs in South Africa and has naturalised (Personal observation, 2017) "Naturalised from South America." Fish et al (2015) "First reported in South Africa around 2003/ 2004, forming dense stands of a few hectors where fire had been excluded." Fish et al (2015) The confidence level is high because there is direct relevant observational evidence to support the assessment.	
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria. Personal observation, 2016, 2017	

LIK2 Likelihood of entry via human-aided primary pathways	
Response: Don't know	Confidence: Low
Rationale: "Very attractive and is grown as an ornamental in some countries" Fish et al (2015) "Tussock paspalum was probably introduced in South Africa as an ornamental and horticultural grass." sanbi.org "Introduced in South Africa as an ornamental and horticultural grass." invasives.org.za The confidence level is low because there is no direct observation or clear record of its primary pathway, however, based on its stature and appearance it is speculated that the taxon may have been introduced through the horticultural industry as in other countries such as the USA. Some of the information sources are considered to be of low quality.	
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria. https://www.sanbi.org/resources/infobases/invasive-alien-plant-alert/paspalum-quadrifarium/ http://www.invasives.org.za/legislation/item/850-tussock-paspalum-paspalum-quadrifarium	

LIK3 Habitat suitability	
Response: Fairly probable	Confidence: High
Rationale: "In South America *Paspalum quadrifarium* prefers the same moist habitats as *P. exaltatum* (river banks, lake shores, moist fields). In addition, it also grows in savannas on clay or sand. Outside its original range, *P. quadrifarium* mostly grows in disturbed, unmown areas (Allen & Hall 2003, Jacobs & Wall 1993). Remarkably, its Italian ecological niche corresponds well with the native one since it is chiefly found along river banks (see Garbari	

1972). In Queensland, *P. quadrifarium* inhabits humid coastal and subcoastal ranges, highlands and closed forests (Tothill & Hacker 1983).” Verloove and Reynders (2007) “Ecology: Black soils in wet places; in areas where fire is excluded.” Fish et al (2015) Here in South Africa, *P. quadrifarium* occurs in similar habitats as in the native range which is along a network of a stream between the edge of a timber forest and a pasture land (personal observation, 2017). The confidence level is high because there is direct relevant observational evidence to support the assessment.
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria. Verloove, F. and Reynders, M. (2007). Studies in the genus *Paspalum* (Paniceae, Poaceae) in Europe—2. The Quadrifaria group. Willdenowia, 37(2), pp.423-430. Personal observation, 2017

LIK4 Climate suitability	
Response: Fairly probable	Confidence: Medium
Rationale: The climate is suitable is some parts of the Area. According to a study conducted by Renteria et al. (2017), *P. quadrifarium* has low established risk and a small predicted area (below 5 % of the Area). This means that the species is predicted to establish in a small part of the Area, across very few biomes. However, my species distribution model visually shows a relative occurrence rate of > 5 % but < 20 % (see also Figure LIK4 in the appendix of this report). The confidence level is medium because there is direct observation from the sources to support the information, but the results of the data is not in accordance.	
References: Renteria, J.L., Rouget, M. and Visser, V. (2017). Rapid prioritization of alien plants for eradication based on climatic suitability and eradication feasibility. Austral Ecology, 42(8), pp.995-1005.	

LIK5 Unaided secondary (dispersal) pathways	
Response: Very unlikely	Confidence: Medium
Rationale: “*Paspalum quadrifarium* spreads rapidly through the rhizomes and the seeds”. invasives.org Potentially, the seeds can be carried to other parts of the country by water through the network of streams, however, the dispersal of the species is yet to be thoroughly studied. “Accordingly, this species is here considered tenuously established and its dispersal and naturalization remain to be studied and documented.” Riefner et al. (2010) The confidence is Medium because some of the information is inferred.	
References: http://www.invasives.org.za/legislation/item/850-tussock-paspalum-*paspalum-quadrifarium*	

Riefner Jr, R.E., Denham, S.S. and Columbus, J.T. (2010). *Paspalum pubiflorum* and *P. quadrifarium* (Poaceae) new to California, with a key and notes on invasive species. Journal of the Botanical Research Institute of Texas, pp.761-770.

LIK6 Human aided secondary (dispersal) pathways	
Response: Fairly probable	Confidence: Low
Rationale: There is no record of human-aided dispersal into other parts of the Area, however, since *P. quadrifarium* is introduced in South Africa as an ornamental and horticultural grass (Fish et al. 2015; invasive.org), it can potentially be introduced in other parts of the area as such. *P. quadrifarium* is also grazed upon by cattle where it occurs (Personal observation, 2017) It also has a potential to be dispersed and spread as a stowaway The confidence is low because there is no direct observation to support the information.	
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria. http://www.invasives.org.za/legislation/item/850-tussock-paspalum-*paspalum-quadrifarium* Personal observation, 2017	

3. Consequences

IMP1 Environmental impact (Table 3)	
Response: MO	Confidence: High
Rationale: Base on impact through competition with native species	
References: See below	
IMP1a: Competition	
Response: MO	Confidence: High
Rationale: "In Sydney, for instance, it is a declared noxious weed that, once established, forms extremely dense infestations that outcompete native vegetation (Sydney Weeds Committees 2005)." Verloove and Reynders (2007) "*Paspalum quadrifarium* Lam. ("paja colorada", thereafter "paspalum") is a bunch grass (1.50 m tall) that, under low disturbance regimes, excludes other species and forms dense patchy stands locally called "pajonal"." Laterra (1997) *"Paspalum quadrifarium* Lam. is a warm-season and perennial grass with tall canopy that excludes other species, and forms dense stands locally known as 'pajonales'." Picone et al. (2003) "This aggressive species forms extremely dense infestations, quickly outcompeting native plant species." Gray et al (2010)	

"Tussock paspalum is an aggressive grass which forms extremely dense infestations. Rhizomes spread horizontally and send up suckers, which form a large dense clump, thus outcompeting native plants." Invasives.org The confidence level is high because the information is not contradictory and there are reliable / good quality data source on impact of alien taxa. Impact magnitude does not reach the score of MR as there is no evidence of local or population extinction
References: Verloove, F. and Reynders, M. (2007). Studies in the genus *Paspalum* (Paniceae, Poaceae) in Europe—2. The Quadrifaria group. Willdenowia, 37(2), pp.423-430. Laterra, P., 1997. Post-burn recovery in the flooding Pampa: Impact of an invasive legume. Journal of Range Management, pp.274-277. Picone, L.I., Quaglia, G., Garcia, F.O. and Laerra, P. (2003). Biological and chemical response of a grassland soil to burning. Journal of Range Management, pp.291-297. Gray, C.P., K. A. Rawlins, D.J. Moorhead, and C. T. Bargeron. (2010). Invasive Plants to Watch for in Georgia. The University of Georgia. Center for Invasive Species and Ecosystem Health, Tifton GA, Revised BW-2010-100. 58 p. http://www.invasives.org.za/legislation/item/850-tussock-paspalum-*paspalum-quadrifarium* Moorhead, D., Rawlins, K. and Bargeron, C. (2010). Tussock Paspalum: A New Invader in the Coastal Plain. University of Georgia, Center for Invasive Species and Ecosystem Health.

IMP1b: Predation	
Response: DD	Confidence:
Rationale:	
References:	
IMP1c: Hybridisation	
Response: DD	Confidence:
Rationale:	
References:	
IMP1d: Transmission of disease	
Response: DD	Confidence:
Rationale:	
References:	
IMP1e: Parasitism	
Response: DD	Confidence:
Rationale:	
References:	
IMP1f: Poisoning/toxicity	
Response: DD	Confidence:
Rationale:	
References:	

IMP1g: Bio-fouling	
Response: DD	Confidence:
Rationale:	
References:	
IMP1h: Grazing/herbivory/browsing	
Response: DD	Confidence:
Rationale:	
References:	
IMP1i: Chemical, physical or structural impact on ecosystem	
Response: MN	Confidence: Medium
Rationale: "Alive or dead, mature clumps are highly combustible, and hence are able to change fire regimes." environment.gov The confidence is medium because the information is to some extent ambiguous Impact magnitude is not MO because there is no evidence of population size decline of any native species	
References: http://www.environment.gov.au/cgibin/biodiversity/invasive/weeds/weeddetails.pl?taxon_id=6390#	
IMP1k: Interaction with other alien species	
Response: DD	Confidence:
Rationale:	
References:	

IMP2 Socio-economic impact (Table 3)	
Response: MC	Confidence: Low
Rationale: Based on impact on animal production	
References: See below	
IMP2a: Agriculture	
Response: DD	Confidence:
Rationale:	
References:	
IMP2b: Animal production	
Response: MC	Confidence: Low
Rationale: "One of such systems are the grasslands dominated by *Paspalum quadrifarium* ('paja colorada'), an unpalatable species that usually forms monospecific stands ('pajonal') in the Flooding Pampa of Argentina." Laterra and Solbrig (2001)	

"Paja colorada has very low nutritional value for cattle except at the post burn regrowth stage. Consequently, it does not provide suitable forage for young cattle or breeding females with high levels of nutrient requirements. "Juan et al (2000) "It is important to note that cattle avoid mature Paspalum spp. Tussocks although after the pajonal is burned young tillers become intensely grazed." Herrera and Laterra (2009) The confidence is low due to the fact that there is no direct evidence of impact on animal production Impact magnitude not more than MC because it is not wide spread
References: Laterra, P. and Solbrig, O.T. (2000). Dispersal strategies, spatial heterogeneity and colonization success in fire-managed grasslands. Ecological Modelling, 139(1), pp.17-29. Juan, V.F., Monterroso, L., Sacido, M.B., Aequo, E. and Cauhépé, M.A. (2000). Postburning legume seeding in the Flooding Pampas, Argentina. Journal of Range Management, pp.300-304. Herrera, L.P. and Laterra, P. (2009). Do seed and microsite limitation interact with seed size in determining invasion patterns in flooding Pampa grasslands? Plant Ecology, 201(2), pp.457-469.

IMP2c: Mariculture/aquaculture	
Response: DD	Confidence:
Rationale:	
References:	
IMP2d: Forestry	
Response: DD	Confidence:
Rationale:	
References:	
IMP2e: Infrastructure and administration	
Response: DD	Confidence:
Rationale:	
References:	
IMP2f: Human health	
Response: DD	Confidence:
Rationale:	
References:	
IMP2g: Human social life	
Response: DD	Confidence:
Rationale:	
References:	

IMP3 Closely related species' environmental impact	
Response: N/A	Confidence:

Rationale:
References:

IMP4 Closely related species' socio-economic impact	
Response: N/A	Confidence:
Rationale:	
References:	

IMP5 Potential impact	
Response: MO	Confidence: Low
Rationale: Structural on ecosystems: In South Africa *P. quadrifarium* occurs in a transitional zone between a timber forest and a pasture land of small-statured grasses because *P. quadrifarium* is a large turf grass which can form impenetrable strands there is a potential risk of the species to transform the structure of the pasture land over time. Forestry production: Because of where it occurs in South Africa, *P. quadrifarium* has the potential impacts on forestry production, where it can potentially outcompete with timber seedlings thereby reducing their yield though this is likely a small impact given the land preparation prior to planting. Infrastructure and administration*: P. quadrifarium* also occur along the roads (along N2 between Kokstad and Port Shepstone and along R56) in its mature stage where it can grow over 2m high, *P. quadrifarium* can cause a physical obstruction for motorists as well as pedestrians. The confidence level is low because there is no direct observation of the information.	
References: https://www.sanbi.org/resources/infobases/invasive-alien-plant-alert/paspalum-quadrifarium/ Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria. Herrera, L.P., Texeira, M. and Paruelo, J.M. (2013). Fragment size, vegetation structure and physical environment control grassland functioning: a test based on artificial neural networks. Applied Vegetation Science, 16(3), pp.426-437.	

