Chapter 1

Understanding gamba grass and its impacts

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At a glance

- **This chapter describes the biology, ecology and impacts of gamba grass.**
- **Gamba grass is a large perennial tussock grass from Africa that grows to 5 m tall.**
- **It was formally released in Australia in the 1980s as a pasture grass for cattle.**
- **It has invaded tropical savannas across northern Australia with a large potential for further spread.**
- **It spreads by seed transported via contaminated vehicles, machinery and hay; also by wind, water and animals.**
- **Gamba grass germination and establishment is higher in disturbed areas.**
- **Gamba grass produces large amounts of biomass which fuels intense and dangerous fires, resulting in serious environmental, cultural, social and economic impacts.**
- **It's a serious threat to native plants and animals.**
- **Understanding the biology and ecology of gamba grass is key to developing management strategies that will reduce its impacts.**

What is gamba grass?

Gamba grass (*Andropogon gayanus* Kunth) is a large perennial tussock grass which grows up to 5 m tall and can form dense monocultures. Introduced to northern Australia as a pasture species, it's since invaded savanna ecosystems in the Northern Territory, Queensland, and Western Australia (Setterfield et al. 2018). Gamba grass fuels intense

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Gamba grass tussocks grow up to 5 m tall and form dense stands.

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fires, reducing biodiversity and threatening the safety of people and property. Gamba grass can also reduce the availability of traditional foods for First Nations people and limit access to culturally significant sites.

Gamba grass has spread by both human means (sowing, vehicles, machinery, hay) and natural means (wind, water, animals). Management is critically important in reducing seed production, preventing further gamba grass spread, and minimising the impacts of gamba grass where it's established.

This chapter explores aspects of the ecology and impacts of gamba grass that are important to consider when managing gamba grass, including:

- where it grows and how to identify it
- its current and potential distribution in Australia
- its life cycle and the characteristics that enable it to spread rapidly and out-compete native grasses
- its reproduction and the main pathways of spread
- the range of impacts once it establishes, including the serious impacts on fire behaviour.

Origin and history

Gamba grass in its native range

Gamba grass is native to the savannas of tropical and subtropical Africa, in areas with a similar climate to northern Australia. It's found from Senegal on the west coast to Sudan on the east coast, and south to Mozambique, Botswana and South Africa (Csurhes and Hannan-Jones 2016). These savannas experience extended dry seasons, similar to those in northern Australia, and gamba grass is typically found growing below an altitude of 980 m with rainfall between 400 and 1,500 mm per year (Bowden 1964). There are several varieties of gamba grass within its native range in Africa. These differ in form, physical characteristics, climatic tolerance and the types of habitats they occupy, and include varieties that can survive in waterlogged soils (Bowden 1964).

Introduction to Australia

Gamba grass was introduced into northern Australia to trial as a pasture grass for cattle fodder, with the aim of increasing agricultural productivity (Grace

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Gamba grass forms dense, tall monocultures.

et al. 2004; van Klinken and Friedel 2017). A robust gamba grass cultivar 'Kent' was developed in the Northern Territory over several decades, starting at the Katherine Research Station in 1946 (Oram 1987). Kent was initially developed by crossing two varieties – one from Nigeria and another from Africa via Brazil (Grace et al. 2004; Oram 1987). Gamba grass pasture trials continued through the 1960s and 1970s, and it was officially released through the Northern Territory Herbage Plant Liaison Committee in 1978 and listed in the Register of Australian Herbage Plant Cultivars in 1986 (Oram 1987).

In the Northern Territory, the Kent cultivar was strongly promoted by the government to producers, and the cultivar was planted widely as a pasture grass and for mine-site rehabilitation (Whitehead and Wilson 2000). This cultivar is now a widespread weed and occurs in a range of land tenures across northern Australia (Setterfield et al. 2018).

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Cattle grazing on gamba grass near Batchelor, NT.

In Queensland, the first herbarium records of cultivated gamba grass are from 1942 at pasture trials at Fitzroy Vale near Rockhampton (Csurhes and Hannan-Jones 2016). Later, herbarium records from 1992 document naturalised infestations of gamba grass in woodland near Bamaga (Csurhes and Hannan-Jones 2016). There are records through the 1990s and early 2000s from a range of locations in Cape York and near Mareeba (Csurhes and Hannan-Jones 2016).

In Western Australia, gamba grass was promoted as a pasture grass during the early 1990s, with a government technical note mentioning its benefits (McCartney 1991). It's believed that gamba grass was aerially broadcast at El Questro station in the East Kimberley in the early 1990s.

