

COUNTING THE COST

Economic impacts of gamba grass in the Northern Territory



This report is an independent research paper commissioned by Pew Charitable Trusts and Environment Centre Northern Territory and written by Techa Beaumont, Thomas Keily and Simon Kennedy of the Centre for Conservation Geography.

Date: November 2018

Cover Photo: Weed Management Branch NT, Department of Environment and Natural Resources.

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The Centre for Conservation Geography is a research group established in June 2011 to provide expert technical support and advice to government and non-government decision makers and stakeholders. The centre's focus is to apply world's best practice in decision support to planning for biodiversity conservation. Based in Australia, our goal is to build a multi-disciplinary team capable of providing support to conservation decisions being made across the world's ecoregions.

The Centre for Conservation Geography currently has projects across Australia and in the Southern Ocean. Our areas of expertise are in marine and terrestrial protected area planning including protected area performance assessment, cost-efficient conservation priority setting and planning for multiple objectives (e.g. carbon sequestration and biodiversity protection).

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EXECUTIVE SUMMARY

Gamba grass (*Andropogon gayanus*) is a weed that is highly invasive in the tropical savannas of Northern Australia. In the Northern Territory, it is increasingly acknowledged as one of the most significant threats to ecosystems and property. Although gamba grass has received increased attention from Government recently, core infestations of up to 1.5 million hectares in the Darwin, Batchelor and Katherine regions continue to expand. New infestations have been discovered throughout the savanna region from remote Arnhem land to Groote Eylandt, demonstrating aggressive expansion through multiple pathways of seed dispersal.

The economic costs of these gamba grass weed invasions in the Northern Territory are also escalating rapidly. Leading researchers point to a 'lack of adequately resourced on-ground action across the region of potential invasion' (Setterfield, Rossiter-Rachor & Adams, 2018) as the weed continues to spread despite statutory requirements stipulating that it must be either controlled or eradicated across the entire Northern Territory. Efforts to document and calculate the full economic consequences of this containment failure are ongoing. It is clear that up-front resourcing of early intervention and control measures are more cost effective than dealing with the rising costs of managing further gamba grass invasions.

This report is a rapid synthesis and analysis of available literature and data to inform policy makers on the varied economic impacts of gamba grass infestation and thus, the potential costs of delayed or inadequate responses, or a failure to act.

In particular, the report brings together data and research which demonstrates that:

- Insufficient resourcing of gamba grass control efforts costs the Northern Territory tens of millions of dollars annually, most significantly in fire management and weed control, but also in lost opportunities from the growing carbon sector. These costs will continue to increase if gamba grass expands further across the Territory.
- Adequate resourcing of on-ground action aimed at stemming the expansion of gamba grass will provide significant future savings both to Government and private actors. Increasing investment in control and eradication now reduces future costs that would otherwise be payable in perpetuity.
- Significant investment is needed to assist private landowners to control gamba grass and to protect public assets, such as Litchfield National Park. Failure to control gamba infestations now will likely result in a situation in which management is both financially and logistically unfeasible in the future.
- Gamba grass poses a serious threat to the burgeoning carbon industry in the Northern Territory. Infested regions already amount to potentially lost revenue opportunities of over one million dollars per annum and this weed threatens the viability of existing and future carbon projects.

It is clear from this body of research that delayed action or insufficient investment in managing gamba grass will result in escalating weed control and firefighting costs, with decreasing prospects for successful containment and control over time (Adams et al., 2015).

The Northern Territory Government needs to urgently allocate sufficient resources to control and eradicate gamba grass. In particular, it is vital that additional resources are targeted at early eradication of small and/or strategic infestations and to ensure the control and containment of larger infestations.

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ACKNOWLEDGEMENTS

The authors of this report are indebted to the long-term and extensive research conducted by scientific researchers and their government counterparts in the Northern Territory and further afield researching and documenting the impacts of gamba grass invasions. In particular, a large proportion of the material presented in this report is based on the extensive body of work published by researchers Associate Professor Samantha Setterfield (University of Western Australia), Dr Vanessa Adams (University of Tasmania), Dr Natalie Rossiter-Rachor (Charles Darwin University) and their various collaborators. However, all errors within this document remain the authors' own.

Thanks are also due to the various Ranger groups and savanna carbon abatement project staff who gave their time to discuss these issues, as well as staff at Bushfires NT and the NT Weed Management Branch for assistance in accessing data and sharing information.

INTRODUCTION

This report documents and, where possible within available public data, quantifies some of the known impacts and associated costs borne by public and private actors. It brings together and supplements existing research that has highlighted the costs associated with containing or failing to contain gamba grass infestation within the Northern Territory.

While many impacts of invasion are open to potential valuation, such as the cost of weed control, fire management in invaded areas and loss of infrastructure, other impacts are harder to quantify but are no less grave. Impacts that are difficult to quantify include the radical transformation of biodiversity and ecosystem services, loss of cultural resources and traditional food sources, impacts on public safety and the health of fire fighters and the general public.

Scientists have long argued for effective risk management that includes an assessment of the cost effectiveness of gamba grass management options with respect to the range of social, cultural, environmental and economic impacts (Setterfield, 2009a; Setterfield 2009b, Adams & Setterfield, 2016). Existing research highlights the benefit of documenting direct and indirect invasion costs to assess the risks associated with ongoing gamba grass incursions and determine the appropriate level of investment for fire and weed management strategies (Setterfield, 2009b, Setterfield et al., 2013).

Research has demonstrated that prevention and early responses to invasive species, such as gamba grass, provide the greatest economic returns (Adams & Setterfield, 2016). In particular, projections based on existing research highlight that inadequate funding for weed management strategies in the short term will place massive and avoidable cost burdens on both the Northern Territory Government and private actors in the future (Adams & Setterfield, 2013; Setterfield et al., 2013; Setterfield et al., 2018). This research also points to a major disconnect between the increasing costs of responding to fire intensification in areas infested with gamba grass and the more limited resourcing for implementation of gamba grass control strategies (Setterfield et al., 2013).

Understanding economic and other impacts resulting from ineffective management of gamba grass enables interventions that will ensure limited public resources are applied in the most cost-effective manner.

This report has been developed as a resource for decision makers and the general public in the Northern Territory to better understand the full range of risks, impacts and trade-offs involved in decisions that affect resourcing of gamba grass management. The report is intended to aid the consideration of appropriate responses that will most efficiently and effectively direct public and private resources to containing and limiting the negative impacts of gamba grass in the Northern Territory.

This report touches upon some of the main economic impacts while acknowledging the full extent of these costs is much greater than what we can currently quantify with existing publicly available information. The report is structured as follows.

This introductory section provides an overview of the issues and extent of the impacts of gamba grass infestations in the Northern Territory as well as the current management regime.

The first section on gamba grass weed management provides information on the current rates of expansion of gamba grass, existing and potential weed management costs associated with efforts to control gamba grass and the implications of various approaches to control or eradicate the weed.

The second section provides an overview of the impacts of gamba grass invasion on fire regimes and associated costs of fire management. One of the most well documented public burdens of gamba grass invasion is increased fire severity, leading to major increases in firefighting costs and damages to both public and private property.¹

The third section on gamba grass and its impacts for the carbon sector provides an overview of the lost opportunities, threats and impacts on the carbon farming industry, a growing sector that brings a range of economic and social opportunities, particularly for remote Indigenous communities.

This analysis is followed by conclusions and recommendations for consideration for future actions.

GAMBA GRASS INFESTATIONS IN THE NORTHERN TERRITORY

Gamba grass is a tall African perennial grass first introduced into Australia in the 1930s for use as a cattle pasture in the Northern Territory and Queensland. Since its introduction, gamba grass has proven to be highly invasive, leading to ecosystem degradation, habitat loss and species decline (Beeton, 2009). Extensive economic, social, cultural and environmental costs associated with gamba grass invasions, and in particular threats to human safety and property, are of increasing public concern (Beeton, 2009; Csurhes & Hannan-Jones, 2016).

Gamba grass has shown itself to be one of the most destructive weeds in the Northern Territory. It spreads easily through pasture, bushland, riverine systems and transport corridors, and has diverse invasion pathways including via wind, water, animals and vehicles.

Gamba grass is viewed as the invasive grass species that poses the greatest threat to Australian savannas (Herbert, 2012; Setterfield et al, 2013). Northern Australia contains nearly a third of the total global area of remaining intact tropical savanna (Woinarski et al., 2007). While much of Australia's savanna is largely intact, invasive grasses such as gamba pose a major threat to its ecological function and biodiversity, particularly through increased fuel loads and changed fire regimes (Setterfield et al., 2010).

IMPACTS OF GAMBA GRASS INVASIONS IN THE NORTHERN TERRITORY

The impacts of gamba grass invasion are diverse and infestations in the Northern Territory have been shown to affect an array of economic, social, cultural and environmental values, such as biodiversity and environmental values, Indigenous cultural resources, human health and safety and threatens industries such as tourism and carbon farming (Drucker & Setterfield, 2008; Adams & Setterfield, 2013; Setterfield et al, 2013).

Gamba grass was declared a weed in the Northern Territory in 2008, which prevented new plantings of the species. This occurred following a cost benefit analysis that demonstrated the public burden of dealing with the weed's impacts was greater than any private benefits gained by pastoralists (Drucker & Setterfield, 2008). Since then, a growing evidence base points to a range of escalating economic and other impacts associated with gamba grass invasions in the Northern Territory.

¹ Wildfires cause significant social and economic impacts such as the loss of grass fodder for livestock, damage to public and private infrastructure, impact on sensitive vegetation communities (e.g. rainforest patches) and cultural sites (Setterfield et al., 2013). The rapid spread of unchecked or unmanaged gamba grass is proving to have enormous impacts on fuel loadings and fire management within the Top End. The number of wildfires and man-hours spent fighting them is steadily increasing each year (Bushfires NT, 2015).

Gamba grass displaces native plant species, becoming the dominant plant species. This weed transforms biodiverse savanna ecosystems in which native grasses grow to around one metre high into monocultures of gamba grass towering up to four metres high (Csurhes, 2005). These changes reduce access to important cultural resources of Indigenous people including traditional foods and sacred sites (Setterfield et al., 2013). Hunters and tourists are also increasingly limited in accessing country infested by gamba grass.