4. Management

MAN1 What is the feasibility to stop future immigration?	
Response: Medium	Confidence: Medium
Rationale: According to the pathways identified in BAC14, the feasibility to stop future immigration is low as it will be difficult to stop *P. quadrifarium*'s seeds and rhizomes as a contaminant, stowaway or an escape as although not a widespread species, it is likely to stowaway in goods or contaminant.	

If the species is introduced via the horticultural industry, then the industry can be regulated to stop future immigration of the species. It is a major horticultural in other countries (USA, Canada) it is likely to be introduced as seed bought through the internet.
References:

MAN2 Benefits of the Taxon	
MAN2a Socio-economic benefits of the *Taxon*	
Response: Low	Confidence: Low
Rationale: *P. quadrifarium* currently has no benefit in South Africa, in its native range, it is used for grazing of livestock before it matures and after burning. In the Americas, *P. quadrifarium* has some horticultural value and it is sometimes cultivated as an ornamental grass known as Crown grass, Golden-top grass, or evergreen Paspalum.	
References: Verloove, F. and Reynders, M. (2007). Studies in the genus *Paspalum* (Paniceae, Poaceae) in Europe—2. The Quadrifaria group. Willdenowia, 37(2), pp.423-430. Laterra, P. (1997). Post-burn recovery in the flooding Pampa: Impact of an invasive legume. Journal of Range Management, pp.274-277.	
MAN2b Environmental benefits of the *Taxon*	
Response: Low	Confidence: Low
Rationale: There is no evidence to support the environmental benefits of *Paspalum quadrifarium* in South Africa. However, in its native range, the species play a huge role in the structure of flooding grasslands of Argentina, where it is said to promote higher floristic richness and lower presence of alien plants, however, similar effect in South Africa may be undesirable	
References: Perelman, S.B., Burkart, S.E. and Leon, R.J.C. (2003). The role of a native tussock grass (*Paspalum quadrifarium* Lam.) in structuring plant communities in the Flooding Pampa grasslands, Argentina. Biodiversity & Conservation, 12(2), pp.225-238.	

MAN3 Ease of management (Table 4)	
Response: Medium	Confidence: Medium
Rationale: Ease of management is medium because some aspects make it difficult to manage *Paspalum quadrifarium* is highly accessible and fairly easy to detect, however, its seeds are persistent and produce in large numbers. It starts reproducing during the juvenile stage and can also reproduce vegetatively using rhizomes. See below also	
References: See below	
MAN3a How accessible are populations?	

Response: easy access (0)	Confidence: High
Rationale: The current population is easily accessible but some parts of the area in private land where one must get permission and concern to access the species. Specific transportation (4X4) is required as the current location is within and at the edge of a timber forest where there are no tar roads, and some parts can be slippery after rain (clay soil).	
References: Personal observation, 2017	
MAN3b Is detectability critically time-dependent?	
Response: No (0)	Confidence: High
Rationale: Flowers twice a year and inflorescence stay up to 6 months, thus the name "evergreen Paspalum". However, In the absence of inflorescences (maybe cut) and in the presence of other large turf grasses such as Miscanthus *capensis, Paspalum quadrifarium* can be difficult to detect, it is likely to have produced seeds when it is detectible	
References: Verloove, F. and Reynders, M. (2007). Studies in the genus *Paspalum* (Paniceae, Poaceae) in Europe—2. The Quadrifaria group. Willdenowia, 37(2), pp.423-430. https://www.sanbi.org/resources/infobases/invasive-alien-plant-alert/paspalum-quadrifarium/ Personal observation, 2017	
MAN3c Time to reproduction	
Response: < 1 year (2)	Confidence: High
Rationale: *Paspalum quadrifarium* spreads rapidly through rhizomes and seeds, flowers and seeds produced twice a year even at a juvenile stage.	
References: Verloove, F. and Reynders, M. (2007). Studies in the genus *Paspalum* (Paniceae, Poaceae) in Europe—2. The Quadrifaria group. Willdenowia, 37(2), pp.423-430. https://www.sanbi.org/resources/infobases/invasive-alien-plant-alert/paspalum-quadrifarium/	
MAN3d Propagule persistence	
Response: 1–5 years (1)	Confidence: Medium
Rationale: *Paspalum quadrifarium* has long seed persistence of more than 1 year and the seeds can be dormant during the winter season.	
References: Verloove, F. and Reynders, M. (2007). Studies in the genus *Paspalum* (Paniceae, Poaceae) in Europe—2. The Quadrifaria group. Willdenowia, 37(2), pp.423-430. Laterra P. (1997) Post-burn recovery in the flooding Pampa: Impact of an invasive legume. J. Range Manage. 50, 274–7.	

Vignolio, O.R., Laterra, P., Fernández, O.N., Linares, M.P., Maceira, N.O. and Giaquinta, A. (2003). Effects of fire frequency on survival, growth and fecundity of *Paspalum quadrifarium* (Lam.) in a grassland of the Flooding Pampa (Argentina). *Austral Ecology*, *28*(3), pp.263-270.

MAN4 Has the feasibility of eradication been evaluated?	
Response: Don't know	Confidence: Low
Rationale: There has been attempts to eradicate *P. quadrifarium,* however, the extent of invasion and the size of the populatoion is not known. It is suspected that the population might be larger than what it was initialy found or estimated. The overall feasibility of eradicating the species is not yet assessed, however, there has not been regrowth or re-sprout from areas where it has been removed.	
References: Expert 1: Lesley Henderson Personal observation, 2017	

5. Calculation

Likelihood = Fairly probable

Parameter	Likelihood	Stages	Final assessment
LIK1	Probable	P(entry) = Probable	P(invasion) = Fairly probable
LIK2	Don't know		
LIK3	Fairly probable	P(establishment) = Fairly probable	
LIK4	Fairly probable		
LIK5	Very unlikely	P(spread) = Fairly probable	
LIK6	Fairly probable		

Consequence = MO

Parameter	Mechanism/sector	Response
IMP1a	Competition	MO
IMP1b	Predation	DD
IMP1c	Hybridisation	DD
IMP1d	Disease	DD
IMP1e	Parasitism	DD
IMP1f	Poisoning/toxicity	DD
IMP1g	Bio-fouling	DD
IMP1h	Grazing/herbivory/browsing	DD
IMP1i	Chemical, physical or structural impact on ecosystem	MN
IMP1k	Interaction with other alien species	DD
IMP2a	Agriculture	DD
IMP2b	Animal production	MC

IMP2c	Mariculture/aquaculture	DD
IMP2d	Forestry	DD
IMP2e	Infrastructure	DD
IMP2f	Health	DD
IMP2g	Social life	DD

Risk = High

		Consequences				
		MC	MN	MO	MR	MV
Likelihood	Extremely unlikely	low	low	low	medium	medium
	Very unlikely	low	low	low	medium	high
	Unlikely	low	low	medium	high	high
	Fairly probable	medium	medium	high	high	high
	Probable	medium	high	high	high	High

Ease of Management = Medium

Parameter	**Question**	**Response**
MAN3a	How accessible are populations?	0
MAN3b	Is detectability critically time-dependent?	0
MAN3c	Time to reproduction	2
MAN3d	Propagule persistence	1
Man3	**Sum**	3

Supplementary material

Appendix BAC7: Provide here a map of the native range, if possible. If the map is available in a file, please insert a low-res copy (<1MB) and provide the file name and (if possible) a link to a higher resolution copy below.

https://www.gbif.org/species/4154990

Appendix BAC8: Provide here a map of the global alien range, including the range within the *Area*, if possible. If the map is available in a file, please insert a low-res copy (<1MB) and provide the file name and (if possible) a link to a higher resolution copy below.

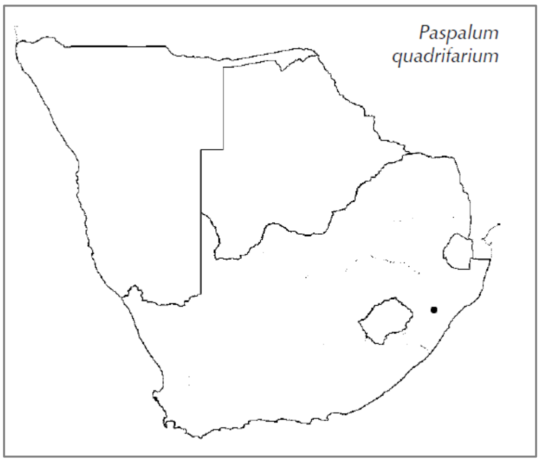


Figure BAC8a: Current distribution of *P. quadrifarium* in South Africa (Fish et al. 2015)

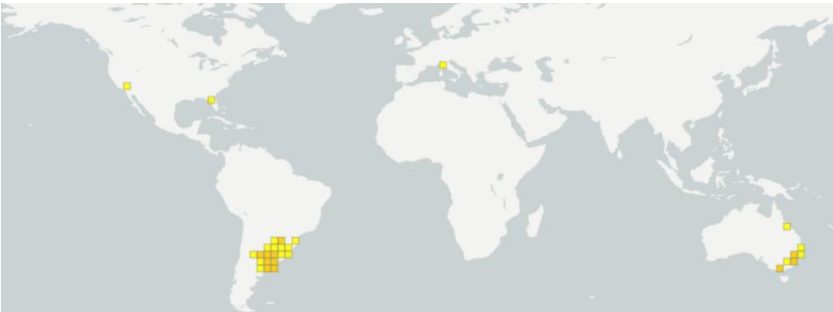


Figure BAC8b: Global distribution of *P. quadrifarium* (alien and native) (https://www.gbif.org/species/4154990)

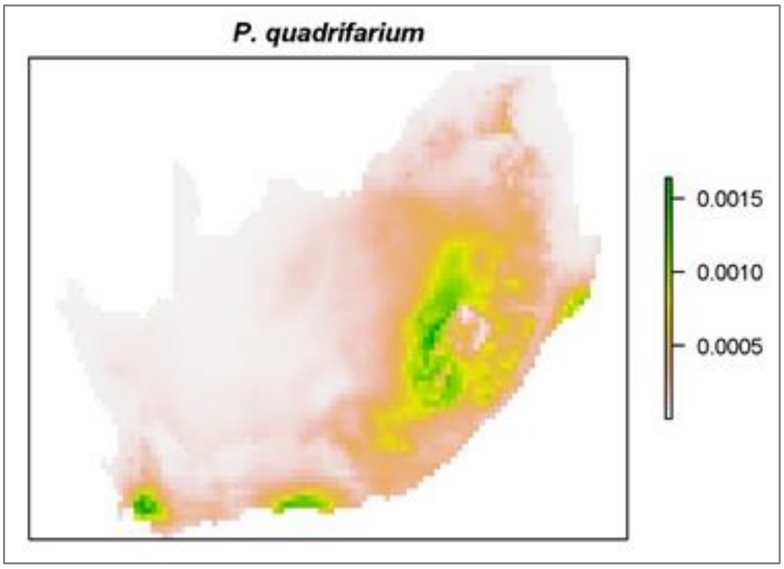
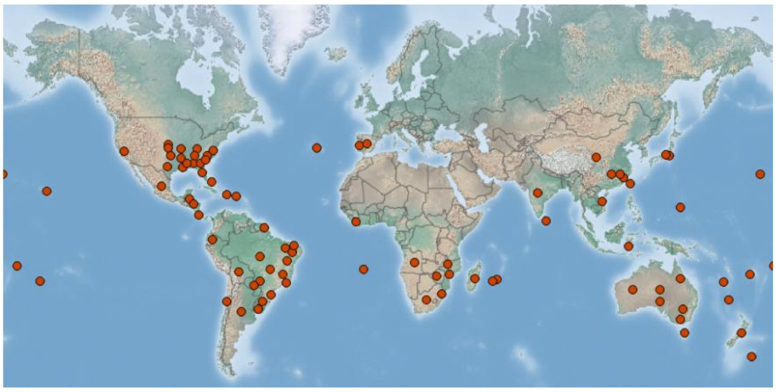


Figure LIK4: Relative occurrence rate of *P. quadrifarium* in South Africa (in correspondence with LIK4 Climate suitability of this report).