Identification

Gamba grass is an erect perennial grass which forms dense tussocks up to 1 m in diameter and 5 m tall. It produces numerous thick tillers, consisting of a stem and a seedhead. In Australia, gamba grass tussocks dry out in the dry season and begin regrowth early in the following wet season. Tussocks can live for several years, although the exact lifespan in Australia is unknown.

Gamba grass leaves are long, linear and up to 85 cm long and 3 cm wide, with a prominent white midrib. Leaves are generally covered with fine soft hairs, especially when young, although this can vary.

Gamba grass inflorescences (groups of flowers) consist of a hairy spikelet, giving a fluffy appearance (Cameron 1996). The seeds are light brown to brownish-black and are 2–3 mm long and 1 mm wide (Csurhes and Hannan-Jones 2016).

Gamba grass tussocks have three types of roots: an extensive network of fibrous roots just beneath the soil surface, vertical roots that extend down to a depth of over 80 cm, and cord roots which are stout roots that appear to act as an anchor for the plant (Bowden 1964).

The physical characteristics of gamba grass may vary across its geographic range in Australia. This may be in response to either variable environmental factors (e.g. soil type, nutrient availability, climate etc.) or genetic differences, due to the number of cultivars that are believed to be present. the most typical characteristics of gamba grass are described here.

Habit

- Gamba grass is a dense, clumping tussock grass with drooping leaves (typical form).
- Tussocks can grow to 5 m high and 1 m in diameter.
- There's seasonal variation in height and appearance, associated with flowering, seeding and environmental factors.

Gamba grass tussock

Dense mature gamba grass prior to seeding

Dense gamba grass after it has senesced (dried out)

Seedlings

- Seedlings typically have hairy stems and leaves.
- They usually grow near mature plants.

Stems and branches

- Stems and branches are fine and slender in young plants (a) and are robust and erect in mature plants (b and c).
- They're typically covered in soft hairs (a and b).
- Hairless varieties can occur (c).

(a) Fine stems

(b) Robust stems

(c) Hairless variety

Leaves

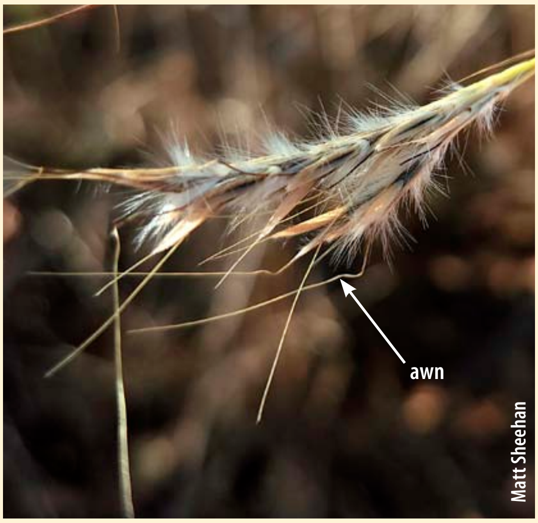
- Leaves are 30–85 cm long and 3 cm wide.
- They have a distinctive white midrib.
- They're usually covered in soft, downy hairs (a).
- Hairless varieties can occur (b).
- Leaves can have a purple tinge (c).
- The leaf sheath is hairy (d).

Flowers and seeds

- Flower heads occur on tall stems above the leaves.
- Flower heads are large and branched and consist of V-shaped pairs of slender flower clusters (4–9 cm long).
- Flower clusters have 10–14 joints, each bearing a pair of very hairy flower spikelets.
- What are usually referred to as 'seeds' are flower spikelets. These are shed from the plant intact, along with their awns.
- The true seed inside the spikelet is light brown to brownish black and about 2.3 mm long and 1 mm wide.

Flower cluster


Flower spikelet



Spikelet with 'seed'

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Where does gamba grass grow?

Preferred habitat

Gamba grass has invaded the tropical savannas of northern Australia, which cover approximately 25% of the Australian continent, an area of around 2 million square kilometres (Hutley and Setterfield 2019). This region has a tropical climate, with a distinct wet season followed by an almost-rainless dry season. Gamba grass has a wide climatic tolerance and is well adapted to Australian savannas, including the annual drought period. In the Northern Territory, gamba grass grows in locations where the average annual rainfall ranges from approximately 1,700 mm (Darwin) to 700 mm (Daly Waters). In Queensland, it's been recorded in locations where the average annual rainfall ranges from approximately 2,000 mm (Weipa) to 900 mm (Mareeba) (Australian Bureau of Meteorology 2024).