The replacement of native grasses with gamba grass alters fire regimes (Setterfield et al., 2005). Fuel loads for gamba grass are around 11 tonnes per hectare compared to 3.6 tonnes per hectare for native grasses (Setterfield et al., 2010), and have been recorded at up to 30 tonnes per hectare (Setterfield et al., 2013). The resulting fires are eight times more intense than any native grass fire (Rossiter et al., 2003), increasing the risks of injury or damage to the public and to property.

Intense fires fuelled by gamba grass threaten the safety of people and property. Threats to homes, life and the safety of firefighting personnel are increasing over time (Setterfield et al., 2013; Setterfield et al., 2018). Changes in fire severity dramatically increase the direct costs of fire management (Setterfield et al., 2013). The cost of firefighting management is discussed in subsequent sections of this report.

Gamba grass has proven itself to be a major ecosystem transformer in Australia's tropical savannas, reducing tree cover, changing water availability, depleting nutrients and increasing greenhouse gas emissions (Rossiter et al., 2003; Rossiter et al., 2004; Adams & Setterfield, 2013). Gamba grass outcompetes native grasses and shifts vegetative structure through altered fire regimes. Repeated intense, late dry season fires have the potential to convert diverse native ecosystems into a monoculture of invasive grasses (Rossiter et al., 2003; Setterfield et al., 2010), leading to decreased tree cover and changes to the nitrogen content in the soil (Rossiter-Rachor et al., 2009). Scientists predict rapid and significant ecosystem decline in the region's iconic national parks if gamba grass is not controlled and contained (Petty et al., 2012).

Changing ecosystem processes and fuel loads, increased likelihood of severe fires and associated greenhouse gas emissions in areas with gamba grass infestations, along with the cost of weed management, also threaten the financial viability of savanna fire abatement activities (Adams & Setterfield 2013). These issues are discussed in more detail later in this report.

CURRENT MANAGEMENT REGIME FOR GAMBA GRASS

Gamba grass is one of 32 weeds of national significance (WONS) and has been declared a key threatening process under the *Environment Protection and Biodiversity Conservation Act 1999*². It is also assessed as a very high risk weed in the Northern Territory under the *Weeds Management Act 1993*. The statutory Weed Management Plan for Gamba Grass (*Andropogon gayanus*) outlines legal requirements for control³, under which land owners and occupiers are required to manage gamba grass growing on their properties (DENR, 2018b).

The Weed Management Plan for Gamba Grass (*Andropogon gayanus*), first put in place in 2010 and then updated in 2018, classifies two zones with differing requirements for managing gamba grass. Class A areas are those in which gamba grass is to be eradicated. It covers all areas of the NT except in areas classified as Class B. Class B stipulates areas where the growth and spread of gamba grass is to be controlled, with the aim to limit it to currently infested areas, gradually reducing its presence. Under the *Weeds Management*

² In 2009, the Australian Government listed gamba grass as a key threatening process under the *Environment Protection and Biodiversity Conservation Act 1999* and it is one of the five listed grasses in the *Threat abatement plan to reduce the impacts on northern Australia's biodiversity by the five listed grasses* (DSEWPC, 2012).

³ These plans establish the legal requirements and management actions to be undertaken by all owners and occupiers of land on which the declared weed is present in the Northern Territory. Section 9(2) of the Act requires all owners and occupiers to comply with a statutory weed management plan relating to a weed. Non-compliance is a level 3 environmental offence under the *Environmental Offences and Penalties Act, 2011*. Non-compliance may include failure to undertake any of the required actions specified in a plan. (DENR, NT Government, 2018)

Act 1993, property owners and occupiers are required to manage (control and contain infestations) or eradicate gamba grass on their property according to the zone in which the property is located. It is the expectation of the Northern Territory Government that owners and occupiers of land in the Class B zone control all infestations of gamba grass towards eradication (DENR, 2018b).

FIGURE 1: CLASSIFICATION OF LAND IN THE NORTHERN TERRITORY FOR MANAGEMENT OF GAMBA GRASS UNDER THE *WEEDS MANAGEMENT ACT 1993*



(Source: DENR, NT Government, 2018b)

The goals of the current plan are to halt the spread beyond existing core or isolated infestation areas and, over time, to reduce the size and density of core gamba grass infestations in the Class B zone, and eradicate all isolated infestations in the Class A zone (DENR, 2018b).

Despite legislative requirements, the Weed Management Branch NT acknowledges in its 2017 review of the Weed Management Plan for Gamba Grass that there remains a significant number of landowners not meeting their requirements and placing themselves and others at risk of wildfires fuelled by gamba grass (NT Government, 2017).

In 2018, the Weed Management Plan for Gamba Grass was updated to provide clearer and more readily enforceable requirements for landowners (DENR, 2018b). However, the effectiveness of the new plan is likely to be constrained by the limited resources available to the Weed Management Branch NT for outreach, monitoring and compliance.

RESOURCING OF GAMBA GRASS MANAGEMENT IN THE NORTHERN TERRITORY

Documenting the full extent of the Government and private sector responses to controlling and managing the impacts of gamba grass is challenging due to the role multiple agencies play in weed management on lands under their direct management. For example, the efforts from Bushfires NT in establishing fire breaks and reducing fuel loads contribute significantly to the management of gamba grass infestations. Similarly, other Government agencies, such as the Department of Infrastructure, Land and Planning, undertake fire and weed control on vacant crown lands and roadsides. There are also intersecting roles between the Weed Management Branch NT and Bushfires NT as far as the control and management of gamba grass is concerned, with variable priorities and approaches that are not always streamlined or undertaken in a consistent manner (Moon & Adams, 2016).

While \$1.5 million dollars is allocated in the upcoming budget to fire and weed management on Crown lands, other resourcing is imbedded in the budgets of diverse departments and agencies. On top of dedicated State Government allocations to weed and fire management, various public agencies (including Parks NT, Roads NT and the Power and Water Corporation), local councils, private landowners and mining companies expend significant time and resources controlling gamba grass on their properties. Grant funding has also recently been directed to support Ranger groups in responding to gamba grass.

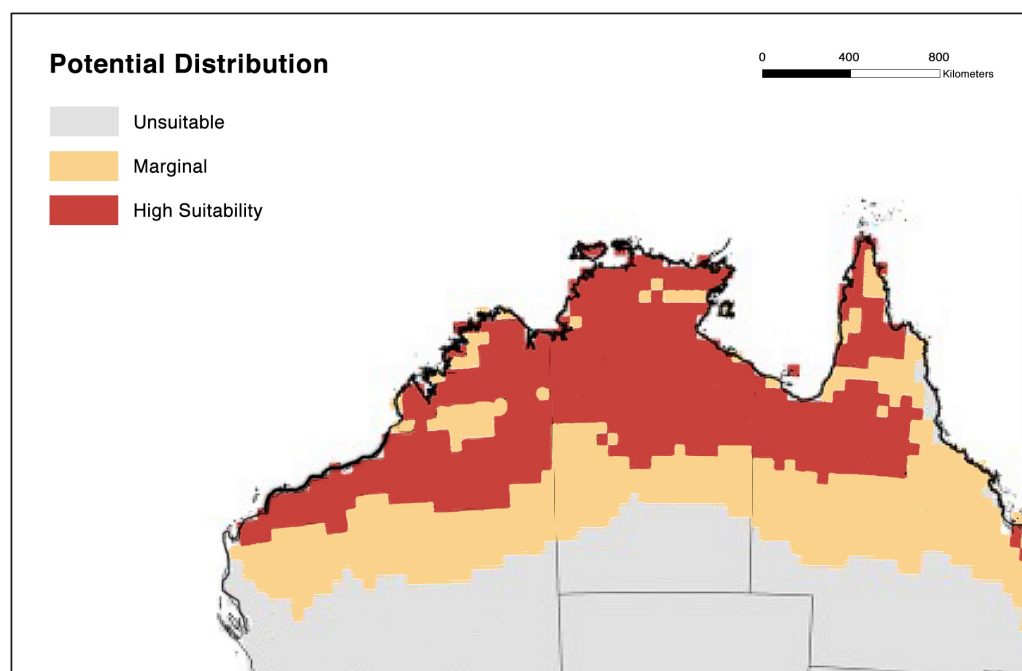
The adequacy of current gamba grass resourcing needs to be assessed in light of the increasing amount of government resources required to address the negative impacts of gamba grass infestation. Delay in action or insufficient investment in managing gamba grass results in escalating costs of control, reduced economic returns from management actions and a decreased feasibility of management (Adams et al., 2015). Delays also present broader impacts and costs that include fire management and response costs, loss of economic opportunities and damage to infrastructure. In this year's budget, the NT Government dedicates only \$1.5 million towards the management of fire and weeds on Crown land, while an allocation of \$38 million is made in the budget for fire management and response costs (NT Parliament, 2018). A large part of this second expenditure on fire management and response, as will be discussed in Chapter 1 below, has been linked back to inadequate management and ongoing rapid expansion of gamba grass invasions across the Territory.

CURRENT AND PREDICTED GAMBA GRASS INVASION

Gamba grass has the potential to invade all tall, tropical grass savannas in northern Australia given its broad ecological tolerance and rapid expansion rates (Bowman, n.d). Modelling predicts that most of Australia's tropical savanna is suitable for invasion (Petty et al., 2012).

While 1.0-1.5 million hectares of the Northern Territory are currently infested with gamba grass, it is estimated the **potential invasion range is at least 38 million hectares** (NT Government, 2018).