Risk Analysis Report: *Paspalum urvillei*

Summary sheet

***Taxon*:** *Paspalum urvillei* Stead (1853)	***Area*:** South Africa
Compiled by: Khensani Vulani NKUNA	**Approved by:** (leave empty)
Picture of *Taxon*  https://www.gbif.org	**Global distribution map**  http://www.cabi.org/isc/datasheet/109621
Risk Assessment summary: The overall likelihood of entry, spread and establishment for *Paspalum urvillei* is unlikely, because although it already occurs in the country its likelihood of entry (deliberately) via human aided pathways is unlikely due to its low benefits. It also has small habitat and climatic suitability, and the species dispersal capabilities are slow and short distance. It is a common weed mostly found in disturbed areas. It has the potential to compete with native species and cereal grains in the disturbed areas (i.e. agricultural land). It is not palatable and provides minimal nutrition to live stock after maturity. Impacts of *P. urvillei* are minor therefore, its overall risk in South Africa is low.	**Risk score:** **Low**
Management options summary: Populations of *P. Urvillei* in South Africa are easily accessible, however, without the flower heads the species resembles *P. dilatatum* which can make detectability harder. Propagules (seeds) are also persistent and takes 1-2 years to reach its reproduction stage. Management feasibility of *P. urvillei* in South Africa is therefore medium.	**Ease of management:** **Medium**
Recommendations: I recommend that *Paspalum urvillei* should not be listed in the NEM:BA regulations. Because it has very low risks in South Africa.	**Listing category:** **Do not list**

1. Background

BAC1 Name of assessor(s)	
Name of lead assessor	Khensani Vulani NKUNA
BAC2 Contact details of assessor (s)	
Lead assessor	Organisational affiliation: South African National Biodiversity Institute, Kirstenbosch Research Centre, Cape Town, South Africa
	Email: khensani.vulani@gmail.com
	Phone: 0825946710
BAC3 Name(s) and contact details of expert(s) consulted	
Expert (1)	Name: Lesley Henderson
	Expertise: Weed Scientist (SAPIA)
	Email: HendersonL@arc.agric.za
	Phone: + 27 33 335 9190
Expert (2)	Name: Sigrun Ammann
	Expertise: GSSA president
	Email: SigrunA@elsenburg.com
	Phone: +27 44 803 3726
Expert (3)	Name: Dave Gooodenough
	Expertise: Pasture scientist (ARC)
	Email: GoodenoughD@arc.agric.za
	Phone: + 27 33 335 9190
I acknowledge the alien grass working group for referring me to the above-mentioned experts. Lesley Henderson - provided knowledge on climate suitability and population accessibility Sigrun Ammann - provided knowledge on human aided pathways and potential impacts Dave Gooodenough - provided knowledge on the potential impacts of the species and its introduction pathway	
BAC4 Scientific name of *Taxon* under assessment	
Taxon name: *Paspalum urvillei*	Authority: Steud 1853
Comments: Species level	
References: Govaerts R. (ed). For a full list of reviewers see: http://apps.kew.org/wcsp/compilersReviewers.do (2018). WCSP: World Checklist of Selected Plant Families (version Aug 2017). In: Species 2000 & ITIS Catalogue of Life, 2018 Annual Checklist (Roskov Y., Abucay L., Orrell T., Nicolson D., Bailly N., Kirk P.M., Bourgoin T., DeWalt R.E., Decock W., De Wever A., Nieukerken E. van, Zarucchi J., Penev L., eds.). Digital resource at www.catalogueoflife.org/annual-checklist/2018. Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-884X.	

BAC5 Synonym(s) considered

Synonyms: *Paspalum dilatatum* var. parviflorum Doll (synonym), *Paspalum griseum* Hack. ex Corrêa, nom. nud. (ambiguous synonym), *Paspalum griseum* Hack. ex Loefgr. (ambiguous synonym), *Paspalum larranagae* Arechav. (synonym), *Paspalum ovatum* var. parviflorum Nees (synonym), *Paspalum vaseyanum* Scribn. (synonym), *Paspalum velutinum* Trin. ex Nees, pro syn. (synonym), *Paspalum virgatum* var. parviflorum Doll (synonym), *Paspalum virgatum* var. pubiflorum Vasey (synonym)

Comments:
Species level

References:
Govaerts R. (ed). For a full list of reviewers see: http://apps.kew.org/wcsp/compilersReviewers.do (2018). WCSP: World Checklist of Selected Plant Families (version Aug 2017). In: Species 2000 & ITIS Catalogue of Life, 2018 Annual Checklist (Roskov Y., Abucay L., Orrell T., Nicolson D., Bailly N., Kirk P.M., Bourgoin T., DeWalt R.E., Decock W., De Wever A., Nieukerken E. van, Zarucchi J., Penev L., eds.). Digital resource at www.catalogueoflife.org/annual-checklist/2018. Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-884X.

BAC6 Common name(s) considered

Common names:
English: Vasey grass, Giant paspalum; Spanish: Hierba de Vasey, Maizapo, Paja boba, French: Epinard, Herbe de Vasey, Paspale d'Urville; Chinese: Si mao que bai, Italian: Paspalo eretto,

Comments: the most used English common name is Vasey grass

References:
https://www.cabi.org/ISC/datasheet/109621

BAC7 What is the native range of the *Taxon*? (map in Appendix BAC7)

Response: Bolivia, Brazil, Argentina, Chile, Paraguay and Uruguay	Confidence: High

Comments:
“Native to the New World” cabi.org
The confidence level is high because the sources are not contradicting each other, and the databases are a reliable source on the species global distribution

References:
https://www.cabi.org/ISC/datasheet/109621
https://florabase.dpaw.wa.gov.au/
https://keyserver.lucidcentral.org/weeds
https://www.gbif.org/species/2705650

BAC8 What is the global alien range of the *Taxon*? (map in Appendix BAC8)

Response: Australia, USA, Brazil, Argentina, Taiwan, South Africa, Japan, New Zealand, Paraguay, Reunion, Swaziland, Mozambique, Zimbabwe, Rwanda, Burundi, Spain, Vietnam	Confidence: High

Comments:
Confidence level is high because the sources concur with each other.

<table>
<tr><td colspan="3">References:
https://www.cabi.org/ISC/datasheet/109621
http://ausgrass2.myspecies.info/content/paspalum-urvillei
https://www.gbif.org/occurrence/search?taxon_key=2705650</td></tr>
<tr><td colspan="3">BAC9 Geographic scope = the Area under consideration</td></tr>
<tr><td colspan="3">Area of assessment: South Africa</td></tr>
<tr><td colspan="3">Comments:</td></tr>
<tr><td colspan="3">BAC10 Is the Taxon present in the Area?</td></tr>
<tr><td colspan="2">Response: Yes</td><td>Confidence: High</td></tr>
<tr><td colspan="3">Comments:
P. urvillei is a common weed in South Africa occurring in damp disturbed areas
GPS coordinate: S29° 32.866' E30° 12.281'</td></tr>
<tr><td colspan="3">References:
Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria
South African National Biodiversity Institute. (2016). Botanical Database of Southern Africa (BODATSA) [dataset]. doi: to be assigned.</td></tr>
<tr><td colspan="3">BAC11 Availability of physical specimen</td></tr>
<tr><td colspan="2">Response: Yes</td><td>Confidence in ID: High</td></tr>
<tr><td colspan="3">Herbarium or museum accession number: PRE0628161-0 (Brahm’s code)
Live species also available across South Africa</td></tr>
<tr><td colspan="3">References:
South African National Biodiversity Institute. (2016). Botanical Database of Southern Africa (BODATSA) [dataset]. doi: to be assigned.</td></tr>
<tr><td colspan="3">BAC12 Is the Taxon native to the Area or part of the Area?</td></tr>
<tr><td>The Taxon is native to (part of) the Area.</td><td>No</td><td>Confidence: High</td></tr>
<tr><td>The Taxon is alien in (part of) the Area.</td><td>Yes</td><td>Confidence: High</td></tr>
<tr><td colspan="3">Comments:</td></tr>
<tr><td colspan="3">References:
Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria
South African National Biodiversity Institute. (2016). Botanical Database of Southern Africa (BODATSA) [dataset]. doi: to be assigned.</td></tr>
<tr><td colspan="3">BAC13 What is the Taxon’s introduction status in the Area?</td></tr>
<tr><td>The Taxon is in cultivation/containment.</td><td>No</td><td>Confidence: Low</td></tr>
<tr><td>The Taxon is present in the wild.</td><td>Yes</td><td>Confidence: High</td></tr>
</table>

<table>
<tr><td>The Taxon has established/naturalised.</td><td colspan="2">Yes</td><td>Confidence: High</td></tr>
<tr><td>The Taxon is invasive.</td><td colspan="2">Don’t know</td><td>Confidence: Low</td></tr>
<tr><td colspan="4">Comments:
P. urvillei grows in disturbed moist areas in South Africa, there is no record of the species invading natural ecosystem. I am therefore uncertain whether the species is invasive in the country.</td></tr>
<tr><td colspan="4">References:
Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015) identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria</td></tr>
<tr><td colspan="4">BAC14 Primary (introduction) pathways</td></tr>
<tr><td>Release</td><td colspan="2">No</td><td>Confidence: Low</td></tr>
<tr><td>Escape</td><td colspan="2">Yes</td><td>Confidence: High</td></tr>
<tr><td>Contaminant</td><td colspan="2">No</td><td>Confidence: Low</td></tr>
<tr><td>Stowaway</td><td colspan="2">No</td><td>Confidence: Low</td></tr>
<tr><td>Corridor</td><td colspan="2">No</td><td>Confidence: Low</td></tr>
<tr><td>Unaided</td><td colspan="2">No</td><td>Confidence: Low</td></tr>
<tr><td colspan="4">Comments:
P. urvillei was introduced into South Africa as a trial species for pasture (Expert 3).
“Widely introduced as a pasture grass around the world” cabi.org, Fish et al. (2015)</td></tr>
<tr><td colspan="4">References:
Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria
Expert 3: Dave Goodenough
https://www.cabi.org/ISC/datasheet/109621</td></tr>
</table>

2. Likelihood

<table>
<tr><td colspan="2">LIK1 Likelihood of entry via unaided primary pathways</td></tr>
<tr><td>Response: Probable</td><td>Confidence: High</td></tr>
<tr><td colspan="2">Rationale:
The species is already in South Africa
“Frequency in southern Africa: Common. Distribution: Naturalised from South America. “Fish et al. (2015)
However, the species is sessile and probability of introduction unaided is highly unlikely
Confidence level is high because there is direct relevant observational evidence to support the assessment</td></tr>
<tr><td colspan="2">References:
Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria</td></tr>
</table>

LIK2 Likelihood of entry via human aided primary pathways

Response: Unlikely	Confidence: Medium
Rationale: “Widely introduced as a pasture grass around the world” cabi.org, Fish et al (2015) “Introduced into South Africa as a trial species for pasture” (Expert 3) The likelihood of entry via human aided pathways is unlikely because pathways available are infrequently used, the species has very little use and is not in demand in the country. The confidence level is medium because *P. urvillei* is not preferred for pasture in South Africa and it is not expected to be introduced in large quantities for that used.	
References: https://www.cabi.org/ISC/datasheet/109621 Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria Experts 3: Dave Goodenough	