Natalie Rossiter-Rachor

Gamba grass on rocky outcrop near Mareeba, Queensland.

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Savanna invaded by gamba grass near Batchelor, ~120 km south of Darwin in the Northern Territory. This photo shows gamba grass in the early wet season, with gamba grass forming almost the entire understorey (in green).

Gamba grass has established in a broad range of habitats and soil types in northern Australia – from savanna woodlands on relatively dry lateritic soils and even rocky outcrops to the more closed forests on the black soil of floodplain margins (Flores et al. 2005). Gamba grass is often abundant in the wetter parts of the landscape, such as creek lines and other riparian habitats, but it doesn't tolerate prolonged inundation (Barrow 1995; Flores et al. 2005). Early growing advice was that cultivar Kent would grow on most soils of the Top End and that it was particularly suited to gravelly upland soils where other grasses couldn't survive.

Current distribution

Gamba grass is found in the Northern Territory, Queensland and Western Australia. The largest infestations are in the Top End of the Northern Territory and Cape York in Queensland. An intensive management program in Western Australia's East Kimberley region, has successfully reduced gamba grass occurrence, and it's considered close to being eradicated from the state (Snow 2022). Single plants occasionally establish outside the eradication zone, usually on major highways near the border with the Northern Territory. This region is actively monitored, and plants are controlled if found (D. Chemello, personal communication, June 26, 2024).

A map of recorded occurrences of gamba grass in Australia is shown in Figure 1.1. While some mapping exists at state, regional and local scales, large knowledge gaps remain in our understanding of the current distribution of gamba grass across northern Australia. Large areas of the Northern Territory and Queensland have no baseline survey data of gamba grass. In addition, some existing gamba distribution data is very old (20–50 years old), and the quality of that data can't be verified. Up-to-date current distribution data is critical for best practice weed management. It allows weed managers to plan and prioritise weed management to protect the assets valued by land managers.

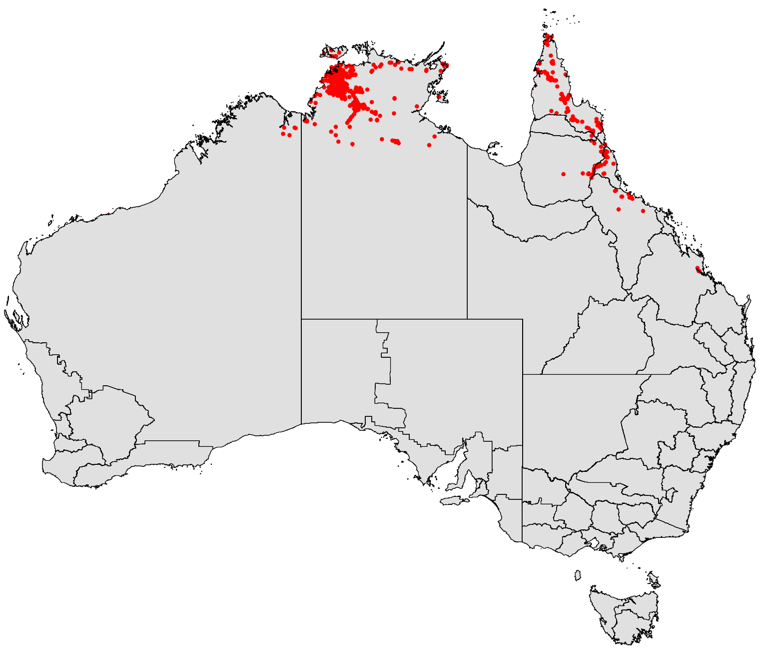


Figure 1.1 Reported occurrences of gamba grass in Australia (based on data ranging from 1960 to 2023). Sites older than 10 years where gamba grass has been confirmed eradicated were removed from the dataset. Source: Atlas of Living Australia 2023, reproduced by Dr Farzin Shababi, Macquarie University.

Potential distribution

Without active management, gamba grass could spread across much of northern Australia (Adams and Setterfield 2016; Csurhes and Hannan-Jones 2016). Habitat suitability modelling predicts a high risk of gamba grass invasion across the savanna regions of Western Australia, the Northern Territory and Queensland (see Figure 1.2; Pintor et al. 2019). Note that habitat suitability modelling should be used as a guide only. For example, existing naturalised populations of gamba grass are established further south than what is indicated as highly suitable in Figure 1.2.