FIGURE 2: GAMBA GRASS HAS THE POTENTIAL TO INVADE THE ENTIRE TROPICAL SAVANNA REGION OF NORTHERN AUSTRALIA

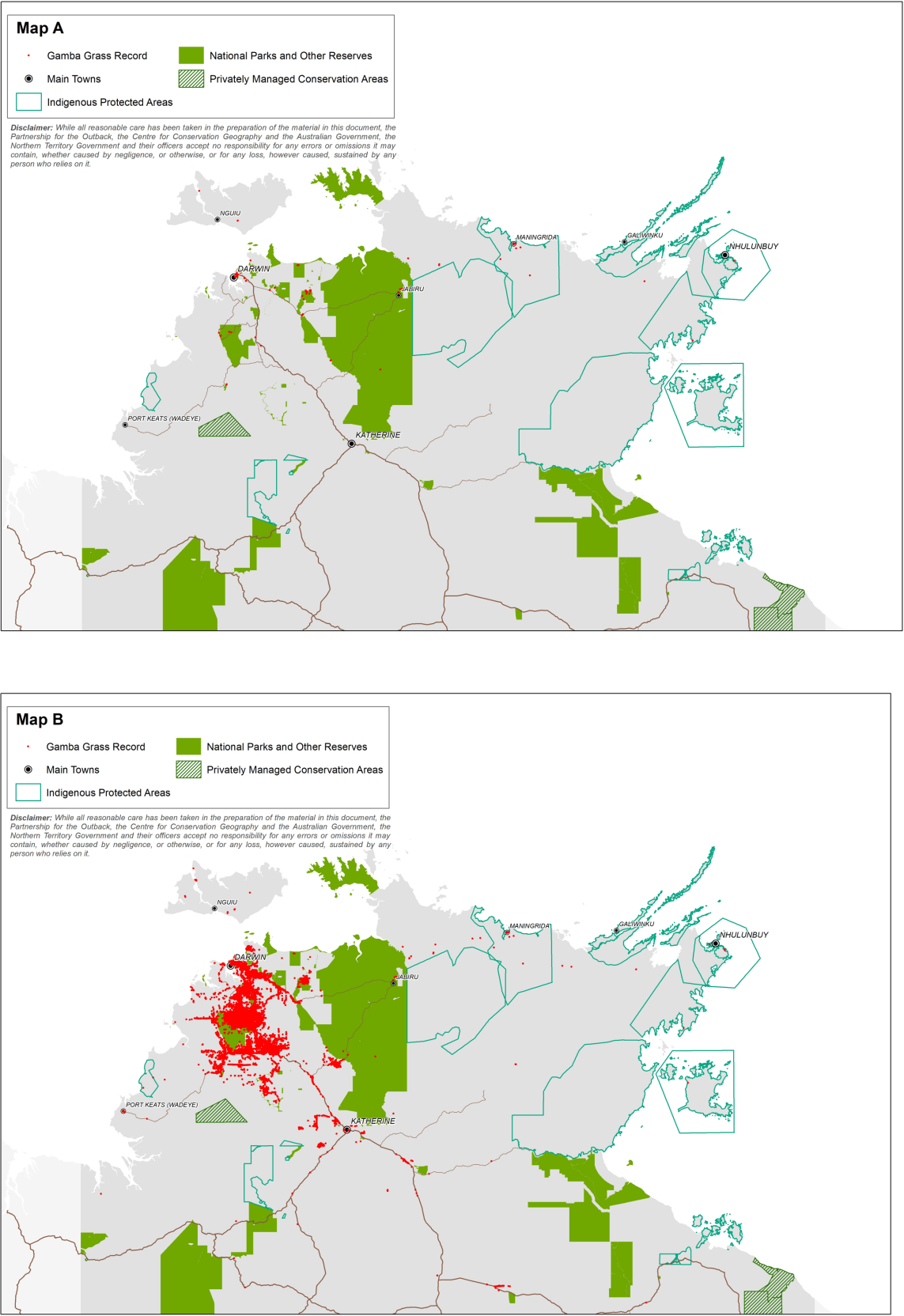


(Source: adapted from Setterfield et al., 2013 based on data from the NT Government)

Gamba grass has rapid rates of spread, leading experts to believe it is merely a matter of time before it can realise its geographic potential (Bowman, n.d.). The rapid speed of gamba grass invasion from initial source paddocks in the 1990s to present distributions is of grave concern given its broad ecological tolerance and demonstrated capacity to invade a range of savanna habitats (Bowman, n.d.). The plant can take over ecosystems in under five years, as areas of gamba grass with very low cover density (or less than 1% coverage) can transition from individual clumps to medium and high level cover within two to five years, particularly in more suitable habitats such as riparian corridors (Setterfield et al, 2013).

In comparison to other invasive species such as para grass, gamba grass has a lower estimated wait time (i.e. the time it takes for the plant to reach a stage of maturity at which seed production occurs). This results in a much higher average spread rate (Adams et al., 2015). Gamba grass is also able to disperse and establish itself in uncleared native vegetation from nearby areas, such as pastoral lands, traveling fast along riparian corridors and through unintentional infestations on roadsides and other areas of disturbance.

FIGURE 3 (A & B): THE SPREAD OF GAMBA GRASS IN THE NORTHERN TERRITORY FROM 2000 (MAP A) TO 2015 (MAP B)



CURRENT STATUS OF GAMBA GRASS INFESTATIONS

By 2015, the known area of gamba grass infestations in the Northern Territory extended south approximately 350 km from Darwin to Katherine in the Daly River Catchment. It is estimated that gamba grass covers up to 1.5 million ha of the Northern Territory (NT Government, 2018) and is abundant in the Darwin rural region including a core infestation in Litchfield National Park, 100 km south of Darwin (Adams & Setterfield, 2015). Large gamba grass infestations exist inside the park (originating from adjacent pastoral leases), with around 18% of the park predicted to be infested Darwin (Adams & Setterfield, 2015). Kakadu National Park and Fish River Conservation Reserve are both adjacent to sites of dense gamba grass infestations that require ongoing management to prevent serious infestation in the parks (Petty et al., 2012). Similarly, various carbon projects managed by Indigenous Ranger programs are also neighbouring major infestations⁴.

While Indigenous ranger groups have reported success in eradicating and keeping in check more isolated infestations of gamba grass, generally the trend is one of ongoing expansion of infested areas, an increase in density of many core infestations and ongoing threat of spread to more isolated and remote areas.

In the Coomalie region where core infestations are present, the current extent of invasion is expected to at least double in the next 10 years in the absence of further management actions, and in some areas an eightfold increase in gamba grass infestations is predicted (Adams & Setterfield, 2015).

These general trends of rapid and aggressive expansion are reflected in data at the localised and regional level across infestation areas. In particular:

- As at 2017, 50% of the known infestations are not being actively managed in the areas around Katherine (Weed Management Branch NT, 2017⁵). This is an area considered to be at a critical point in the weed invasion cycle in which eradication is still possible.
- New infestations in Nitmiluk National Park have spread from neighbouring properties and recent identification of gamba grass by remote ranger groups has occurred on Groote Eylandt, Wadeye, Gove, Gapuwiyak, Maparru and Ramingining⁶ (Weed Management Branch NT, 2017)
- Infestations in the Berry Springs region have more than doubled in six years and infestations of 10% density or greater have increased by around six times in this same time period (unpublished data, available from authors on request)

In the Litchfield and surrounding region, scientific modelling has also predicted that:

- Based on data available in 2015, gamba grass is expected to expand from covering 18% to covering 32% of Litchfield National Park by 2025 and almost half the park by 2040 (Adams et al., 2015; Adams & Setterfield, 2015).
- Across the broader Litchfield region, over the same ten year timeframe (2015-2025), an eight-fold increase in infestations was predicted without management action (Adams et al., 2015; Adams & Setterfield, 2015).

⁴ The Fish River Station has spent significant resources battling incursions from intensive gamba grass infestations in adjacent pastoral properties awhile the Mimal and Jawoyn Indigenous Rangers have known infestations adjacent to their management areas.

⁵ Specifically, the report stated that 'Approximately 50% of known infestations in the A zone around the Katherine region are under active management.'

⁶ Specifically, the report stated that 'WMB contacted by remote ranger group which had identified gamba grass on Groote Eylandt. Other remote groups which also contacted WMB include: Wadeye, Gove, Gapuwiyak, Maparru and Ramingining... Parks and Wildlife Commission NT, identifying new infestations of gamba grass in Nitmiluk NP spreading from neighbouring properties'.

THE ESCALATING COST OF FIRE CONTROL

SUMMARY:

High intensity fires caused by gamba grass infestations have resulted in large increases firefighting costs while also exacerbating the detrimental environmental and social impacts of bushfires. The costs of fire management are escalating rapidly in the absence of sufficient resourcing to control and prevent further spread of gamba grass.

In 2017, the costs associated with responding to individual gamba grass wildfires was substantially higher than those previously documented, with over \$300,000 spent in only five days in the Darwin River region. The most expensive individual wildfire cost \$102,130, double the cost of any other previously reported gamba grass wildfire.

The average cost of managing a gamba grass wildfire is estimated at 26 times that of an equivalent native grass fire. The costs of being on standby to respond to fires in the Batchelor area have increased by 30 times to deal with the increased intensity of gamba grass fires.

If gamba grass continues to expand in the Katherine area, it is expected that the increases in fire management costs experienced in the Darwin and Batchelor areas will also be realised in the Katherine region in as little as five years.

These increasing costs of standby firefighting capacity, along with the expense of fighting the more intense fires, could potentially result in millions of dollars of additional expenditure per annum if gamba grass infestations are not extensively controlled.

Gamba grass infestations have resulted in substantial increases in the economic costs of fire management while also exacerbating the detrimental environmental and social impacts of bushfires. Bushfires NT has highlighted that increased fire frequency and intensity linked to gamba grass infestations threatens life, assets and environment, with the growing number of incidents related to gamba grass infestations straining firefighting capacity, as well as increasingly putting firefighters and the public at risk (DENR, 2018a; DENR, 2018d). In the Vernon Arafura Regional Bushfire Management Plan (DENR, 2018d), gamba grass is identified as the greatest single driver of change in the region and a major cause of escalating costs of fire management.