LIK3 Habitat suitability	
Response: Unlikely	Confidence: High
Rationale: “Near water or in moist places, along water furrows, roadsides and stream banks on sandy loam, disturbed areas.” Fish et al. (2015) *“Paspalum urvillei* grows in savannas and disturbed habitats, often in moist, poorly draining soils that are saturated for more than 50% of the year, although well-drained soils are also suitable. It will tolerate drought conditions for part of the growing season but requires comparatively high total annual rainfall (preferably 1000-1500 mm). Its roots are shallow (20-50 cm), growing best in medium to heavy soils of moderate fertility. It is best suited for high light conditions. In its native range it is found in tropical climates with suitable rainfall; its introduced range extends into warm temperate climates, again provided that there is sufficient rainfall. It is tolerant of fire, drought, and flooding” cabi.org “Widely naturalised. Can invade grasslands, shrublands and wetlands. Establishes in highly disturbed natural ecosystems.” florabase.dpaw.wa.gov.au Habitat suitability of *P. urvillei* is unlikely because it is specific to moist areas and outside artificial habitats those habitats are met in a marginal part of the country. Confidence level is high because there is direct relevant observational evidence to support the assessment	
References: https://www.cabi.org/ISC/datasheet/109621 https://florabase.dpaw.wa.gov.au/ Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015) identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria	

LIK4 Climate suitability	
Response: Unlikely	Confidence: High

Rationale: The species distribution indicates that there is suitable climate in South Africa for *P. urvillei,* with *a* relative occurrence rate of > 5 % but < 20 % (see also Figure LIK4 in the appendix of this report). "*P. urvillei* is present across most provinces in South Africa, the climate suitability of the species is wide, however the species prefers disturbed moist area" (Expert 1) "Found in tropics worldwide. Frequency in southern Africa: Common… Limpopo, Gauteng, Mpumalanga, Kwa-Zulu Natal, Western Cape, Eastern Cape." Fish et al. (2015) Confidence level is high because there is direct relevant observational evidence to support the assessment and data/information are not controversial or contradictory
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria Expert 1: Lesley Henderson

LIK5 Unaided secondary (dispersal) pathways	
Response: Unlikely	Confidence: Medium
Rationale: *"P. urvillei* is dispersed by water, animals, machinery, vehicles, footwear, contaminated grain and agricultural practices. It spreads both by seed and by rhizome." cabi.org "This species reproduces mainly by seed, which are dispersed by wind, water, animals." keyserver.lucidcentral.org Unaided secondary pathway for *P. urvillei* is unlikely because the species is sessile and dispersal capabilities are slow and short distance (< 50km in 10 years). Confidence level is medium because there is some direct observational evidence to support the assessment, but some information is inferred.	
References: https://keyserver.lucidcentral.org/weeds https://www.cabi.org/ISC/datasheet/109621 Expert 1: Lesley Henderson	

LIK6 Human aided secondary (dispersal) pathways	
Response: Fairly probable	Confidence: High
Rationale: Seeds are hairy, can easily attach to clothes and livestock. (Expert 2) "…upper glume and lower lemma fringed on margins with silky hairs giving a woolly appearance…" Fish et al (2015) It may be introduced intentionally as a minor agricultural crop due to its use as a forage grass" cabi.org "This species reproduces mainly by seed, which are dispersed by … vehicles, machinery, and in contaminated soil and agricultural produce." keyserver.lucidcentral.org	

The human aided secondary pathway of P. urvillei is fairy probable because it is easily accessible by humans and livestock its propagules (seeds) are easily moved by attaching to clothes, skin and hides. Confidence level is high because there is direct relevant observational evidence to support the assessment and data/information are not controversial or contradictory
References: Expert 2: Sigrun Ammann Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015) identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria

3. Consequences

IMP1 Environmental impact (Figure 3)	
Response: MN	Confidence: High
Rationale: Minor due to impacts through competition with native species Also see below	
References: See below	
IMP1a: Competition	
Response: MN	Confidence: Medium
Rationale: “*Paspalum dilatatum* and *P. urvillei* (dallis grass and vasey grass), commonly over 3.3 ft (1 m) in height, are perennial grasses that invade disturbed areas with open tree canopies.” Anderson et al. (1992) This grass has a growing habit like tussock, with a relative faster growing rate and larger leaves than the other species. These attributes allowed *P. urvillei* to compete for light with L. *multiflorum* during spring, explaining its high contribution in the TP during summer.” Oliveira et al. (2015). It is now widely naturalized and is able to invade grasslands, shrublands and wetlands. It invades and establishes in highly disturbed natural ecosystems where it grows into dense stands, displacing indigenous vegetation and altering the lower strata (Western Australian Herbarium, 2012).” cabi.org Confidence level is medium because there is some direct observation to support the assessment but the data/information from the sources is contradictory. For example, according to cabi.org P. urvillei invades natural ecosystems and alters the lower strata, but the ecosystems are disturbed, suggesting that P. urvillei is not the main cause of the impacts.	
References: Anderson, S.J., Stone, C.P. and Higashino, P.K. (1992). Distribution and spread of alien plants in Kipahulu Valley, Haleakala National Park, above 2,300 ft. elevation. Alien plant invasions in native ecosystems of Hawaii: management and research. University of Hawaii Cooperative National Park Resources Studies Unit, Honolulu, pp.300-338. Oliveira, L.B., Soares, E.M., Jochims, F., Tiecher, T., Marques, A.R., Kuinchtner, B.C., Rheinheimer, D.S. and de Quadros, F.L. (2015). Long-Term Effects of Phosphorus on	

<table>
<tr><td colspan="2">Dynamics of an Overseeded Natural Grassland in Brazil. Rangeland Ecology & Management, 68(6), pp.445-452.
http://www.cabi.org/isc/datasheet/109621</td></tr>
<tr><td colspan="2">IMP1b: Predation</td></tr>
<tr><td>Response: DD</td><td>Confidence:</td></tr>
<tr><td colspan="2">Rationale:</td></tr>
<tr><td colspan="2">References:</td></tr>
<tr><td colspan="2">IMP1c: Hybridisation</td></tr>
<tr><td>Response: MC</td><td>Confidence: High</td></tr>
<tr><td colspan="2">Rationale:
“In addition, there are problems in the case of P. urvillei, because this species can breed with the yellow-anthered P. dilatatum Vacaria, resulting in morphologically intermediate types between P. urvillei and P. dilatatum yellow anthered.” Miz and de Souza-Chies (2006)
“However, P. urvillei easily hybridizes with P. dasypleurum in controlled crosses (crossability = 5 3.9%), but P. dasypleurum is geographically isolated from P. urvillei.” Quarín and Caponio (1995)
“On the other hand, evidence for ongoing gene flow was only found between Vacaria and P. urvillei. Valls and Pozzobon (1987) reported, on the basis of field observations, that Vacaria formed natural hybrids with P. urvillei where their areas of distribution overlapped, whereas natural hybrids between Virasoro or P. dilatatum ssp. flavescens and P. urvillei have not been recorded.” Speranza (2009)
“Interspecific hybridisation and backcrossing were used in an attempt to transfer the ergot resistance of Paspalum urvillei (vaseygrass) into a sexual biotype of P. dilatatum (dallisgrass). A number of crosses have been made between a sexual form of P. dilatatum (2n = 40) and P. urvillei (2n = 40) but the F1 hybrids died before flowering (Burton 1943; Burson 1983).” Schaaf (2003)
Hybridisation between P. urvillei and the species mention in the sources above is of minimal concern (MC) because it is not observed in the wild (natural environment).
Confidence level is high because there is direct relevant observational evidence to support the assessment and data/information are not controversial or contradictory.</td></tr>
<tr><td colspan="2">References:
Miz, R.B. and de Souza-Chies, T.T. (2006). Genetic relationships and variation among biotypes of dallisgrass (Paspalum dilatatum Poir.) and related species using random amplified polymorphic DNA markers. Genetic Resources and Crop Evolution, 53(3), pp.541-552.
Quarín, C.L. and Caponio, I. (1995). Cytogenetics and reproduction of Paspalum dasypleurum and its hybrids with P. urvillei and P. dilatatum ssp. flavescens. International Journal of Plant Sciences, 156(2), pp.232-235.
Speranza, P.R. (2009). Evolutionary patterns in the Dilatata group (Paspalum, Poaceae). Plant Systematics and Evolution, 282(1-2), pp.43-56.
Schrauf, G.E., Blanco, M.A., Cornaglia, P.S., Deregibus, V.A., Madia, M., Pacheco, M.G., Padilla, J., García, A.M. and Quarín, C. (2003). Ergot resistance in plants of Paspalum dilatatum incorporated by hybridisation with Paspalum urvillei. Tropical Grasslands, 37(3), pp.182-186.</td></tr>
<tr><td colspan="2">IMP1d: Transmission of disease</td></tr>
<tr><td>Response: MC</td><td>Confidence: Low</td></tr>
</table>

Rationale: “cultivated as pasture for hay as it is frost resistant and only occasionally susceptible to ergo” Fish et al (2015) Impact through transmission of disease to native plants is of minimal concern because it is infrequent Confidence level is low because there is no direct observational evidence to support the assessment from the source and the source is not the best quality to report on this impact.	
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria	
IMP1e: Parasitism	
Response: DD	Confidence:
Rationale:	
References:	
IMP1f: Poisoning/toxicity	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1g: Bio-fouling	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1h: Grazing/herbivory/browsing	
Response: DD	Confidence:
Rationale:	
References:	
IMP1i: Chemical, physical or structural impact on ecosystem	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1k: Interaction with other alien species	
Response: DD	Confidence: Low
Rationale:	
References:	

IMP2 Socio-economic impact (Figure 3)	
Response: MC	Confidence: High
Rationale: Impact magnitude is MC- due to impacts on human health. Also see below	
References: See below	
IMP2a: Agriculture	
Response: MC	Confidence: Low

Rationale: "Vaseygrass (*Paspalum urvillei* Steud.) is a weed in environments where limpograss [*Hemarthria altissima* (Poir.) Stapf & Hubb.] is a productive pasture grass." Newman and Sollenberger (2005) The Mexican rice borer, *Eoreuma loftini* (Dyar) (Lepidoptera: Crambidae), is a key pest of sugarcane (Saccharum spp. hybrids). This range expansion has likely been supported by >22 other host plants, including graminaceous weeds and forage, e.g., Vasey's grass (*Paspalum urvillei* Steud.)" Showler and Moran (2014) Impacts on agricultural production is of minimal concern because the economic loss are minor and in a small scale Confidence level is low because there is no direct observational evidence to support the assessment and some of the information inferred	
References: Newman, Y.C. and Sollenberger, L.E. (2005). Grazing management and nitrogen fertilization effects on vaseygrass persistence in limpograss pastures. Crop science, 45(5), pp.2038-2043. Showler, A.T. and Moran, P.J. (2014). Associations between host plant concentrations of selected biochemical nutrients and Mexican rice borer, Eoreuma loftini, infestation. Entomologia Experimentalis et Applicata, 151(2), pp.135-143.	
IMP2b: Animal production	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2c: Mariculture/aquaculture	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2d: Forestry	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2e: Infrastructure and administration	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2f: Human health	
Response: MC	Confidence: Low
Rationale: "The pollen of *P. urvillei* is mildly allergenic (PollenLibrary.com, 2012)." cabi.org	
References: http://www.cabi.org/isc/datasheet/109621	
IMP2g: Human social life	
Response: DD	Confidence: Low
Rationale:	
References:	