Research suggests that gamba grass is still in the early stages of invasion and that it's likely to continue spreading across northern Australia. Climate suitability modelling of gamba grass potential distribution (Adams and Setterfield 2016; Csurhes and Hannan-Jones 2016), together with our knowledge of its ability to germinate under a wide range of temperatures, suggests that gamba grass currently occupies only a very small percentage of its potential range. This means we currently have a window of opportunity to strategically manage gamba grass where it occurs to prevent further spread and future impacts.

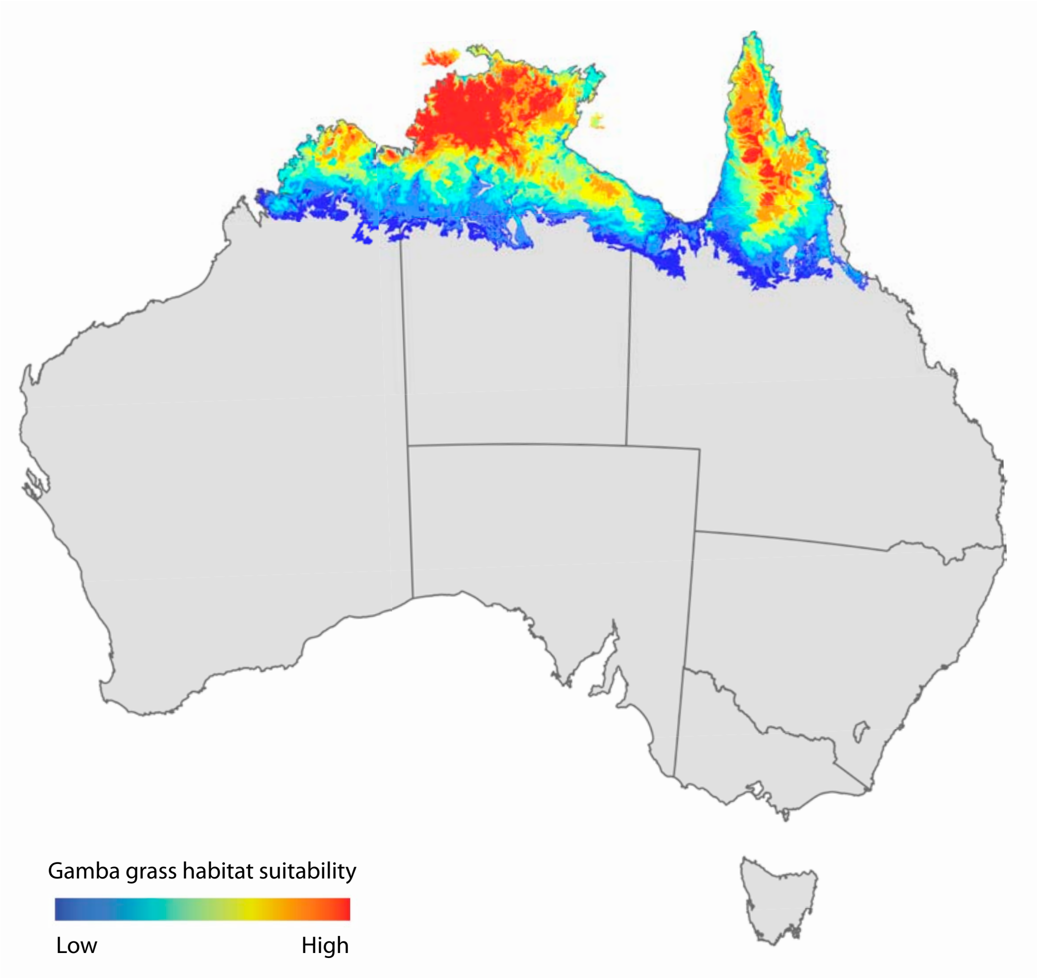


Figure 1.2 Gamba grass habitat suitability map. Reproduced with permission from Pintor et al. (2019).

Gamba grass life cycle

Germination

Germination mainly occurs between October and February, during the wet season (Table 1.1), but may occur at other times if there is enough soil moisture.

Active growth

Gamba grass actively grows mainly in the wet season and into the early dry season, up until June. The bright green growth of gamba grass into the dry season, when native grasses have already browned off, helps managers as it makes gamba grass easy to find by aerial and ground surveys (Rossiter-Rachor et al. 2023).