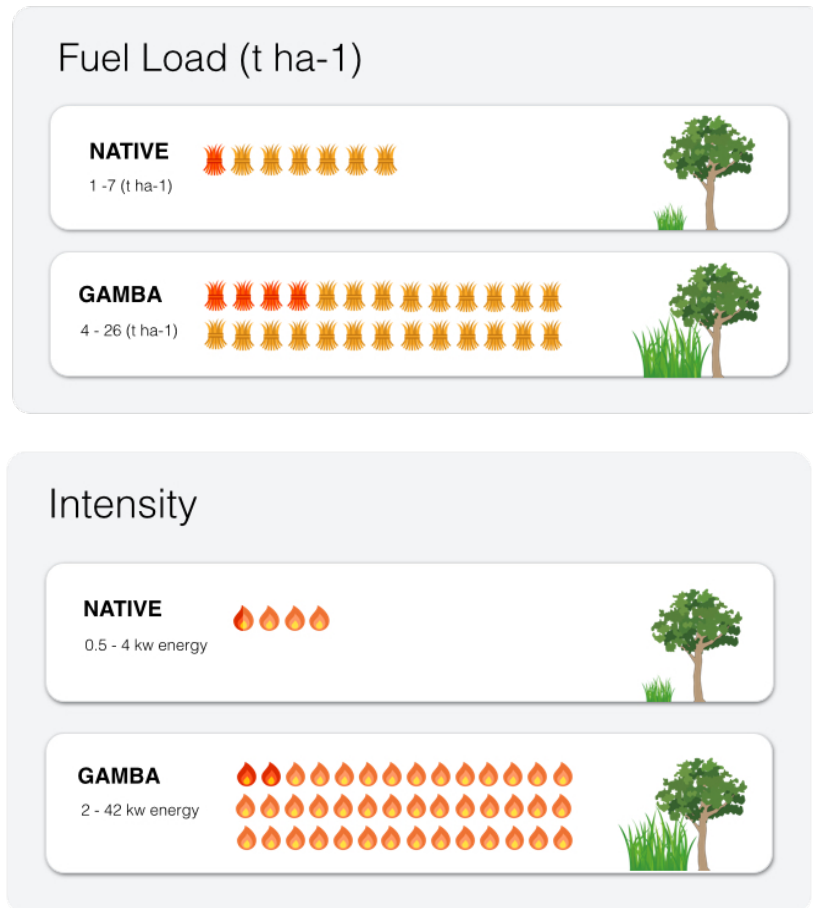
As invasion extends to the landscape and regional level, researchers have highlighted the growing risks to the region's environmental, economic and cultural assets (Setterfield et al., 2013). Overwhelming evidence clearly demonstrates escalating economic costs of responding to these risks and fighting fires (Setterfield, 2009a, 2009b; Setterfield et al., 2010, 2013, 2018).

FIRE CHARACTERISTICS OF GAMBA GRASS

Gamba grass grows up to four metres tall, and has very high fuel loads that lead to more intense and destructive fires in areas where it is present. While native grass has fuel loads from 4-6 tonnes per hectare (6 tonnes per hectare is very uncommon), gamba grass fuel loads can accumulate up to 30 tonnes per hectare and are on average 15-18 tonnes per hectare (Setterfield et al., 2010). Fire intensity in the early dry season in savanna landscapes invaded by gamba grass is up to 12 times higher than that in native grass savannas

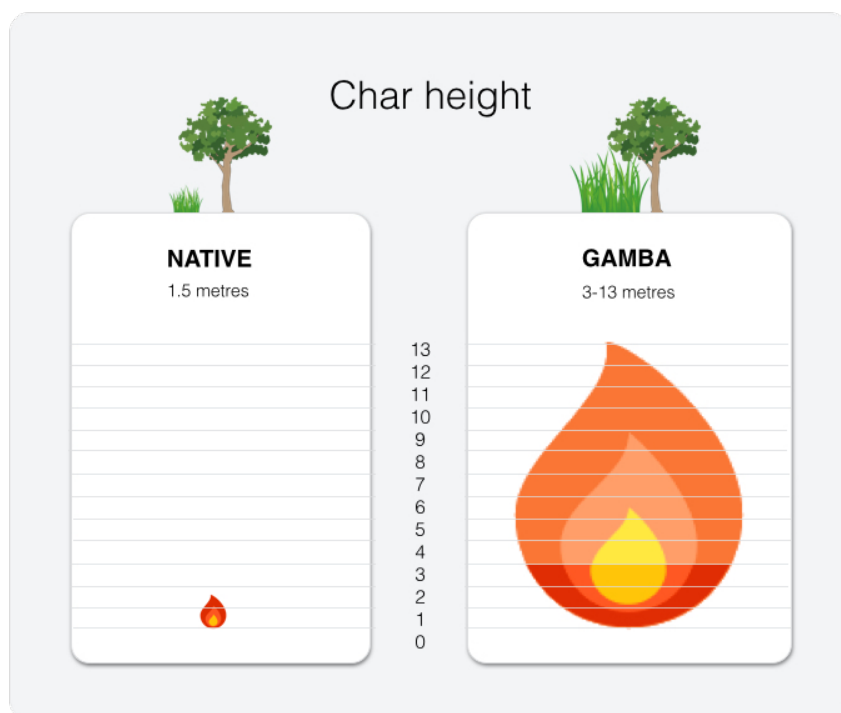
(Rossiter et al., 2003). The result is hot, fast-moving, highly intense blazes, which require 10 to 20 times the resources needed to fight a single native grass fire (Setterfield et al., 2013).

FIGURE 4: FIRE CHARACTERISTICS OF GAMBA GRASS COMPARED TO NATIVE GRASS



Gamba grass fuel loads are 4 to 10 times higher than native grasses.

Gamba grass fires can be up to 12 times more intense than native grass fires.



Gamba grass fires burn up to 9 times higher than native grass fires and can reach up to 13 metres into the tree canopy.

(Source of data: Setterfield, 2009b).

COMPARATIVE COSTS OF GAMBA VS NATIVE FIRES

Changes in fire characteristics caused by gamba grass have had important implications in terms of the cost of bushfire response in infested regions of the Northern Territory as well as the safety of firefighters and the general public.

There are three main categories of economic costs that are each linked to the increased fuel loads and more intense fires that result from gamba grass. These are:

1. The cost of equipment and personnel who are required to be on standby to respond to incidents when severe weather warnings are declared in areas of dense gamba grass infestations;
2. The costs of actually fighting the high intensity fires that result from gamba grass infestations; and
3. The damage to property and infrastructure that results from these more intense fires.

INCREASED COSTS OF EQUIPMENT ON STANDBY TO RESPOND TO GAMBA GRASS FIRES

In areas of dense gamba grass infestation in the Northern Territory such as Batchelor and Darwin, fire managers have had to introduce new and expensive fire management measures that are more typical of temperate forest fire management (Setterfield et al., 2013). These measures include assigning more staff to fire management, altering firefighting vehicles to provide more fire protection and using water bombing aircraft (Whatley, S., Bushfires NT, pers. comm. in Setterfield et al., 2013). By contrast, the resources on standby prior to 2007 were two staff members and a 4-Wheel Drive fitted with firefighting equipment (Setterfield et al., 2013). These arrangements proved ineffective when managing the intensity of gamba grass fires (Setterfield et al., 2013).

Based on these additional staffing and equipment requirements, the cost per day to be on standby in readiness for fighting wildfires during periods of severe weather warning in the Batchelor region **increased by 30 times from \$474 to \$13,264 between 2007 and 2010** (Setterfield et al., 2013⁷) and has continued to increase to a minimum cost of between \$15,000-\$18,000 per day in 2018⁸ (Gardener, M., pers. comm., 2018). Based on these figures, daily standby costs have risen in absolute terms by \$2,500-\$5,000 since 2010⁹. Based on 29 fire ban days declared in this region in 2018, an amount of \$464,000¹⁰ was spent on the core costs of being on standby in preparation for fires on high risk days. The actual amount would be significantly higher once additional staffing cost of firefighters on call are incorporated, and this does not include the actual costs of fighting fires on these days.

⁷ We have utilised the historical figures in this paper and adjusted for inflation to 2018 figures to provide parity of costings. Original figures from this paper were \$375 per day in 2007 and \$11,422 in 2010. We utilised the Reserve Bank of Australia's advised inflation rates available through their online inflation calendar. See <https://www.rba.gov.au/calculator/annualDecimal.html>.

⁸ The estimated cost of \$15,000 for fire ban days is not the total costs of being on standby, but calculated based on the headquarter staff and equipment on standby including helicopter and water bombing aircrafts. This daily standby cost increased to \$18,000 on public holidays. Additional staffing and overtime costs represent an additional amount on top of this figure. (Gardener, M., Bushfires NT, pers. comm., 2018).

⁹ By adjusting previous costings to 2018 dollars this provides an estimate of absolute increase from 2010 to 2018 that accounts for inflation.

¹⁰ This figure is calculating utilising a figure of \$16,000 which is considered a conservative figure of the cost of fire ban days, taking into account that they disproportionally occur on weekends and public holidays in the Vernon Arafura region (Gardener, M., pers. comm., 2018)

FIGURE 5: BEFORE AND AFTER GAMBA GRASS INVASION – STANDBY COSTS ON FIRE BAN DAYS IN THE VERNON FIRE MANAGEMENT AREA.



In response to the intensity of gamba grass fires, the daily cost of equipment required to be on standby to respond to fires has increased by 30 times from 2007-2010 and has continued to increase in absolute terms.

(Source: 2007 and 2010 data presented in Setterfield et al., 2013 updated to 2018 dollars and 2018 data from Gardener M., Bushfires NT, pers. comms., 2018).

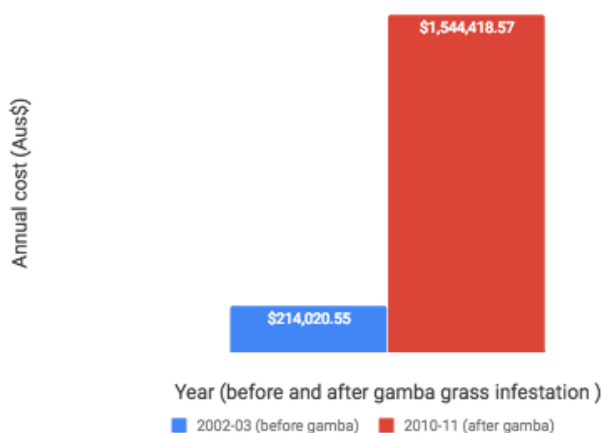
INCREASE IN THE COSTS OF FIGHTING GAMBA GRASS FIRES

Gamba fires are also more expensive to manage, with exponential increases in both the costs of individual wildfires and the overall annual fire management costs in the Vernon fire control zone (the region with the densest infestations of gamba grass in the Northern Territory) following gamba grass infestation.

Annual fire management costs in this region have risen drastically since gamba invasion from \$214,021 in 2002-03 to \$1,544,419 in 2010-11, with over \$800,000 of the overall costs in 2011 directed to wildfire management (data sourced from Setterfield et al., 2013 and recalculated in 2017 dollars). Bushfires NT staff estimate they will spend over a million dollars on wildfire management alone in 2018, demonstrating that this figure has continued to increase along with the intensification of gamba grass infestations in the region.¹¹

¹¹ While gamba grass is one factor in the growing wildfire costs, another is the increasing population in the rural fringe area that contributes to the growing incidents of fire.