IMP3 Closely related species' environmental impact	
Response: N/A	Confidence:
Rationale:	
References:	

IMP4 Closely related species' socio-economic impact	
Response: N/A	Confidence:
Rationale:	
References:	

IMP5 Potential impact	
Response: MN	Confidence: Low
Rationale: Animal production: *P. urvillei* is not palatable when mature, can also harden which may injure livestock when they graze (Expert 3). Transmission of diseases: this species invades agricultural and pasture lands, it is susceptible to ergot and can transmit the diseases to the crops or the pasture grass (Expert 2). Confidence level is low because there is some direct observation by the experts but most of their information is inferred	
References: Expert 3: Dave Goodenough Expert 2: Sigrun Ammann	

4. Management

MAN1 What is the feasibility to stop future immigration?	
Response: Low	Confidence: Low
Rationale: *P. urvillei* was introduced into South Africa for pasture, however it is not a suitable pasture grass it is therefore no longer primarily used for pasture. Chances for the species to be re-introduced for pasture are low as it has low nutritional value, however, this species also occurs in our neighbouring countries (i.e. Mozambique, Zimbabwe, and Swaziland)	
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria http://www.cabi.org/isc/datasheet/109621	

MAN2 Benefits of the Taxon	
MAN2a Socio-economic benefits of the *Taxon*	
Response: Low	Confidence: Medium

Rationale: *"Paspalum urvillei* is cut for hay in the United States, and the hay is classed as good. It is used as a silage crop in Sri Lanka (FAO, 2012b). It is a minor forage crop in the United States but is generally considered a weed in subtropical coastal Australia and is not as palatable to grazing animals as other pasture grass species, quickly becoming coarse and avoided by stock (FAO, 2012b). "cabi.org "Economics: Young growth palatable and nutritious, but its palatability quickly diminishes as the plant matures, becoming stalky when old; cultivated as pasture for hay as it is frost resistant and only occasionally susceptible to ergot; old inflorescences were used as whisk brooms for brushing lint; a weed that is difficult to control when the plant reaches maturity." Fish et al. (2015) *P. urvillei*'s socio-economic value in South Africa is low because it does not serve its primary purpose of introduction (i.e. for pasture), due to unpalatability, it is not in demand and there are other species serving that purpose. Confidence level is medium because there is some direct observational evidence to support the assessment, but some information is inferred	
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria http://www.cabi.org/isc/datasheet/109621	
MAN2b Environmental benefits of the *Taxon*	
Response: Low	Confidence: Low
Rationale: *"P. urvillei* was among native grasses used to control invasive South African lovegrass, *Eragrostis plana*, in a study in Brazil "cabi.org Environmental benefits of *P. urvillei* are low because there is data deficiency to support the benefit, and the ones mentioned on the source are not desirable for South Africa.	
References: http://www.cabi.org/isc/datasheet/109621	

MAN3 Ease of management (Table 4)	
Response: Medium	Confidence:
Rationale: Ease of management is medium because some aspects make it difficult to manage Populations of *P. urvillei* are easily accessible in South Africa, however, detectability is time dependent. See also below	
References: See below	
MAN3a How accessible are populations?	
Response: 0	Confidence: Low
Rationale:	

This grass occurs in disturbed moist area where humans and livestock have cause disturbances i.e. hiking trails, road sides, riparian areas, along a drainage system, etc. the populations are fairly accessible
References: Expert 1: Lesley Henderson

MAN3b Is detectability critically time-dependent?	
Response: 2	Confidence: High
Rationale: "Resembles *P. dilatatum*, which has a larger spikelet, 3–4mm long and fewer racemes." Fish et al (2015)	
References: Fish L., Mashau A.C., Moeaha M.J., Nembudani M.T. (2015). Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. Strelitzia 36. South African National Biodiversity Institute, Pretoria	
MAN3c Time to reproduction	
Response: 1	Confidence: Medium
Rationale: "1-2 years to reach sexual maturity." vro.agriculture.vic.gov.au	
References: http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/lwm_pest_plants	
MAN3d Propagule persistence	
Response: 1	Confidence: Low
Rationale: "Mature plant produces viable propagules for at least 3 years, but unlikely to be more than 10 years, as this is a grass. Seeds survived at least 9 months under various experimental conditions" vro.agriculture.vic.gov.au	
References: http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/lwm_pest_plants	

MAN4 Has the feasibility of eradication been evaluated?	
Response: No	Confidence: Low
Rationale:	
References:	

5. Calculations

Likelihood = Unlikely

Parameter	Likelihood	Stages	Final assessment
LIK1	Probable	P(entry) = Probable	P (invasion) = Unlikely
LIK2	Unlikely		
LIK3	Unlikely	P(establishment) = Unlikely	
LIK4	Unlikely		

LIK5	Unlikely	P (spread) = Fairly probable	
LIK6	Fairly probable		

Consequence = MN

Parameter	**Mechanism/sector**	**Response**
IMP1a	Competition	MN
IMP1b	Predation	DD
IMP1c	Hybridisation	MC
IMP1d	Disease transmission	MC
IMP1e	Parasitism	DD
IMP1f	Poisoning/toxicity	DD
IMP1g	Bio-fouling	DD
IMP1h	Grazing/herbivory/browsing	DD
IMP1i	Chemical, physical, structural impact	DD
IMP1k	Interaction with other aliens	DD
IMP2a	Agriculture	MC
IMP2b	Animal production	DD
IMP2c	Mariculture/aquaculture	DD
IMP2d	Forestry	DD
IMP2e	Infrastructure	DD
IMP2f	Human health	MC
IMP2g	Human social life	DD

Risk = Medium

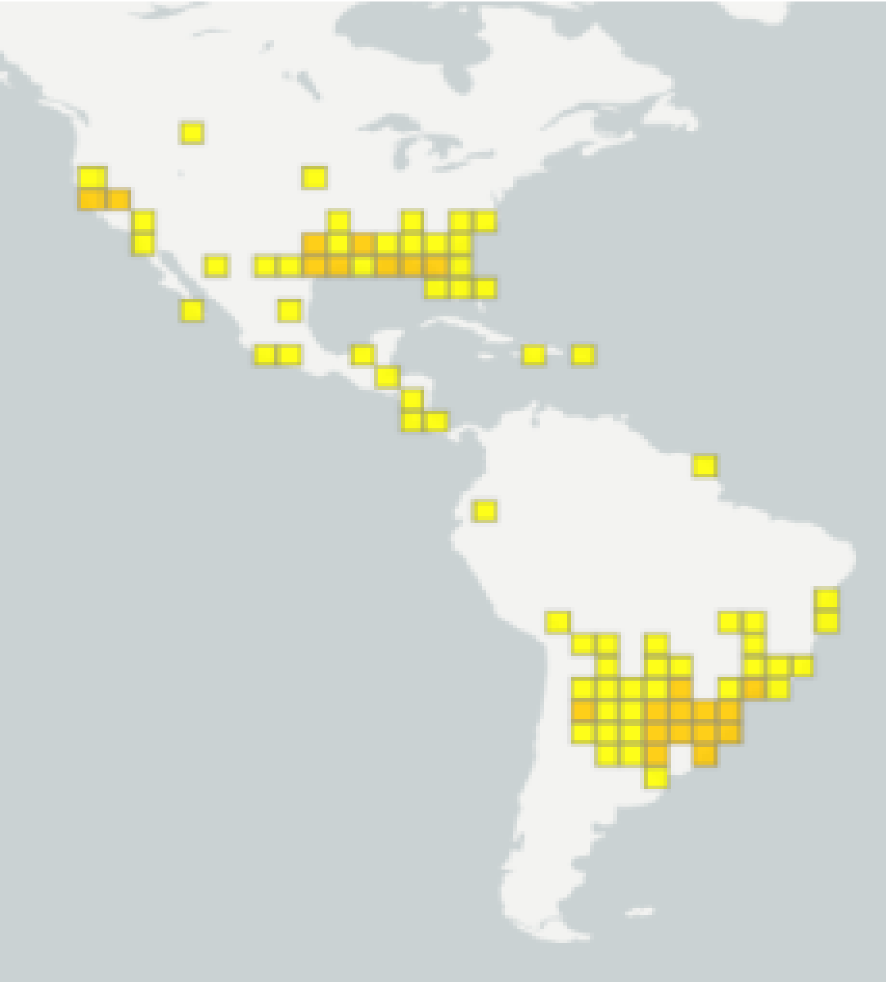
		Consequences				
		MC	MN	MO	MR	MV
Likelihood	Extremely unlikely	low	low	low	medium	medium
	Very unlikely	low	low	low	medium	high
	Unlikely	low	low	medium	high	high
	Fairly probable	medium	medium	high	high	high
	Probable	medium	high	high	high	high

Ease of management = Medium

Parameter	**Question**	**Response**
MAN3a	How accessible are populations?	0
MAN3b	Is detectability critically time-dependent?	2
MAN3c	Time to reproduction	1
MAN3d	Propagule persistence	1
MAN3	**SUM**	4

Supplementary to add to answer sheet

Appendix BAC7: Provide here a map of the native range, if possible. If the map is available in a file, please insert a low-res copy (<1MB) and provide the file name and (if possible) a link to a higher resolution copy below.



https://www.gbif.org/species/2705650

Appendix BAC8: Provide here a map of the global alien range, including the range within the *Area*, if possible. If the map is available in a file, please insert a low-res copy (<1MB) and provide the file name and (if possible) a link to a higher resolution copy below.

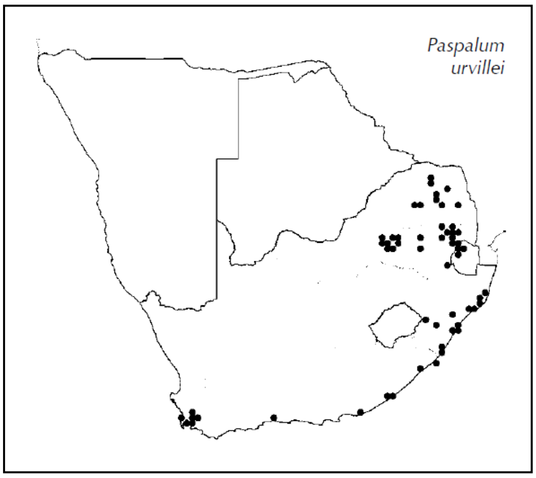


Figure 1: Current distribution of *P. urvillei* in South Africa (Fish et al. 2015)

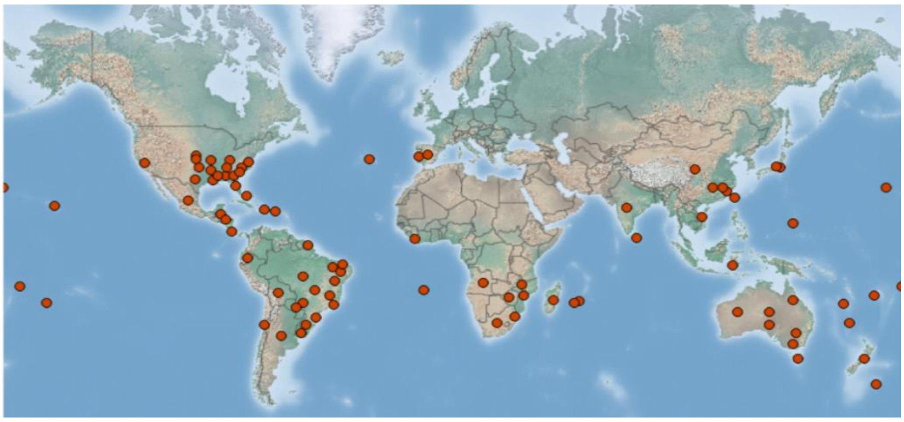


Figure 2: Global distribution of *P. urvillei* (alien and native) (http://www.cabi.org/isc/datasheet/109621)