Flowering

Flowering starts in the early dry season. Gamba grass plants are triggered to start forming flowers when the day length is less than about 12–14 hours (Csurhes and Hannan-Jones 2016). This synchronised flowering generally occurs in April–May, but flowering may also occur at other times later in the dry season if there is enough soil moisture or it is slashed or grazed.

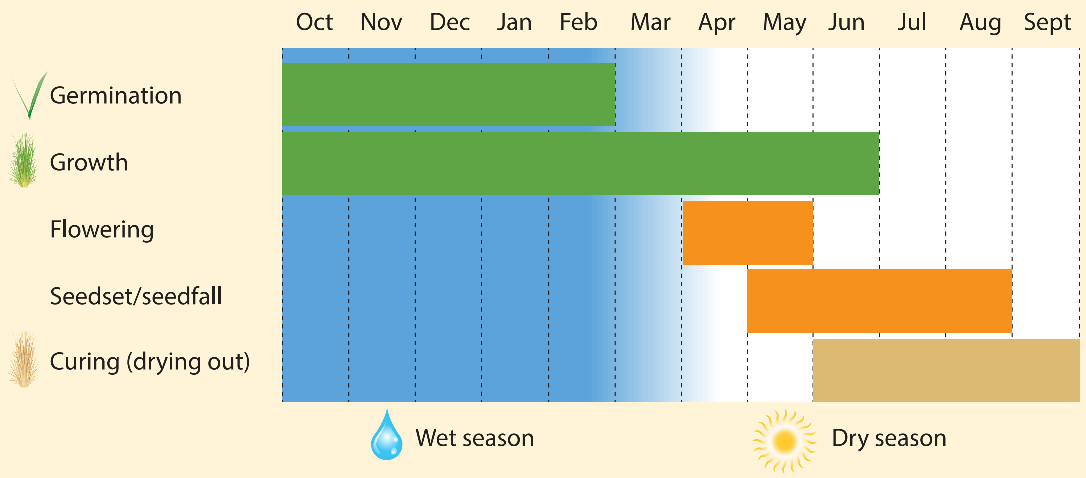
Seed set and seed fall

Seed matures approximately 4–6 weeks after first flowering (Harrison 1998), generally between May and August (Barrow 1995) but may occur in other months. It's worth noting that the timing of gamba grass seeding is later than native grasses across northern Australia, which generally seed March–May (late wet season to early dry season) (Murphy et al. 2021).

Senescence and curing

After seeding, gamba grass plants begin to senesce and dry out, a process known as curing. This happens during the mid-to-late dry season (June–August). Unlike native grasses, which cure at the end of the wet season, gamba grass doesn't fully dry until the late dry season (July–August) when the fire risk is at its highest (Setterfield et al. 2013). See 'impacts of gamba grass' section for further discussion.

Table 1.1 The general timing of the life cycle and growth pattern of gamba grass including germination, active growth, seed set, seed fall, and curing (drying out). The wet season is shown indicatively between October and March, but this varies across Northern Australia and year to year. Note that the timing of different stages will depend on the timing of the wet season and other factors like disturbance. Symbols courtesy of the NESP Resilient Landscapes Hub, nesplandscapes.edu.au.