FIGURE 6: ANNUAL FIRE MANAGEMENT COSTS IN THE VERNON FIRE MANAGEMENT AREA BEFORE AND AFTER MAJOR GAMBA GRASS INFESTATIONS (2002/03 -2010/11).

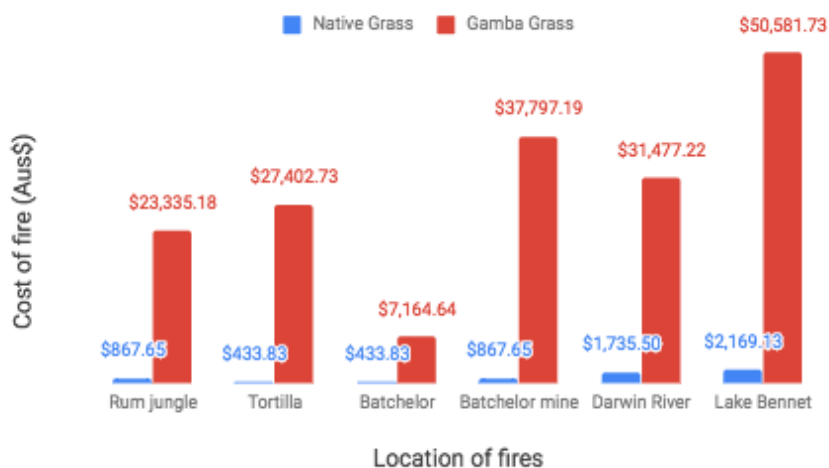


The annual cost of fire management is more than seven times its pre-gamba costs in the Vernon fire control zone (updated to 2017 dollars from data presented in Setterfield et al., 2013).

(Source: data from Setterfield et al., 2013, updated from 2010 to 2017 dollars).

Similarly, a comparison of the costs of managing individual wildfires in five locations pre- and post-invasion showed **an average cost of \$1,085 for native grass fires prior to invasion compared to \$29,626 per fire for gamba grass fires post-invasion** (costs updated from 2010 to 2017 figures from data presented in Setterfield et al.,2013).

FIGURE 7: FIRE FIGHTING COSTS FOR PAIRED FIRES IN FIVE LOCATIONS PRE AND POST GAMBA GRASS INFESTATION



The average costs of individual fires increased by 27 times in a comparison of native grass vs gamba grass fires (Setterfield et al., 2013).

(Source: data from Setterfield et al, 2013, updated from 2010 to 2017 dollars. Paired fires were selected based on the closeness of site of ignition).

INTENSIFICATION OF COSTS OF GAMBA GRASS FIRES 2017 AND BEYOND

The costs of fighting gamba grass fires continue to escalate as the introduced weed invades larger areas, but also as the density of gamba grass infestations and overall fuel loads increases. It is common for areas in rural Darwin and around Batchelor to have 50-90% gamba grass in the vegetation cover which vastly increases the fuel load and associated risks.

In 2017, the cost of managing gamba grass wildfires was substantially higher than any year previously reported, setting a new record for costs incurred through fighting a single wildfire. The most expensive wildfire in 2017 was \$102,130 compared to 2013 when the previous highest costed wildfire was \$50,558. Researchers link this cost increase back to increasing gamba grass infestations (Setterfield et al., 2018). In 2017, \$300,000 was spent in only five days in the Darwin area fighting bushfires (Setterfield et al., 2018).

DAMAGE TO PROPERTY AND INFRASTRUCTURE

Damage to property and infrastructure caused by gamba grass fires is a major economic cost that is difficult to quantify based on currently available information. An annual cost of around \$1,500,000 was previously estimated for property loss and damage as part of a cost benefit analysis undertaken of gamba grass infestations (Setterfield, 2009b). Anecdotal evidence points to a range of other material damage to property that includes producer losses from non-pastoral holdings such as orchards¹², as well as homes, property fencing, vehicles and buildings (Vanovac, 2018; Vanovac et al., 2018; Vanovac & Judd, 2018; Heaney, 2018).

IMPLICATIONS FOR FIRE MANAGEMENT IN THE FUTURE

Given the ongoing expansion and increased density of current gamba grass infestations, fire management and response costs are likely to keep increasing.

If trends of ongoing expansion of gamba grass infestations in areas such as Katherine continue, fire response in this region could require similar extra resources as those required in the densely infested region around Batchelor in as little as 5-6 years. In 2018, the Katherine region had only four fire ban days, compared to 29 in the Batchelor-Darwin area (Gardener, M., pers. comm., 2018) and in the Katherine region fires continue to be managed with ground staff and vehicles (Gardener, M., pers. comm., 2018). However, the Katherine region's bushfire management plan for 2018 has identified the increasing fuel load due to gamba as a high risk, with more high intensity fires threatening life, property, industry and the environment (DENR, 2018a). The increasing risk to homes and property, escalating insurance costs and the potential impacts on important industries, such as tourism from the closure of roads and tourist sites, are all additional economic threats posed by a failure to contain what is now limited but rapidly expanding gamba grass infestations in this region.

CONCLUSIONS

The research summarised above provides evidence of the escalating costs of fire management associated with gamba grass infestations that will continue to rise as core infestations become denser and as more regions of the Northern Territory become infested.

While current levels of infestation are estimated to result in more than \$1 million annually in firefighting response costs in the Batchelor region alone (Gardener, M., pers. comm., 2018), this amount will continue to rise if control and eradication efforts are not increased. There is also the concerning potential that, without effective efforts to reduce the spread of gamba grass, fire ban days will increase in the Katherine region due

¹² The review of the gamba grass management plan identified the "(n)eed to consider gamba grass infestations adjoining orchards - if this gamba burns, the outside 2 rows of produce can be damaged/ruined." (comment by Bushfires NT in Weed Management Branch NT, 2017).

to fuel loads associated with gamba grass along with the costs of being on standby for and the likelihood of fighting more intense gamba grass fires.

These increasing costs of standby firefighting capacity, along with the expense of fighting more intense gamba grass fires and the associated property damage could result in millions of dollars of additional expenditure per annum if gamba grass infestations are not more extensively controlled.

WEED MANAGEMENT COSTS

SUMMARY

As gamba grass infestation continues to expand, there is decreasing likelihood that eradication or control of the weed will be logistically achievable or financially viable. Early intervention provides the clearest return on investment for weed management under all scenarios.

Urgent action is needed. Delaying action will result in millions of additional dollars in weed control efforts in the future and make either control or eradication increasingly unlikely in areas that pose risks to key tourist and cultural assets.

There are important economic arguments for strategic investment in eradication rather than solely investing in control efforts. The cost of eradication as opposed to controlling infestations is a higher investment in the short term. However, eradication costs are estimated to be two thirds cheaper than that of control costs when considered over the long term.

COST EFFECTIVENESS OF EARLY INTERVENTION IN WEED CONTROL

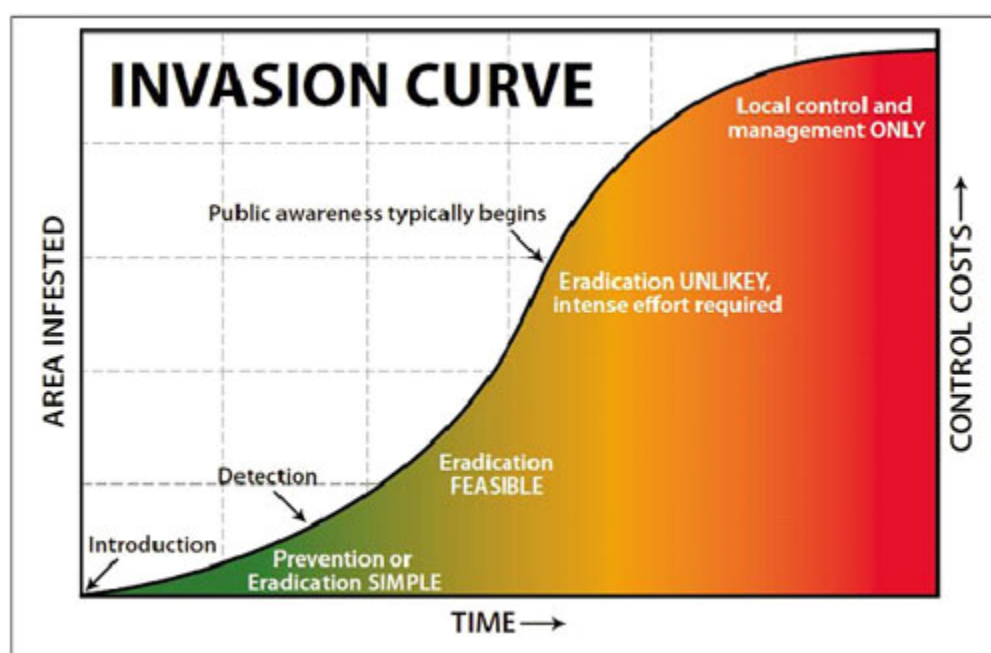
Research has demonstrated that (a) larger invasions of gamba grass are more expensive and less feasible to control, and (b) that delay of control (whether through late discovery, delayed decision to act or insufficient response) reduces the likelihood that eradication or containment will be achievable (Epanchin-Niell & Wilen, 2012 quoted in Adams et al., 2015).

Core gamba grass infestations are at risk of becoming unmanageable due to insufficient intervention in the early stages of invasion. This issue presents a significant economic burden for government as well as private landholders to manage the weed in perpetuity.

At least \$15 million is spent every year on weed management in the Northern Territory by various agencies and actors (WMB, 2015), with estimations that at least a third to half of this is related to efforts to control gamba grass.

The weed invasion curve below demonstrates the way in which delayed action makes eradication increasingly less likely. Delay also reduces the likelihood that controlling and limiting the spread of the weed is achievable and financially viable. While areas with the densest infestations of gamba grass around Darwin and Batchelor are currently facing the reality that control is the only feasible management strategy, the infestations around Katherine are still at a point where eradication is possible if intense effort is applied.

FIGURE 8: WEED INVASION CURVE CHARTING AREA INFESTED AND CONTROL COSTS OVER TIME.



Source: (Adirondack Almanack, 2013).