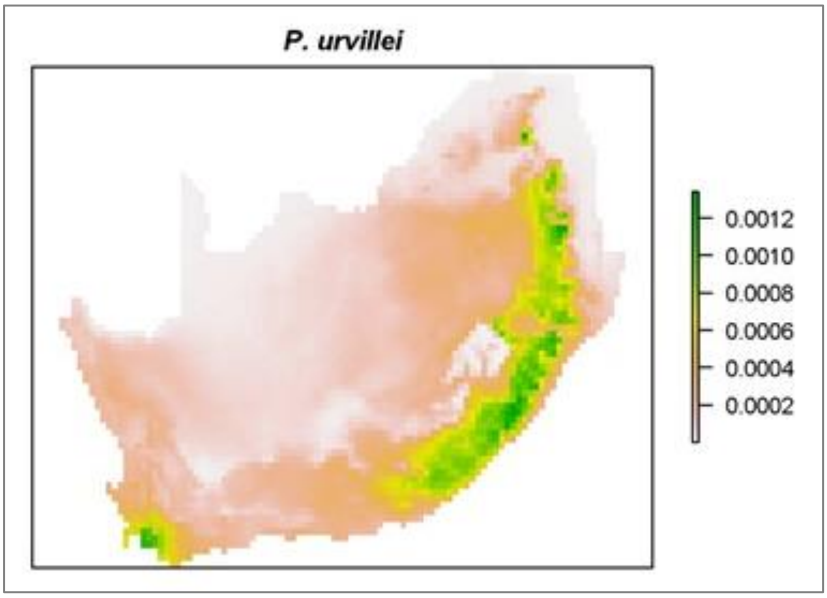
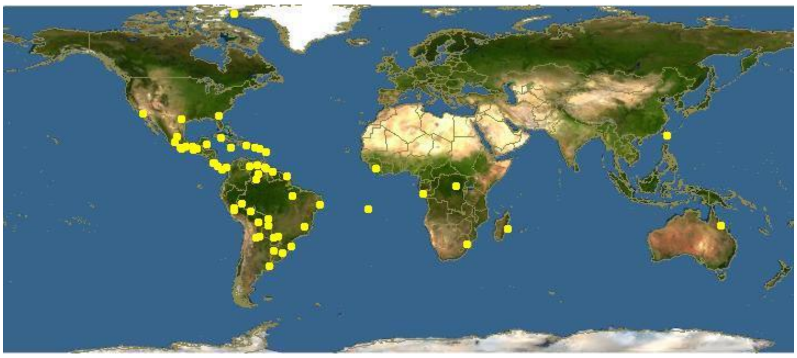


Figure LIK4: Relative occurrence rate of *P. urvillei* in South Africa

Risk Analysis Report: *Paspalum virgatum*

Summary sheet

***Taxon*:** *Paspalum virgatum* L. (1759)	***Area*:** South Africa
Compiled by: Khensani Vulani NKUNA	**Approved by:**
Picture of *Taxon*  http://eol.org/pages/1114557	**Alien distribution map** (BAC8)  https://www.discoverlife.org/mp/20m?map=Paspalum+virgatum
Risk Assessment summary: Likelihood of entry, spread and establishment for *Paspalum virgatum* is very unlikely in South Africa. *P. virgatum* was introduced in the country as a pasture species, but it seems it did not survive to naturalise. Species distribution modelling also indicate a very small suitable range in south Africa. There is no evidence on the environmental and socio-economic impacts of *P. virgatum.* It is closely related to *P. intermedium* and this species grows along the roads and hybridize with other *Paspalum* species, including *P. virgatum.* However, these impacts are of minor concern because hybridization is not recorded in the wild (only laboratory studies) and *P. intermedium* only invaded disturbed areas such as roadsides. The overall risk posed by *P. virgatum* in South Africa is therefore low.	**Risk score:** **Low**
Management options summary: Managing *P. virgatum* in South Africa will be difficult because of the information paucity with regards to the whereabouts of the species' populations, their accessibility and whether its identification is time dependent. *P. virgatum* has multiple ways of reproducing, i.e. by seeds and vegetatively using rhizomes, which can also lower its management feasibility.	**Ease of management:** **Difficult**

Recommendations:	**Listing category:**
P. virgatum is a low risk species in South Africa, and there is no information reporting on its impacts elsewhere. It is habitat specific and its suitable habitat is very small in South Africa. Ease of management is made difficult by the lack of information on this species in general. Studies looking on its environmental and socio-economic impacts should be conducted in introduced ranges where it has naturalised. I recommend that *P. virgatum* should not be listed in the NEMBA regulations because of its low risk score.	**Do not list**

1. Background

BAC1 Name of assessor(s)	
Name of lead assessor	**Khensani Vulani NKUNA**
BAC2 Contact details of assessor (s)	
Lead assessor	Organisational affiliation: South African National Biodiversity Institute, Kirstenbosch Research Centre, Cape Town, South Africa
	email: khensani.vulani@gmail.com
	Phone: 0825946710
BAC3 Name(s) and contact details of expert(s) consulted	
Expert (1)	Name: Lesley Henderson
	Expertise: Weed Scientist (SAPIA)
	Email: HendersonL@arc.agric.za
	Phone: + 27 33 335 9190
Expert (2)	Name: Caroline Mashau
	Expertise: Poaceae herbarium curator at the South African National Biodiversity Institute (Pretoria)
	Email: c.mashau@sanbi.org.za
	Phone: 0847916363
Expert (3)	Name: Marike Trytsman
	Expertise: curator Forage Genebank at ARC-API Roodeplaat
	Email: MTrytsman@arc.agric.za
	Phone: 0128088000

Comments: I acknowledge the Alien Grass Working Group for referring me to expert 1 and 2 (Lesley Henderson and Caroline Mashau), and Sigrun Ammann for referring me to expert 3 (Marike Trytsman). Lesley Henderson: provided information on the climate suitability and potential impacts of the species Caroline Mashau: provided information on the herbarium specimen availability Marike Trytsman: provided information on specimen availability in the GenBank and introduction pathway
BAC4 Scientific name of *Taxon* under assessment
Taxon name: *Paspalum virgatum* — Authority: L. (1759)
Comments: Species level
References: Govaerts R. (ed). For a full list of reviewers see: http://apps.kew.org/wcsp/compilersReviewers.do (2018). WCSP: World Checklist of Selected Plant Families (version Aug 2017). In: Roskov Y., Orrell T., Nicolson D., Bailly N., Kirk P.M., Bourgoin T., DeWalt R.E., Decock W., De Wever A., Nieukerken E. van, Zarucchi J., Penev L., eds. (2018). Species 2000 & ITIS Catalogue of Life, 31st July 2018. Digital resource at www.catalogueoflife.org/col. Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-8858.
BAC5 Synonym(s) considered
Synonyms: *Panicum lagascae* var. virgatum (L.) Kuntze (synonym), *Paspalum lagascae* var. virgatum (L.) Kuntze (synonym), *Paspalum latifolium* Spreng., nom. illeg. (synonym), *Paspalum leucocheilum* C.Wright (synonym), *Paspalum platyphyllum* Schult. & Schult.f. (synonym), *Paspalum virgatum* var. ciliatum Döll, nom. inval. (synonym), *Paspalum virgatum* var. jacquinianum Flüggé (synonym), *Paspalum virgatum* var. linnaeanum Flüggé, nom. inval. (synonym), *Paspalum virgatum* var. stramineum Griseb. (synonym), *Paspalum virgatum* var. willdenowianum Flüggé (synonym), *Paspalum wettsteinii* Hack. (synonym).
Comments: Species level
References: Govaerts R. (ed). For a full list of reviewers see: http://apps.kew.org/wcsp/compilersReviewers.do (2018). WCSP: World Checklist of Selected Plant Families (version Aug 2017). In: Roskov Y., Orrell T., Nicolson D., Bailly N., Kirk P.M., Bourgoin T., DeWalt R.E., Decock W., De Wever A., Nieukerken E. van, Zarucchi J., Penev L., eds. (2018). Species 2000 & ITIS Catalogue of Life, 31st July 2018. Digital resource at www.catalogueoflife.org/col. Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-8858.
BAC6 Common name(s) considered
Common names: Portuguese: Talquezal Spanish: Zacaton, caguazo English: Upright paspalum

<table>
<tr><td colspan="2">Comments:</td></tr>
<tr><td colspan="2">References:
https://www.cabi.org/isc/datasheet/109622
https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=41045#null
Burtt-Davy, J. (1915). Paspalum dilatatum and paspalum virgatum. Agricultural Journal of South Africa, 2 (11), 186 – 190.
Adams, D.E., Perkins, W.E. and Estes, J.R. (1981). Pollination systems in Paspalum dilatatum Poir. (Poaceae): an example of insect pollination in a temperate grass. American Journal of Botany, 68(3), pp.389-394.</td></tr>
<tr><td colspan="2">BAC7 What is the native range of the Taxon? (map in Appendix BAC7)</td></tr>
<tr><td>Response:
USA, Mexico, Central and South America and the Caribbean</td><td>Confidence: Low</td></tr>
<tr><td colspan="2">Comments:
Confidence level is low because of the nature of the source</td></tr>
<tr><td colspan="2">References:
http://www.conabio.gob.mx/malezasdemexico/poaceae/paspalum-virgatum/fichas/ficha.htm</td></tr>
<tr><td colspan="2">BAC8 What is the global alien range of the Taxon? (map in Appendix BAC8)</td></tr>
<tr><td>Response:
Alabama; Argentina Northwest; Belize; Bolivia; Brazil North; Brazil Northeast; Brazil South; Brazil Southeast; Brazil West-Central; Central American Pac; Colombia; Costa Rica; Cuba; Dominican Republic; Ecuador; El Salvador; French Guiana; Gabon; Georgia; Guatemala; Guyana; Haiti; Hawaii; Honduras; Jamaica; Jawa; Leeward Is.; Madagascar; Madeira; Mexico Gulf; Mexico Northeast; Mexico Southeast; Mexico Southwest; Nicaragua; Panam; Paraguay; Peru; Puerto Rico; Suriname; Taiwan; Texas; Trinidad-Tobago; Venezuela; Windward Is.</td><td>Confidence: High</td></tr>
<tr><td colspan="2">Comments:
Confidence level is high because the databases are a reliable data source on the distributions of alien species, and they are not contradicting each other</td></tr>
<tr><td colspan="2">References:
http://www.catalogueoflife.org/col/details/species/id/83e36b32a4eac7b7a7052c2748c55774
https://www.kew.org/data/grasses-db/www/imp07734.htm
https://www.cabi.org/ISC/datasheet/109622</td></tr>
<tr><td colspan="2">BAC9 Geographic scope = the Area under consideration</td></tr>
<tr><td colspan="2">Area of assessment: South Africa</td></tr>
<tr><td colspan="2">Comments:</td></tr>
<tr><td colspan="2">BAC10 Is the Taxon present in the Area?</td></tr>
<tr><td>Response: I do not know</td><td>Confidence: Low</td></tr>
</table>