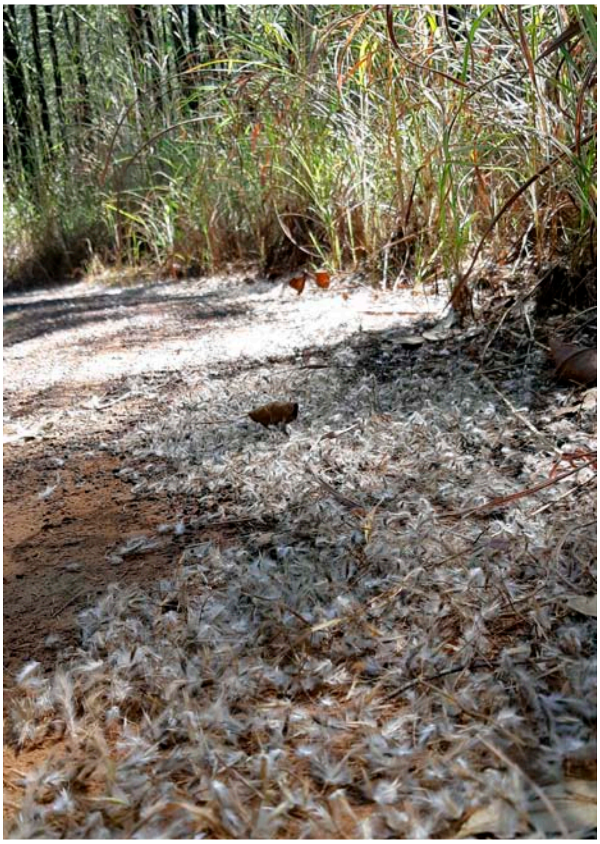


Reproduction and spread

Seed production

Gamba grass seeds prolifically. A single plant can produce up to 244,000 seeds a year (Flores et al. 2005), and approximately 70% of these are viable (Barrow 1995; Bebawi et al. 2018; Flores et al. 2005). This is a far greater amount of viable seed per plant than is produced by either annual or perennial native grasses in northern savanna ecosystems (Flores et al. 2005).

The large amount of viable seed means that gamba grass seed is more likely to be dispersed and colonise new areas. Gamba grass seed heads are light and fluffy, and they're produced 2–4 m above the ground, increasing the likelihood of spread by wind.



Rowena Eastick

Gamba grass seeds blanketing the ground in a heavily invaded site.

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Gamba grass seed heads.

Seed longevity

While gamba grass produces a large amount of seed, the seeds are only viable for a short period of time – making successful control achievable.

The longevity of gamba grass seed has been researched in a range of vegetation and soil types in the Northern Territory and Queensland. This includes studies of the viability of gamba grass seed:

- on the soil surface (Barrow 1995; Bebawi et al. 2018)
- buried at different depths (Bebawi et al. 2018; Flores et al. 2005)
- at different temperatures (Bebawi et al. 2018)
- in the wet–dry topics of the Northern Territory (Barrow 1995; Flores et al. 2005; Setterfield et al. 2004)
- in the dry topics of Queensland (Bebawi et al. 2018).

All studies found that the viability of gamba grass seed declined rapidly to less than 1% after 12 months (Bebawi et al. 2018; Flores et al. 2005; Setterfield et al. 2004). Viability was 0% after 24 months (Bebawi et al. 2018).

For example, a study by Flores et al. (2005) examined the viability of gamba grass seed at savanna and floodplain-margin sites at Mary River National Park (formerly Wildman Reserve), 100 km east of Darwin. The authors buried mesh bags containing seed in July, when gamba grass seed naturally falls. They retrieved the seed bags over the next 12 months. They found that seed viability declined steadily over time and was less than 1% nine months after burial – indicating that gamba grass has little or no residual seed bank (Figure 1.3). Specifically, they found that gamba grass seed viability:

- was approximately 70% in August (one month after burial)
- declined to approximately 50% by October (three months after burial)
- declined to less than 5% by January (six months after burial)
- declined to approximately 1% by April (nine months after burial)
- was negligible (approximately 0.1%) by July (12 months after burial).

It is good news that gamba grass seeds are short-lived. It means that if gamba grass control activities are followed up for 1–2 years, the soil seed bank will be exhausted, and localised eradication should be achievable – but only if all plants are prevented from seeding over the period and no further seed arrives at the site.

Gamba grass seed spread

Understanding and minimising the spread of gamba grass seed is critical to achieving successful management.

> ***Seed spread: key points***
>
> - Dispersal over short distances (up to 100 m) is mostly by wind, water, birds and mammals.
> - Dispersal over long distances (over 100 m) can also occur by wind and water during high wind and flood events. Human-assisted dispersal (e.g. vehicles, machinery, hay) can result in seeds spreading hundreds of kilometres. Long-distance dispersal is the most common way that gamba grass reaches new areas.
> - Ant dispersal is likely to be minor.