COMPARISON OF CONTROL COSTS ACROSS DIFFERENT STAGES OF INVASION

Studies have shown that the costs of managing established weeds are up to 100 times more than the costs of spread prevention (DENR, 2015). It is a widely accepted principle that initial dispersal and spread of weeds is the most effective stage of invasion to target for management as it limits the potential impacts of invasion and produces the greatest management success in terms of costs and feasibility (Adams et al., 2015).

Indicative costs of control and eradication at different stages of invasion can be drawn from regions of the Northern Territory facing varying stages of gamba grass infestation.

For example, Litchfield National Park is approximately 1,500 km² and contains a core infestation of gamba grass. It is acknowledged that eradication is not a feasible alternative in this region and thus, these costs will continue in perpetuity. The costs of controlling gamba grass in the park over a ten-year period have been estimated at a minimum of \$8 million (Adams & Setterfield, 2015).

By contrast, Kakadu National Park covers an area of 20,000 km²; an area more than ten times the size of Litchfield National Park. Gamba grass is currently present in small and/or isolated patches in the park (Director of National Parks, 2015) with significant efforts focused on maintaining control of the growing infestations on its southern and western borders (Woinarski & Winderlich, 2014).¹³ The cost of *eradicating* gamba in Kakadu National Park has been estimated at \$3.5 million over twenty years.¹⁴

¹³ While these figures are not directly comparable and this budget focuses on maintaining control of the existing infestations in and around the borders of Kakadu NP, they do provide indicative figures for response at various stages of invasion. In particular, it is noted that management objectives in Kakadu are for the eradication of new incursions and eradication of current and future patches (Woinarski & Winderlich, 2014).

¹⁴ These estimated costs include initial establishment costs and annual costs including personnel, transport and equipment (Woinarski and Winderlich, 2014).

The Mimal Rangers, who manage an area close to the size of Kakadu, plan to spend approximately \$800,000 over twenty years to keep an area approximately the size of Kakadu free from infestations encroaching from neighbouring properties (Nichols, D., pers. comm., 2018).

These figures provide a clear indication of the cost-effective nature of early intervention, and the importance of continuing to invest to ensure that those on the frontier of gamba grass invasion have the resources needed to monitor and quickly eradicate new infestations.

Research affirms these broad indications and demonstrates that eradication is more cost effective than control for smaller invasions and that, after an infestation has extended into an area greater than 48 hectares, control becomes less expensive than eradication when calculated from the perspective of net present value (Adams & Setterfield, 2015).

Preventing weed spread is by far the cheapest and most effective form of weed management. Once gamba grass has spread and become established, eradication is generally unlikely because of the high costs, which present a significant burden to the public in perpetuity (DENR. 2015).

CORE INFESTATION: LITCHFIELD NATIONAL PARK CASE STUDY

Litchfield National Park is an iconic protected area with highly significant environmental and cultural values. It is currently the Northern Territory's most popular park, with the highest rating of any tourist visitor experience (PWC, 2016) and an estimated 370,000 visitors each year (ABC, 2018). The park is considered to be a key driver of tourism in the Top End (PWC, 2016).

By 2015, 18% of the park was estimated to be covered with gamba grass, with continuing expansion into sites containing important biodiversity and tourism values (Adams & Setterfield, 2015). The infestations are leading to destructive, uncontrollable wildfires which impact on visitor safety and visitor infrastructure and present the greatest threat to the park's biodiversity values (PWC, 2016).

Large financial investments have recently been made in tourism infrastructure within the park: \$38.9 million was directed to infrastructure upgrades in 2015 (Walsh, 2015)¹⁵ and \$12.1 million was spent opening up a new area of the park to visitors in 2018 (ABC News, 2018). By contrast, funding for the management of gamba grass in the park in 2015 was only \$32,000 (Adams & Setterfield, 2016) and there is no publicly available data to suggest that increased funding has been made available since this time. This is despite the fact that the Litchfield National Park Plan of Management identifies the management of gamba grass as critical to the future of the park and is essential for ensuring the long term safety of visitors and the integrity of the natural values of the park (PWC, 2016).

Adams and Setterfield (2015, 2016) compared the costs of control or eradication of gamba grass in the park under a range of scenarios and modelled the likely spread if management action was not intensified. If weed management resourcing levels remain constant,¹⁶ gamba grass was predicted to expand from covering 18% to covering 32% of Litchfield National Park within 10 years, with almost half the park infested by 2040 (Adams & Setterfield, 2015). Across the broader Batchelor region, over the same 10-year timeframe, an 8-fold increase in infestations was predicted without additional management action (Adams & Setterfield, 2016).

If such a scenario eventuates, it will not only have major financial consequences, but it would also critically impact how tourist movement would be managed within the park (Adams & Setterfield, 2016). It is

¹⁵ Government figures estimate these investments alone were expected to generate an annual economic benefit of \$14.4 million (Walsh, 2015).

¹⁶ A figure of \$32,000 spent on gamba grass management in Litchfield National Park is quoted in Adams and Setterfield (2015). No further information is publicly available to suggest that further investment has been made although the Management Plan for the park indicates fundraising to address gamba grass infestations is a major priority (DTC, 2016)

predicted that Litchfield will continue to experience a spread of gamba grass from core infestations, particularly in the north-east section of the park where there are several popular tourist visitation sites and important biodiversity values, unless significant additional investments are made in gamba grass management (Adams & Setterfield, 2015).

Costs and benefits of controlling gamba grass in Litchfield National Park

Current investment in gamba grass control within Litchfield National Park is insufficient to control or limit its spread. The estimated cost of reducing gamba infestations from 18% to 15% of the land area of Litchfield National Park is \$8 million over ten years, including an initial investment of \$1,350,000 with costs reducing from \$950,000 per annum initially to \$350,000 per annum in the longer term (Adams & Setterfield, 2015). This investment would allow the eradication of smaller infestations across the park and containment of core infestations in the north and south of the park (Adams & Setterfield, 2015). This best practice scenario is expected to prevent 94,000 hectares of further infestation of gamba (Adams & Setterfield, 2015).

It is clear from the research outlined above that statutory obligations to control and limit current infestations are not being realised within Litchfield National Park. This failure to resource sufficient action to address the ongoing expansion of gamba grass in and around Litchfield National Park is a short-sighted failure that threatens the tourism economy in this region and is in stark contrast to the over \$50 million invested in the last five years in developing the park's infrastructure. The benefits of action now considerably outweigh the various costs in perpetuity associated with further gamba expansion and the risks to one of the Northern Territory's most important tourist assets.

COST IMPLICATIONS OF DIFFERENT GAMBA GRASS MANAGEMENT RESPONSES

Different weed management responses have drastically different outcomes and implications. While initial investments in eradication require upfront expenditure, these should reduce significantly within a six to eight year period¹⁷ compared to containment, which has a consistent cost in perpetuity. Taking no action or providing inadequate investment leads to growing expenses related to direct and indirect impacts of infestation, specifically fire management and associated impacts of increased intensity bushfires that, over the medium to long term, far outweigh initial investments in effective management.

CONCLUSIONS

As areas of core gamba grass infestation continue to expand, there is decreasing likelihood that eradication or control of the weed will be logistically achievable or financially viable. The Northern Territory government needs to urgently allocate sufficient resources to ensure statutory obligations for the control and eradication of gamba grass are being met. In particular, resources are vital for early eradication of small and/or strategic infestations and to ensure the control of larger infestations.

Prioritising and providing sufficient funding for the eradication of smaller infestations in the eradication zones of the Gamba Grass Weed Management Plan (2018) is an essential and cost-effective measure that will save significant resources in the long term.

Infestations in Litchfield National Park are at a critical point in which investment of additional resources is urgently needed to bring current major infestations under control. An investment of \$8 million dollars in gamba grass control over ten years, as suggested by Adams and Setterfield (2015) will ensure that

¹⁷ Eradication of a gamba grass infestation is often calculated over the time frame of 6 -8 years depending on size and density (Adams and Setterfield, 2013)

government investments of over \$50 million in the tourist infrastructure will be safeguarded and can generate the expected returns for the Northern Territory economy. Without immediate increases in action to address these infestations, there is a serious risk that the conservation and tourist values of the park will be compromised and that management in the future will not be logistically or financially feasible (DTC, 2016; Adams and Setterfield, 2015).

GAMBA GRASS AND CARBON FARMING

SUMMARY

Carbon farming is worth tens of millions of dollars annually to the Northern Territory economy, and has important social, cultural and environmental benefits in many remote Indigenous communities where it takes place. It is estimated that the industry could generate income of over \$100 million annually in the future.

Gamba grass infestations pose significant threats to the viability of current and future carbon farming under fire abatement methodologies applied in the tropical savannah region. Gamba grass can cause both a significant loss of revenue from exclusions from carbon farming as well as major increases in land management costs associated with control and eradication efforts.

Existing gamba grass infestations within the Northern Territory already rule out the potential for carbon farming on 1.0-1.5 million hectares of land due to the increased likelihood of intense late season fires. This represents a lost opportunity of at least \$1.0-1.5 million annual income from carbon credits under current approaches and up to \$5 million annually under newly adopted carbon methodologies that include opportunities for carbon sequestration.

The presence of a single gamba grass plant in a carbon project area requires the permanent exclusion of a 6.25 hectare region (the size of a pixel on a vegetation map) from a project's carbon accounting under newly adopted 2017-18 methodologies. This is of grave concern to this growing industry, considering that of 899 properties identified as appropriate for inclusion in carbon abatement activities, as of 2013, 199 already had infestations of gamba grass (Adams and Setterfield, 2013)

These new requirements threaten the future viability of many existing individual carbon projects with gamba grass infestations, each currently worth upward of \$0.5-\$1 million annually.

The presence and potential expansion of gamba grass on to properties with current or potential carbon farming projects thus presents a significant threat to the future growth of this industry that could cost upwards of tens of millions of dollars annually in the Northern Territory in the long term.

CARBON FARMING IN THE TROPICAL SAVANNAHS OF AUSTRALIA

Carbon offset programs that achieve reductions in carbon emissions through improved fire management in the savanna region are a rapidly growing industry, currently worth upwards of \$40 million to Northern Australia (McLennan, 2018). Methodologies approved by the Australian Clean Energy Regulator enable savanna burning projects to generate carbon credits through avoiding emissions generated by especially hot and intense late-season fires¹⁸ (DEE, 2018).