<table>
<tr><td colspan="3">Comments:
P. virgatum is listed in Visser et al. (2017) as introduced through pasture research stations: Athole (1934), Leeuwkuil (1938) and Prinshof (1938) for pasture trial.
P. virgatum was planted in 1915 in South Africa, but its current distribution is unknown.
“It is giving good results on the writer’s farm near Vereeniging. At the Mission Station at Oak ford, near Verulam, Natal, it is stated that horses graze this grass greedily, in preference to *P. dilatatum*, and keep in excellent condition on it.” (Burtt-Davy, 1915)
Confidence level is Low because of the uncertainty with regards to the species current distribution.</td></tr>
<tr><td colspan="3">References:
Visser, V., Wilson, J.R., Canavan, K., Canavan, S., Fish, L., Maitre, D.L., Nänni, I., Mashau, C., O'Connor, T.G., Ivey, P. and Kumschick, S. (2017). Grasses as invasive plants in South Africa revisited: Patterns, pathways and management. *Bothalia-African Biodiversity & Conservation*, *47*(2), pp.1-29.
Burtt-Davy, J. (1915) *Paspalum dilatatum* and *paspalum virgatum*. Agricultural Journal of South Africa, 2 (11), 186 – 190.</td></tr>
<tr><td colspan="3">**BAC11 Availability of physical specimen**</td></tr>
<tr><td colspan="2">Response: Yes</td><td>Confidence in ID: Medium</td></tr>
<tr><td colspan="3">Herbarium or museum accession number: PRE0963984
Specimen encoded for SABONET project (extra- Africa collections) (Expert 2).
Specimen collected from Mexico
No record of collection in the genebank Forage Genebank at ARC-API Roodeplaat (Expert 3).</td></tr>
<tr><td colspan="3">References:
Expert 2: Caroline Mashau
Expert 3: Marike Trytsman</td></tr>
<tr><td colspan="3">**BAC12 Is the *Taxon* native to the *Area* or part of the *Area*?**</td></tr>
<tr><td>The *Taxon* is native to (part of) the *Area*.</td><td>No</td><td>Confidence: High</td></tr>
<tr><td>The *Taxon* is alien in (part of) the *Area*.</td><td>Yes</td><td>Confidence: High</td></tr>
<tr><td colspan="3">Comments:
Introduced for pasture trial in Athole (1934), Leeuwkuil (1938) and Prinshof (1938) (Visser et al, 2017).
The confidence level is high because of the records of its introduction history stated in Visser et al. (2017)</td></tr>
<tr><td colspan="3">References:
Expert 2: Caroline Mashau
Visser, V., Wilson, J.R., Canavan, K., Canavan, S., Fish, L., Maitre, D.L., Nänni, I., Mashau, C., O'Connor, T.G., Ivey, P. and Kumschick, S. (2017). Grasses as invasive plants in South Africa revisited: Patterns, pathways and management. *Bothalia-African Biodiversity & Conservation*, *47*(2), pp.1-29.</td></tr>
<tr><td colspan="3">**BAC13 What is the *Taxon*’s introduction status in the *Area*?**</td></tr>
</table>

The *Taxon* is in cultivation/containment.	Don’t know	Confidence: Low
The *Taxon* is present in the wild.	Don’t know	Confidence: Low
The *Taxon* has established/naturalised.	No	Confidence: Low
The *Taxon* is invasive.	No	Confidence: Low
Comments: Unknown Confidence low because there is no other record of this and no distribution or location		
References:		

BAC14 Primary (introduction) pathways		
Release	No	Confidence: Low
Escape	No	Confidence: Low
Contaminant	Yes	Confidence: Low
Stowaway	No	Confidence: Low
Corridor	No	Confidence: Low
Unaided	No	Confidence: Low
Comments: Primary introduced as pasture trial species (Visser et al. 2017) Confidence level is low because I found no record of the species in cultivation (currently) or outside cultivation.		
References: Visser, V., Wilson, J.R., Canavan, K., Canavan, S., Fish, L., Maitre, D.L., Nänni, I., Mashau, C., O'Connor, T.G., Ivey, P. and Kumschick, S. (2017). Grasses as invasive plants in South Africa revisited: Patterns, pathways and management. *Bothalia-African Biodiversity & Conservation*, *47*(2), pp.1-29.		

2. Likelihood

LIK1 Likelihood of entry via unaided primary pathways	
Response: Very unlikely	Confidence: High
Rationale: *P. virgatum* propagules are sessile and usually does not disperse on its own It is very unlikely that *P. virgatum* will enter into South Africa unaided. Confidence level is high because the species has no taxonomic traits that will aid its introduction unaided.	
References: Burtt-Davy, J. (1915) *Paspalum dilatatum* and *Paspalum virgatum*. Agricultural Journal of South Africa, 2 (11), 186 – 190.	

LIK2 Likelihood of entry via human aided primary pathways

Response: Very unlikely	Confidence: Low
Rationale: There was a human aided pathway of introduction in the past but has since stopped, seems as if *P. virgatum* did not naturalise in South Africa after its introduction as pasture. Confidence is low because there is no clear information to support whether the species is still being introduced or not.	
References: Burtt-Davy, J. (1915) *Paspalum dilatatum and Paspalum virgatum*. Agricultural Journal of South Africa, 2 (11), 186 – 190. Visser, V., Wilson, J.R., Canavan, K., Canavan, S., Fish, L., Maitre, D.L., Nänni, I., Mashau, C., O'Connor, T.G., Ivey, P. and Kumschick, S. (2017). Grasses as invasive plants in South Africa revisited: Patterns, pathways and management. *Bothalia-African Biodiversity & Conservation*, *47*(2), pp.1-29.	

LIK3 Habitat suitability	
Response: Unlikely	Confidence: High
Rationale: *P. virgatum* seem to be highly specialised, there is suitable habitat in South Africa but only in a marginal part of the country, it is therefore unlikely for *P. virgatum* to find suitable habitat in South Africa "It does well on heavy wettish soils" (Burtt-Davy, J. 1915) "Swamp" (eol.org) "Moist or swampy ground" (www.efloras.org) The confidence level is high because the sources agree with each other	
References: Burtt-Davy, J. (1915) *Paspalum dilatatum* and *Paspalum virgatum*. Agricultural Journal of South Africa, 2 (11), 186 – 190. http://eol.org/pages/1114557/overview http://www.efloras.org/florataxon.aspx?flora_id=2&taxon_id=200025850	

LIK4 Climate suitability	
Response: Very unlikely	Confidence: High
Rationale: Species distribution indicated a relative occurrence rate of < 5 % (see Figure LIK4 in the appendix of this report) and there is also no known distribution of the plant currently in South Africa, however artificial habitats (in cultivation) have been created in the past. (Expert 1, Burtt-Davy, 1915) Climate suitability of *P. virgatum* in South Africa is therefore very unlikely.	
References: Expert 1: Lesley Henderson Burtt-Davy, J. (1915) *Paspalum dilatatum* and *Paspalum virgatum.* Agricultural Journal of South Africa, 2 (11), 186 – 190.	

LIK5 Unaided secondary (dispersal) pathways

Response: Very unlikely	Confidence: Medium
Rationale: P. virgatum is sessile and does not disperse on its own, therefore the likelihood of this species to spread unaided is very unlikely in South Africa. “It may be grown either from seed or roots; 5 lbs. of seed per acre is usually recommended” (Burtt-Davy, 1915).	
References: Burtt-Davy, J. (1915) *Paspalum dilatatum* and *Paspalum virgatum*. Agricultural Journal of South Africa, 2 (11), 186 – 190.	

LIK6 Human aided secondary (dispersal) pathways	
Response: Don’t know	Confidence: Low
Rationale: I don’t know because there is no information available on the current or recent human aided pathway. However, *P. virgatum* was cultivated in farms and pasture research stations in South Africa (Burtt-Davy, 1915), it was grazed on by livestock	
References: Burtt-Davy, J. (1915) *Paspalum dilatatum* and *Paspalum virgatum*. Agricultural Journal of South Africa, 2 (11), 186 – 190.	

3. Consequences

IMP1 Environmental impact (Figure 3)	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1a: Competition	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1b: Predation	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1c: Hybridisation	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1d: Transmission of disease	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1e: Parasitism	

Response: DD	Confidence: Low
Rationale:	
References:	
IMP1f: Poisoning/toxicity	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1g: Bio-fouling	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1h: Grazing/herbivory/browsing	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1i: Chemical, physical or structural impact on ecosystem	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP1k: Interaction with other alien species	
Response: DD	Confidence: Low
Rationale:	
References:	

IMP2 Socio-economic impact (Figure 3)	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2a: Agriculture	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2b: Animal production	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2c: Mariculture/aquaculture	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2d: Forestry	
Response: DD	Confidence: Low
Rationale:	
References:	

IMP2e: Infrastructure and administration	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2f: Human health	
Response: DD	Confidence: Low
Rationale:	
References:	
IMP2g: Human social life	
Response: DD	Confidence: Low
Rationale:	
References:	

IMP3 Closely related species' environmental impact	
Response: MC	Confidence: Low
Rationale: *P. virgatum* is closely related to *P. intermedium* (Burson, 1981) and *P. intermedium* hybridizes with *P. pubiflorum* "Mean chromosome pairing behavior 35.26 I + 2.37 II for the *P. pubiflorum x P. intermedium* hybrids." Impacts of the closely related species *P. intermedium* through hybridisation is of minimal concern because it occurs in controlled environment (laboratory studies) and the related species does not occur in South Africa. Confidence level is low because of the data deficiency on the environmental impacts of *P. virgatum* and its closely related species	
References: Burson, B.L. (1981). Cytogenetic Relationships Between *Paspalum jurgensii* and P. *intermedium, P. vaginatum,* and *P. setaceum* var. ciliatifolium 1. *Crop Science*, *21*(4), pp.515-519. Actkinson, J.M. and Burson, B.L. (1999). Cytogenetic relationships between *Paspalum pubiflorum* and three South American *Paspalum* species. *International journal of plant sciences*, *160*(4), pp.775-781.	

IMP4 Closely related species' socio-economic impact	
Response: DD	Confidence: Low
Rationale: *Paspalum intermedium* is an introduced roadside weed in the *Flora* region. It is found in Mexico and South America, but not in Central America Impacts on infrastructure: closely related species of *P. virgatum* is weedy along the roads which might cause impacts through infrastructure The socio-economic impacts of *P. intermedium* are unknown and there is data deficiency (DD) in this regard.	
References: Manual of Grasses for North America. (2007). edited by, Mary E. Barkworth, Laurel K. Anderson, Kathleen M. Capels, Sandy Long & Michael B. Piep. Utah State University Press.	

IMP5 Potential impact	
Response: MN	Confidence: Low
Rationale: Impacts through competition with native species: *P. virgatum* is a tall statured species that grows up to 2 m in height, which can give it competitive advantages over short statured grasses and shrubs. "It has a more erect habit of growth from the start" (Burtt-Davy, 1915). "Perennial. Culms stature robust to moderate, 100–200 cm tall. Ligule an eciliate membrane, lacerate. Leaf-blades 10–25 mm wide." (ausgrass2.myspecies.info) Impacts on animal production: P. virgatum may not provide enough nutrients for livestock because it becomes tough and course when mature. "becomes very coarse unless kept closely grazed" (Burtt-Davy, 1915). Confidence level is low because all of the above-mentioned impacts are inferred based on the species traits.	
References: Expert 1: Lesley Henderson Burtt-Davy, J. (1915*) Paspalum dilatatum* and *Paspalum virgatum*. Agricultural Journal of South Africa, 2 (11), 186 – 190. http://ausgrass2.myspecies.info/content/paspalum-virgatum	

4. Management

MAN1 What is the feasibility to stop future immigration?	
Response: High	Confidence: Low
Rationale: *P. virgatum* was introduced in South Africa before, but it seems as if it has failed to naturalise, it does not occur in neighbouring countries and intentional introduction of this species are regulated in the country. Confidence is low because information is inferred	
References: Expert 1: Lesley Henderson	

MAN2 Benefits of the Taxon	
MAN2a Socio-economic benefits of the *Taxon*	
Response: Low	Confidence: Medium
Rationale: *P. virgatum* was planted as pasture in South Africa but was not providing enough pasturage because it hardens, and the leaves margins becomes sharp when it matures, socio-economic benefits are therefore low Confidence is medium because some of the information is inferred but there is direct observation to support the assessment	
References:	

Morales, J. (2012). Patterns of Distribution of *Paspalum* species along environmental gradients landscapes in the Nicaraguan Dry Tropical Forest (Master's thesis, Institutt for biologi). Burtt-Davy, J. (1915) *Paspalum dilatatum* and *Paspalum virgatum*. Agricultural Journal of South Africa, 2 (11), 186 – 190.	
MAN2b Environmental benefits of the *Taxon*	
Response: Low	Confidence: Low
Rationale: It can be used to control soil erosion; however, this benefit can be fulfilled by other species here in South Africa, environmental benefits are therefore low. Confidence is low because information is inferred	
References: Morales, J. (2012). Patterns of Distribution of *Paspalum* species along environmental gradients landscapes in the Nicaraguan Dry Tropical Forest (Master's thesis, Institutt for biologi).	