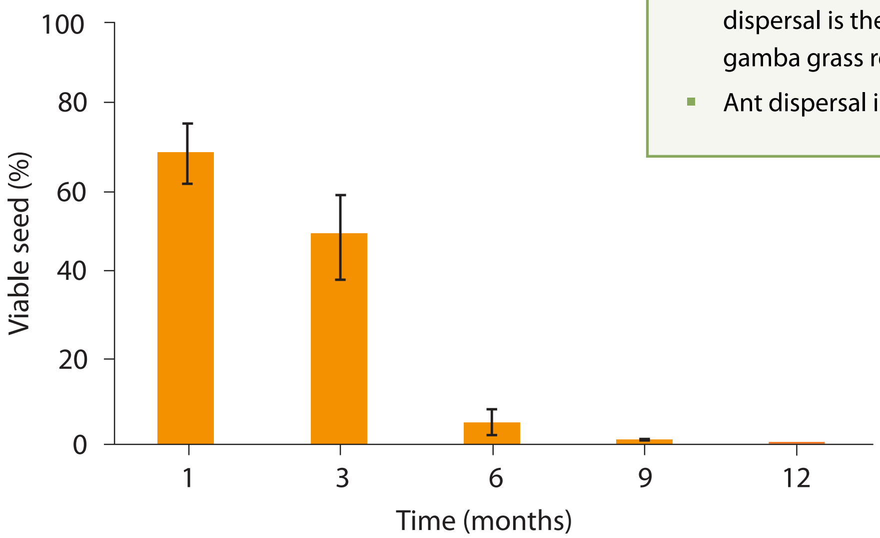

Figure 1.3 Proportion of viable gamba grass seed remaining after one, three, six, nine and 12 months after burial in unburnt savanna at Mary River National Park in the Northern Territory. Values are means ± standard error. Reproduced with permission from Flores et al. (2005).

Most gamba grass seeds fall close to the parent plant, but some can be transported far away. Gamba grass seed heads are small, light and fluffy – ideal for long-distance spread. This long-distance spread is how gamba grass becomes established in new locations, and it can greatly accelerate the invasion of gamba grass in a region. It can also result in re-infestation of sites after control.

Gamba grass seed is spread in two main ways:

- human-mediated spread (e.g. deliberate spread by people, accidental spread by people and vehicles, contaminated produce, domestic/farm animals)
- natural spread (e.g. wind, water, birds and mammals).

Deliberate spread by people was historically a significant pathway of spread, when gamba grass seed was intentionally sown for pastures and hay (Setterfield et al. 2018). Accidental dispersal by people remains a significant pathway of gamba grass spread, including seed spread via vehicles and machinery (particularly slashers and graders), contaminated hay and other products (including soil, sand and fill).

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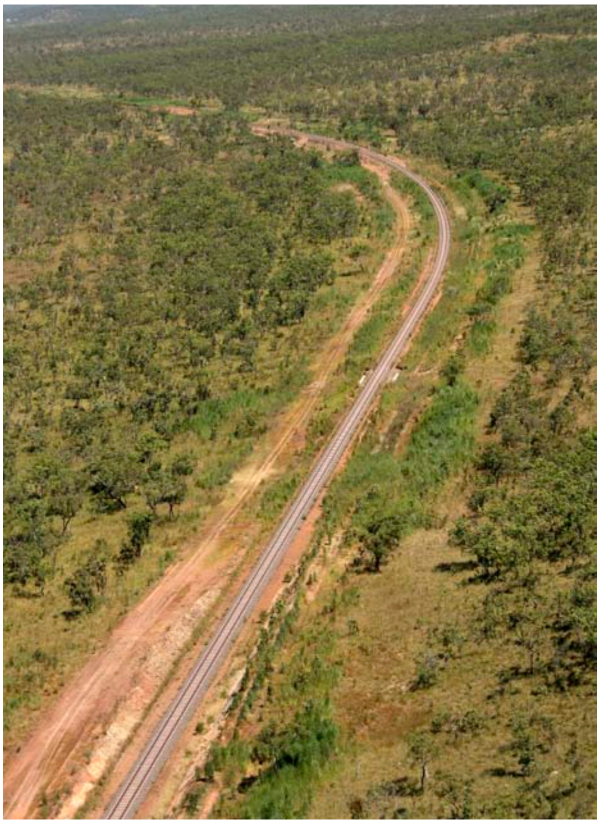
Gamba grass hay bales in the Northern Territory.

Gamba grass spreads rapidly along transport corridors such as roadsides and railway lines, as well as other linear reserves such as power and telecommunication easements and stocking routes. The higher levels of disturbance in these areas makes successful establishment more likely.



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Gamba grass spread along a railway corridor in the Darwin rural area. The gamba grass is lime green.

In the Northern Territory, the spread of gamba grass in the Batchelor region was accelerated by human-mediated dispersal of seed – mostly through the transportation of hay and traffic along major transport routes (Petty et al. 2012).

Wind is the main natural way that gamba grass seed is spread. The seed matures and falls during the windy dry-season months. While most seed falls within 5 metres of the parent plant, as shown in modelling (Murphy et al. 2021) and field studies (Barrow 1995), seed can travel further by wind in given situations. Barrow (1995) observed seed fall 20 m away from that parent plant, and studies in Litchfield National Park in the Northern Territory have documented new gamba grass incursions several kilometres downwind from large source infestations. These were attributed to wind dispersal at higher wind velocities (Rossiter-Rachor et al. 2023). Anecdotal evidence suggests seeds can be picked up by wind during gamba grass fires and transported long distances (Neale 2019).