There are currently 25 savanna burning projects in the Northern Territory and they produce 52% of all Australian savanna burning carbon credits (Moss, L., quoted in DCBR, 2018). The industry is a significant and growing economic driver in remote regions of the Northern Territory with the five projects managed by the Arnhem Land Fire Abatement (ALFA NT) alone generating \$10.7 million of income in 2017 (J. Ansell, CEO ALFA NT, pers. comm., 2018).

The public benefit of carbon farming is much greater because these carbon abatement schemes have been successfully developed based on fire management practices that support natural resource management and provide employment opportunities and a range of positive social, cultural and economic benefits to Indigenous communities in some of the remotest parts of the Northern Territory (Lawler, 2018). In other cases, carbon farming has been vital to ensure the economic viability of otherwise marginal primary industries (Locke, 2017).¹⁹

RISKS TO CARBON FARMING PROJECTS FROM GAMBA GRASS INVASIONS

The expansion of gamba grass into existing and potential locations of carbon farming projects presents a major threat to this emerging industry. Gamba grass reduces carbon stocks stored in savanna ecosystems through more intense and harder to control fires.²⁰

Current savanna fire abatement carbon methodologies enable projects within savanna vegetation where rainfall is 600 mm or more per annum (Aboriginal Carbon Fund, 2016). These savanna fire abatement methodologies could potentially be used across 45 million hectares of the Northern Territory, or up to 30% of the Territory's land mass (DENR, 2018c). Gamba grass infestations sit squarely within this region and on the edge of many existing carbon projects (see Figure 10 below).

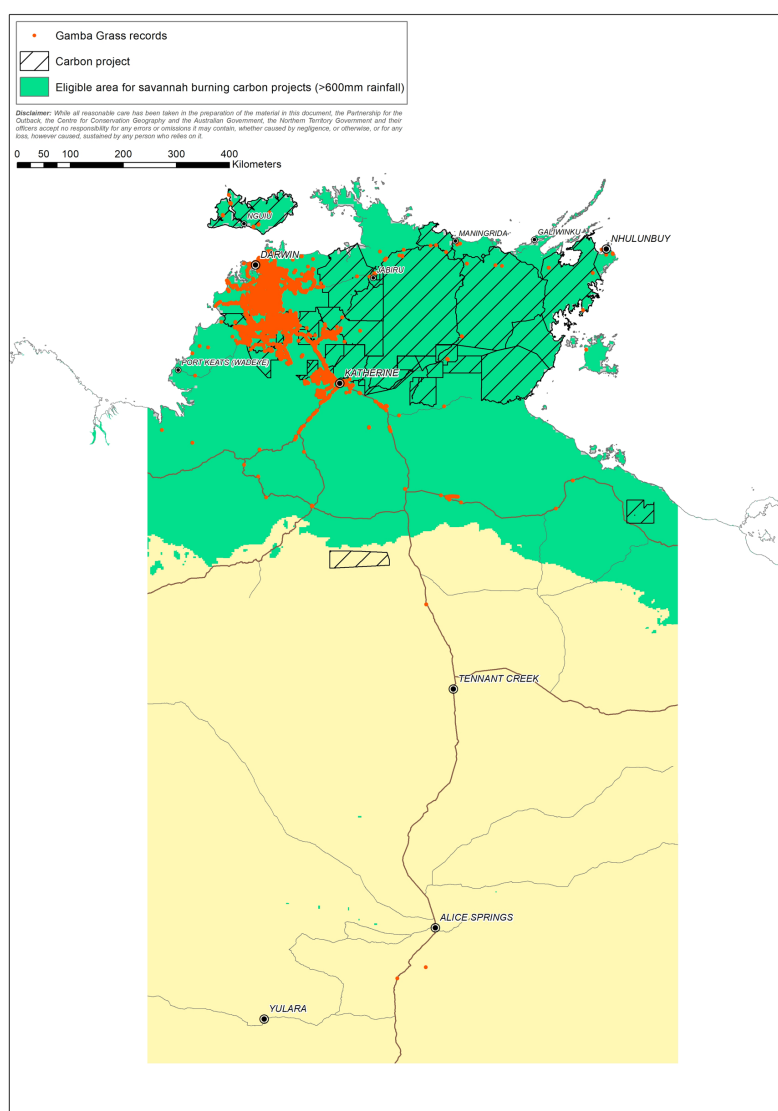
The potential invasion range of gamba grass overlaps significantly with carbon abatement projects. Seventy-five percent of the eligible area for savanna burning is spatially coincident with the high suitability range for gamba grass (Adams & Setterfield, 2013). Of 899 properties identified as appropriate for inclusion in carbon abatement activities, by 2013, 199 already had infestations of gamba grass (Adams & Setterfield, 2013).

¹⁸ The tropical savannahs are the largest single source of greenhouse gas (GhG) and particulate emissions in Australia, emitting approximately 3% of Australia's GhG (Maraseni et al, 2016). GhG emission abatement is achieved in savannah ecosystems by introducing fire management practices that reduce the amount of biomass consumed by fire. This is achieved by reducing the area burnt and the severity of fires.

¹⁹ "I can say categorically we have saved at least three farms from going into receivership, and that's due to the money they've earned by reducing greenhouse gas emissions." Country Carbon's Nicolas Camerona said (Locke, 2017).

²⁰ As *A. gayanus* (gamba grass) abundance increases over time, the above-ground carbon stock will be substantially reduced owing to high-severity *A. gayanus* fuelled fires increase tree mortality (Brooks et al., 2010) and the loss of the woody material via consumption through fire (Rossiter-Rachor et al., 2008).

FIGURE 9: EXISTING PRESENCE OF GAMBA GRASS INFESTATIONS WITHIN THE RAINFALL ZONES IDENTIFIED AS APPROPRIATE FOR SAVANNA FIRE ABATEMENT PROGRAMS



Under the 2015 methodology and current pricing, carbon farming utilising the savanna fire abatement methodology could bring in an estimated \$45 million per year.²¹ In 2017, methodologies were amended to include carbon sequestration as well as emissions avoidance (DEE, 2017). Recalculating the estimated income based on 2017-18 methodologies shows that the industry could potentially be worth upwards of \$99-150 million annually.²²

²¹There is a significant variation in what carbon projects receive per tonne (information that is often commercial in confidence) so we utilise an estimate of between \$10-\$13.65 based on the average price of Australian Carbon Credit Units (ACCUs- each equivalent to a tonne of carbon dioxide) at the auctions held by the Clean Energy Regular in 2016 and 2017. There is also variation on the carbon abatements achieved and thus the range of income per hectare from fire abatement, depending on factors such as the vegetation type, fire history and existing management of land. While this variation has been calculated as between \$0.01 to \$1.99 by Adams and Setterfield (2013, for the purpose of a general estimate we based our calculations on averaged figures from the Aboriginal Carbon Fund, (2016) who estimated that savannah fire abatement projects generated a return of \$1 per hectare. The area of potential carbon farming through savannah fire abatement is estimated as 45 million hectares. Given that spot prices for carbon are often significantly higher than the ACCU prices above, and thus generate more income, this can be seen as a generalized estimate of the potential of the industry that does not account for variations in both pricing and abatements per hectare.

²² This additional figure is generated by integrated an additional 0.22 tonnes of carbon per hectare as per Murphy (2013) to account for potential carbon sequestration into the calculations outlined in the footnote above.

CURRENT AND POTENTIAL IMPACTS OF GAMBA GRASS INVASION ON CARBON FARMING

Gamba grass has already been demonstrated to pose a risk to savanna burning programs in Northern Australia (Adams and Setterfield, 2013) and with tightening rules around the presence of gamba grass within projects, there are very real risks to the viability of carbon projects in the Northern Territory.

LAND MANAGEMENT COSTS OF GAMBA GRASS LIMIT VIABILITY OF PROJECTS

Gamba grass infestations can seriously impact the financial viability of savanna burning projects by drastically increasing land management costs (Adams & Setterfield, 2013). Based on a 2012-13 carbon price of \$23 per tonne, in order to recoup the annual costs of controlling 1 ha of gamba grass infestation, it was estimated that 290 ha of land must be enrolled in annual carbon abatement credits (Adams & Setterfield, 2013).

Based on these calculations, the viability of a carbon farming project is threatened if less than 0.35% of a carbon project is infested by gamba grass.²³ Since 2012-13 carbon prices have nearly halved from the price of \$23 per tonne on which these estimates were made to around \$10-13 per tonne. With this drop in price, the number of hectares enrolled in savanna burning required to fund one hectare of gamba would now be much greater, with an associated decrease in profitability (Adams and Setterfield, 2013).

CURRENT EXCLUSION OF GAMBA GRASS INFESTATIONS FROM CARBON FARMING PROJECTS

Under previous methodologies that continue to govern most carbon projects, only areas with major infestations of gamba grass are excluded from carbon farming. A broad estimate of the lost opportunity to the Northern Territory economy from areas that are currently ineligible for carbon farming due to gamba grass infestation can be placed at anywhere between \$1.0-2.2 million annually in direct income from carbon credits²⁴.

FUTURE IMPACTS UNDER THE UPDATED 2018 SAVANNA FIRE ABATEMENT METHODOLOGY

This economic loss caused by the presence of gamba grass in carbon projects rises dramatically when we consider the adoption of new carbon accounting methodologies that require strict exclusions of any gamba grass from carbon projects. This has potentially greater economic impacts as the 2017-18 methodology also offers the potential for significantly greater income per hectare through the inclusion of carbon sequestration in addition to carbon abatement through fire management to gain additional carbon credits.

For example, the lost opportunity of existing gamba grass infestations to carbon farming grows from between \$1.0-1.5 million to between \$3.2-\$5.0 million.²⁵ If savanna fire abatement projects include sequestration as provided in the new 2017-18 methodologies, they are expected to sequester an additional amount equivalent to 0.22 tonnes of carbon dioxide per hectare per year (Murphy, 2013), increasing the income per hectare from carbon farming by between three and five times (B. Lewis, pers. comm, 2018;

²³ We have utilized the calculations in Adams and Setterfield (2013) that estimated 290ha of land must be enrolled in carbon credits to offset management of 1ha of gamba grass within a carbon project. Based on this ratio, the presence of gamba grass on 0.35% of a carbon project would cancel out the profits on the rest of the property. As this is based on a higher price for carbon than currently offered, an even smaller proportion of gamba grass infestation would threaten the viability of carbon projects. (Adams and Setterfield, 2013).