MAN3 Ease of management (Table 4)	
Response: Difficult (6)	Confidence:
Rationale: Management of *P. virgatum* in South Africa is made difficult because of the lack of information on the species' accessibility and ease of identification. See also below	
References:	
MAN3a How accessible are populations?	
Response: Don't know (2)	Confidence: High
Rationale: I don't know about the accessibility of *P. virgatum's* population in South Africa In its native range it grows in an altitude range of 0 to 1200 m (Morales 2012) Confidence level is high because the source is a good quality source to report on the distribution on the species.	
References: Morales, J. (2012). Patterns of Distribution of *Paspalum* species along environmental gradients landscapes in the Nicaraguan Dry Tropical Forest (Master's thesis, Institutt for biologi).	
MAN3b Is detectability critically time-dependent?	
Response: Don't know (2)	Confidence: low
Rationale: "From the images the seed heads look similar to Tussock paspalum, but one can never be sure" (Expert 1) Confidence level is low because the information is inferred	
References: Expert 1: Lesley Henderson	
MAN3c Time to reproduction	
Response: Don't know (1)	Confidence: Medium
Rationale:	

I don't know how long it takes for the *P. virgatum* to start reproducing. However, it is an allotetraploid, it reproduces by seeds and rhizomes (Morales 2012) Confidence level is medium because there is direct observation to support the assessment, however, some important information is still missing
References: Morales, J. (2012). Patterns of Distribution of *Paspalum* species along environmental gradients landscapes in the Nicaraguan Dry Tropical Forest (Master's thesis, Institutt for biologi).
MAN3d Propagule persistence
Response: 1–5 years (1) | Confidence: High
Rationale: The seeds lose viability over a period of three years, but the plant can also reproduce and be planted by rhizomes as well. Confidence level is high because there was direct observation to support the assessment and the reference is a good quality source to report the persistence of the species' propagules.
References: Kellman, M. (1980). Longevity and susceptibility to fire of *Paspalum virgatum* L. seed. *Tropical Agriculture*, *57*(4), pp.301-304.

MAN4 Has the feasibility of eradication been evaluated?	
Response: No	Confidence: Low
Rationale:	
References:	

5. Calculation

Likelihood = Very unlikely

Parameter	Likelihood	Stages	Final assessment
LIK1	Very unlikely	P(entry) = Very unlikely	P(invasion) = Very unlikely
LIK2	Very unlikely		
LIK3	Unlikely	P(establishment) = Unlikely	
LIK4	Very unlikely		
LIK5	Very unlikely	P(spread) = Don't know	
LIK6	Don't know		

Consequence = DD

Parameter	Mechanism/sector	Response
IMP1a	Competition	DD
IMP1b	Predation	DD
IMP1c	Hybridisation	DD
IMP1d	Disease	DD
IMP1e	Parasitism	DD

IMP1f	Poisoning/toxicity	DD
IMP1g	Bio-fouling	DD
IMP1h	Grazing/herbivory/browsing	DD
IMP1i	Chemical, physical or structural impact on ecosystem	DD
IMP1k	Interaction with other alien species	DD
IMP2a	Agriculture	DD
IMP2b	Animal production	DD
IMP2c	Mariculture/aquaculture	DD
IMP2d	Forestry	DD
IMP2e	Infrastructure	DD
IMP2f	Health	DD
IMP2g	Social life	DD

Risk = Low

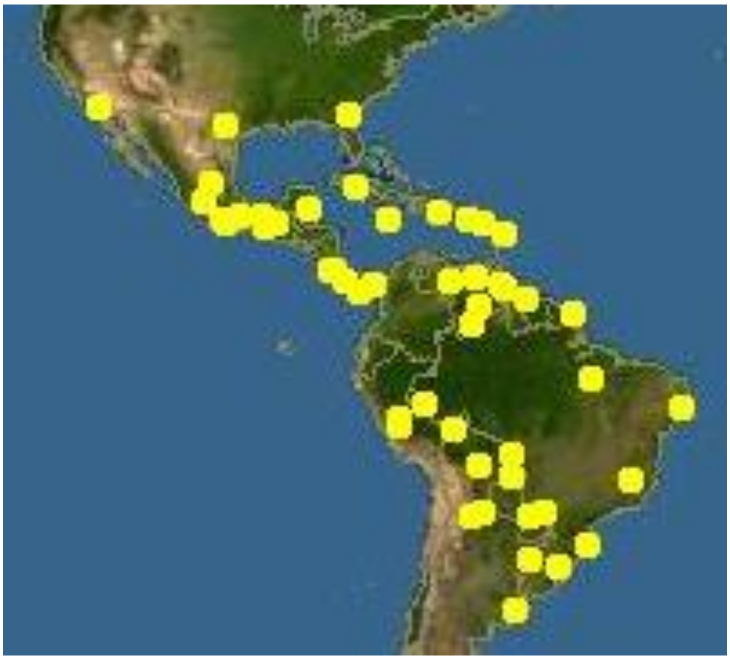
		Consequences				
		MC	MN	MO	MR	MV
Likelihood	Extremely unlikely	low	low	low	medium	medium
	Very unlikely	low	low	low	medium	high
	Unlikely	low	low	medium	high	high
	Fairly probable	medium	medium	high	high	high
	Probable	medium	high	high	high	High

Ease of Management = Medium

Parameter	**Question**	**Response**
MAN3a	How accessible are populations?	2
MAN3b	Is detectability critically time-dependent?	2
MAN3c	Time to reproduction	1
MAN3d	Propagule persistence	1
Man3	**Sum**	6

Supplementary to add to answer sheet

Appendix BAC7: Provide here a map of the native range, if possible. If the map is available in a file, please insert a low res copy (<1MB) and provide the file name and (if possible) a link to a higher resolution copy below.



https://www.discoverlife.org/mp/20m?map=Paspalum+virgatum

Appendix BAC8: Provide here a map of the global alien range, including the range within the *Area*, if possible. If the map is available in a file, please insert a low res copy (<1MB) and provide the file name and (if possible) a link to a higher resolution copy below.

- Map not available for distribution of the taxon in the Area

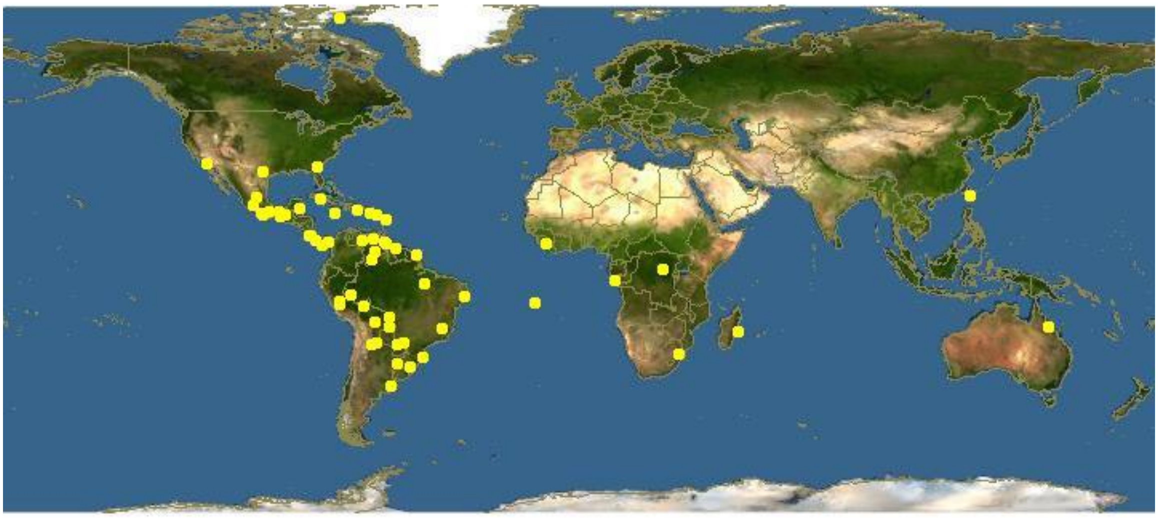


Figure 1: Global distribution of *P. virgatum* (alien and native) https://www.discoverlife.org/mp/20m?map=Paspalum+virgatum

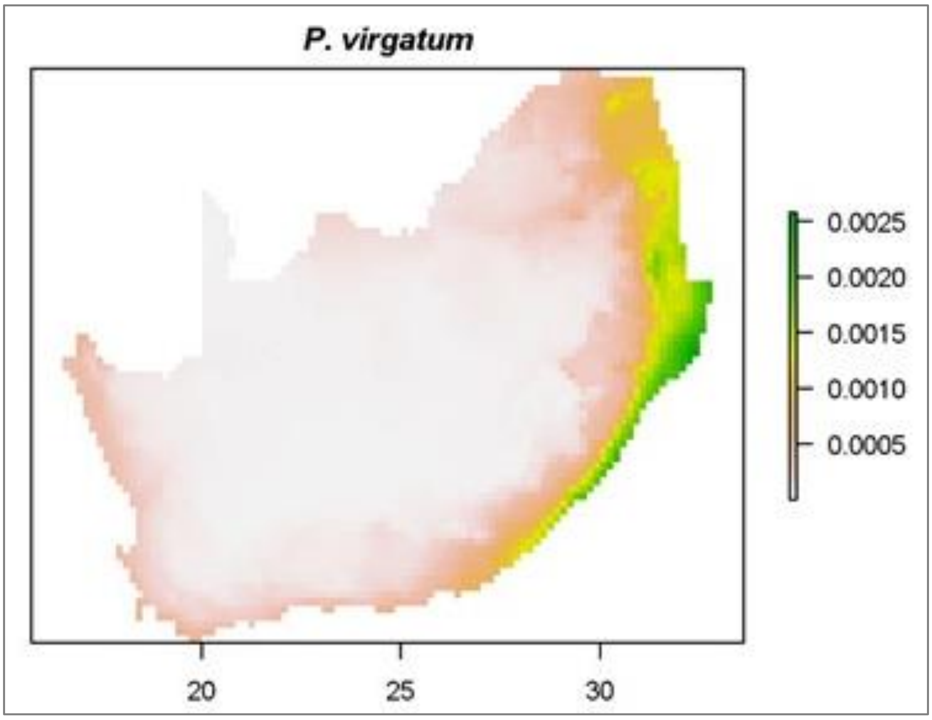


Figure 2: Relative occurrence rate of *P. virgatum* in South Africa