²⁴ The Northern Territory has already potentially lost \$1.0-2.2 million annually in carbon farming income at current carbon pricing. This calculation is based on the assumptions that 1.0-1.5 million hectares of land is currently infested with gamba grass and the average income from carbon farming is \$1 per hectare. When taking into account the additional carbon through new sequestration methods that are estimated to bring in an additional 0.22 tonnes of carbon per hectare, this figure increases to between \$3.2-5 million.

²⁵ This figure is estimated based on the additional 0.22 tonnes of carbon per hectare calculated by Murphy (2013) and a carbon price of between \$10-13.65 per tonne.

Murphy, 2013). Across the land area identified for carbon farming utilising the tropical savanna methods within the Northern Territory, this equates to future potential income of between \$99-\$135 million dollars.²⁶

Requirements for gamba grass management and eradication within carbon projects are much stricter under the 2017-18 methodologies,²⁷ which apply to future carbon abatement projects as well as current projects at the end of their existing crediting period. This new system includes a requirement to monitor and remove gamba grass from project areas within one year or else exclude it from the project area permanently.²⁸ Projects are not able to claim Australian carbon credit units (ACCUs) for project areas that contain gamba grass.²⁹ Pixels that contain a gamba grass record, even if it is not dominant, must not be included in a project area as this will make the project an ineligible project (DoEE, NT Government, 2017). The implication is that even an isolated or occasional occurrence of gamba grass requires the permanent exclusion of a 250 m x 250 m area from a carbon project, equivalent to 6.25 hectares of land.³⁰ It is likely that this will impact the viability of a number of individual operations generating upwards of \$500,000-\$1million dollars annually.

CONCLUSIONS

There are already existing costs and impacts felt by the carbon industry in the Northern Territory from gamba grass invasions. Increasingly, gamba grass is acknowledged by experts as incompatible with savanna burning carbon abatement strategies.

While the current lost opportunity to this industry from areas currently excluded from consideration due to gamba grass infestation can be estimated currently at around \$1.0-1.5 million and up to \$5 million under new sequestration methodologies, the actual cost of gamba grass infestations to the carbon industry is greater, both through reducing the profitability of existing operations that have to invest significant resources in managing gamba grass incursion and the new methodological requirements that carbon farming projects be effectively gamba grass free.

Experts predict that a number of existing projects will slowly become unviable and that gamba grass is a serious limiting factor to future projects (B, Lewis, pers. comm., 2018). These costs to a burgeoning industry are set to rise if additional resources are not directed to both eradicating gamba grass on existing and potential carbon projects as well as preventing its spread from current infestations in proximity to areas of current and future carbon farming potential.

²⁶ Murphy (2013) estimates an additional figure of 0.22 tonnes of carbon per hectare from carbon sequestration, what he calculates is approximately five times the abatement that underpins existing fire projects utilizing carbon abatement methodologies only. When utilising the range of recent carbon pricing of between \$10-\$13.65 per tonne, this results in an additional potential income of \$99-\$135 million per annum based on current carbon pricing. (This figure is derived from multiplying the potential hectares open to carbon farming multiplied by the estimated additional carbon tonnes per hectare and the current carbon price per tonne. While in reality the tonnes per hectare would vary depending on a variety of factors including vegetation type, rainfall and land use this provides a broad estimate of the industry's future potential).

²⁷ Either the *Carbon Credits (Carbon Farming Initiative—Savannah Fire Management—Sequestration and Emissions Avoidance) Methodology Determination 2018 (DEE, 2018a)* or the *Carbon Credits (Carbon Farming Initiative—Savannah Fire Management—Emissions Avoidance) Methodology Determination 2018 (DEE, 2018b)*

²⁸ Part 3 section 14 of the 2017/8 savannah abatement methodology requires that specific weeds be monitored and removed from project areas. The only weed that must currently be monitored and excluded under the new 2017/8 methodology is gamba grass (Clean Energy Regulator, 2018)

²⁹ The 2017/8 methodology requires that if "gamba grass is identified in a project area, it must be excluded by either: 1) Removing the gamba grass from the project area before the end of the reporting period in which it is first identified. A map and evidence of weed clearing must be provided with the relevant offsets report." or "2) Removing the project area that contains the gamba grass by subdividing the project and removing the area that contains gamba grass from the project (in accordance with section 15 of the method). An area removed from the project is removed permanently" (Clean Energy Regulator, 2018).

³⁰ Mapping of gamba grass, even in the context of large infestations has itself proven difficult using satellite and thus in the absence of detailed aerial surveying which is extremely costly, knowledge and documentation of the extent of gamba grass inside carbon projects is an additional challenge and thus also risk and expense for carbon operators wanting to implement new methodologies.

FINDINGS AND RECOMMENDATIONS

CONCLUSIONS

The continued rapid spread of gamba grass in the Northern Territory demonstrates the 'lack of adequately resourced on-ground action across the region of potential invasion.' (Setterfield, Rossiter-Rachor, & Adams, 2018). Statutory requirements to either control or eradicate gamba grass across the entire Northern Territory are not being met. Gamba grass control is not yet effective within management areas. Rather, there continues to be rapid rates of spread, across both private and public lands, posing a threat to public safety, economic activity and the natural environment.

Efforts to document and calculate the economic consequences of this failure are ongoing. While these efforts are likely to underestimate the true cost of gamba grass invasions, due to limited availability of data in relation to some costs, it is clear that up-front resourcing of early intervention and control are more cost-effective options than dealing with the rising costs of managing further gamba grass invasions.

Insufficient resourcing of weed control efforts now costs the Northern Territory tens of millions of dollars annually, most significantly in fire management and weed control, but also in lost opportunity from the growing carbon sector. These costs will continue to increase if gamba grass expands further across the Territory, with a growing number of infestations that will become increasingly difficult and costly to contain.

Gamba grass poses a significant threat to the burgeoning carbon industry in the Northern Territory. It has already ruled out over one million dollars per annum in potential revenue from infested regions and threatens the viability of existing and future carbon projects worth millions to the Territory economy.

Ensuring adequate resourcing of on-ground action now to stem the expansion of gamba grass will provide significant future savings both to the public purse and to private actors. Increasing investment in control and eradication now creates savings by avoiding impacts and costs that are otherwise payable in perpetuity. The longer that effective intervention is delayed, the more extensive and irreversible costs and impacts of gamba grass will be.

Urgent investment and action is needed to ensure that (1) individual private landowners meet their obligations to control gamba grass, and (2) public authorities fulfil their statutory obligations to control and eradicate gamba on public lands. Investing now is vital to avoid escalating costs in the future. A failure to act to control gamba infestations now will likely result in a situation in which management is both financially and logistically unfeasible in the future.

Many impacts of invasion are open to potential valuation, for example, the cost of weed control, fire management of invaded areas and loss of infrastructure. However, other impacts are harder to quantify but are no less grave. These include the radical transformation of natural landscapes, loss of ecosystem services, loss of cultural resources and traditional food sources, impacts on public safety and the health of firefighters and the general public.

It is clear from this body of research that delay in action or insufficient investment in managing gamba grass will result in escalating costs of control, reduced economic returns from management actions and result in a decreased feasibility of management (Adams et al, 2015).

RECOMMENDATIONS

The Northern Territory Government needs to urgently allocate sufficient resources to ensure statutory obligations for the control and eradication of gamba grass are being met. In particular, sufficient resources to ensure early eradication of small and/or strategic infestations and the control of larger infestations will prevent larger and more costly problems developing over time.

1. Containment of gamba grass can be achieved and supported through existing legislation which allows for the Northern Territory Government to issue fines as well as gamba grass management or direction notices to those landholders not actively controlling gamba grass (Adams & Setterfield, 2013). While significant efforts in this regard have led to progress in controlling gamba grass, additional resources are needed to ensure the Weed Management Branch has the capacity to cover required ground in its education, enforcement and compliance activities.
2. There are currently areas of gamba grass infestation, especially on private land, which are not reported. This continues to limit effective control and eradication efforts. Landowners should be clearly liable for the costs of other parties in managing spread across their borders. A sunset clause to set an end date by which landowners must disclose gamba grass on their properties would also address the current open-ended voluntary disclosure which acts as a disincentive for landowners to declare gamba grass on their properties.
3. Resourcing for gamba grass control in regions in and around Litchfield National Park is urgently needed to ensure preservation of significant tourism, cultural and biodiversity values of the region. Government investment in tourism infrastructure in and around the Park should be met with parallel efforts and sufficient resources to contain and limit the threat gamba grass poses to this area. A failure to do so places these significant investments and the potential economic opportunities that are projected from the growing tourism industry at threat.
4. Dedicated resourcing of a cross agency task force to ensure more effective cooperation and coordination between the various government agencies and other entities responsible for gamba grass control, together with on the ground experts, landowners and scientists working on the issue would enable more efficient use of limited resources (Moon and Adams, 2016; DENR, 2018a; DENR, 2018d).
5. Ongoing and comprehensive mapping of gamba grass infestations in the Northern Territory is required to better inform management decisions (McFayden et al., 2008).

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APPENDIX 1: DATA SOURCES FOR MAPS

FIGURE	DATASET	SOURCE
3 (A AND B), 10	Gamba grass distribution	Department of Environment and Natural Resources, © Northern Territory Government, 2018
10	Rainfall	Bureau of Meteorology, 2018
10	Savanna Fire Abatement Projects	Department of Environment and Energy, 2018
3 (A AND B), 10	Conservation Reserves	Centre for Conservation Geography, 2017
3 (A AND B), 10	Indigenous Protected areas	Department of Environment and Energy and the Department of the Prime Minister and Cabinet, 2017
3 (A AND B), 10	Datum and Projection	GDA94

APPENDIX 2: INTERVIEW LIST

Dr Natalie Rossiter-Rachor	Charles Darwin University
Dr Vanessa Adams	University of Tasmania
Ben Lewis	Director, FireStick and Associates
Phil Hickey	Spatial Data Manager, Weed Management Branch NT
Liam Golding	Land Management Coordinator, Jawoyn Rangers
Paul Jenkins	Manager, Strategic Projects, Indigenous Land Corporation
Dr Jennifer Ansell	CEO, ALFA (Arnhem Lands Fire Abatement)
Dominic Nichols	CEO, Mimal/Arafura Swamp Rangers
Belinda Townsend	Manager, Policy and Planning, Weed Management Branch NT
Mark Gardener	Senior Risk Planner, Bushfires NT