Water dispersal is another common natural way that gamba grass seed is spread. The light, fluffy seeds float and are easily transported by water. Gamba grass seed matures and falls in the dry season and can be spread during storms and flooding in the following wet season. Riparian habitats along the edges of rivers and creek lines are important spread corridors, particularly into remote locations, as the higher soil moisture and nutrient levels here are perfect for gamba grass germination.

Studies of gamba grass spread in Litchfield National Park also documented widespread colonisation of creek lines and drainage lines by gamba grass. The long-distance spread by water has contributed to the rapid spread of gamba grass in the park (Adams and Setterfield 2015; Petty et al. 2012).


Natalie Rossiter-Rachor

Gamba grass spread along a small creek line in Litchfield National Park, Northern Territory.

Wild animals, such as birds and mammals, can spread gamba grass seeds over short distances if the seeds work their way into feathers or fur (Murphy et al. 2021). This can also result in long-distance dispersal, although this is less common. Ant dispersal of gamba grass seed is likely to be minor, as the seed lacks an ant-attracting appendage (Murphy et al. 2021). Grain-eating birds have been observed feeding on gamba grass seed in the Northern Territory (Rendall 2022), although this doesn't happen often and the implications on spread, if any, are not known.


Martin Tobias Aakesson

Gouldian finch (Chloebia gouldiae) *with gamba grass seed in its beak, Lee Point, Darwin.*

Understanding the ecology of gamba grass supports management success

- The biology, ecology and spread pathways of gamba grass have been well documented by research, helping guide effective management.
- Less than 1% of seeds remain viable in the soil seedbank after 12 months.
- Adult gamba plants are easy to find in the early dry season, when native grasses have senesced.
- Gamba grass is still early in its invasion, so control now will result in large benefits.

Gamba grass establishment

Gamba grass seeds generally germinate at the start of the wet season following the dry season in which the seeds were shed.

Water availability and temperature trigger germination, with seeds germinating across a broad range of temperatures (17–39°C) (Bebawi et al. 2018). At lower temperatures (13°C), seed remains viable but stays dormant until environmental conditions become favourable for germination. Consequently, in sub-tropical areas, seeds may only germinate in the warmer months of the year. In the tropics, gamba grass seeds can germinate at other times providing there is enough soil moisture (Bebawi et al. 2018; Murphy et al. 2021).

Gamba grass seeds can germinate and establish in undisturbed areas, but seedling establishment and survival is higher in disturbed areas (e.g. where the tree canopy has been removed, in burnt areas, or where the soil has been disturbed) (Barrow 1995; Flores et al. 2005; Setterfield et al. 2005). A study of seedling survival at Mary River National Park showed that simulating soil disturbance by cultivating the soil significantly increased the emergence of gamba grass seedlings (Flores et al. 2005).

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Young gamba grass seedlings growing in a shade house.

Impacts of gamba grass

Gamba grass produces large amounts of biomass every year and outcompetes native plants for space, light and other resources (Rossiter 2001). Its root system is more extensive than the shallower-rooted native grasses, enabling it to use more water and nutrients and contributing to its invasive success across northern Australia (Rossiter-Rachor et al. 2009). Once established, it can form dense monocultures, significantly impacting invaded communities.

Gamba grass invasion increases fuel loads

Gamba grass can grow to 5 m high and 1 m across, producing large amounts of biomass that can fuel bushfires. If dried and weighed, the fuel loads of native grasses is typically between 1 to 3 tonnes per hectare, whereas gamba grass fuel loads can be up to 30 tonnes per hectare (Figure 1.4) (Rossiter et al. 2003; Setterfield et al. 2010) – an order of magnitude greater. The impact on fire behaviour is compounded further by the life cycle of gamba grass compared to that of native grasses. Native savanna grasses start to dry out (or 'cure') after they've finished flowering in February/March, coinciding with the late wet season/early dry season. In contrast, gamba grass remains green well into the dry season and doesn't fully cure until July/August. This results in a large amount of fully cured fuel late in the dry season when air temperatures and wind speeds are highest and humidity is low (Rossiter et al. 2003; Setterfield et al. 2010) – perfect conditions for hot fires.

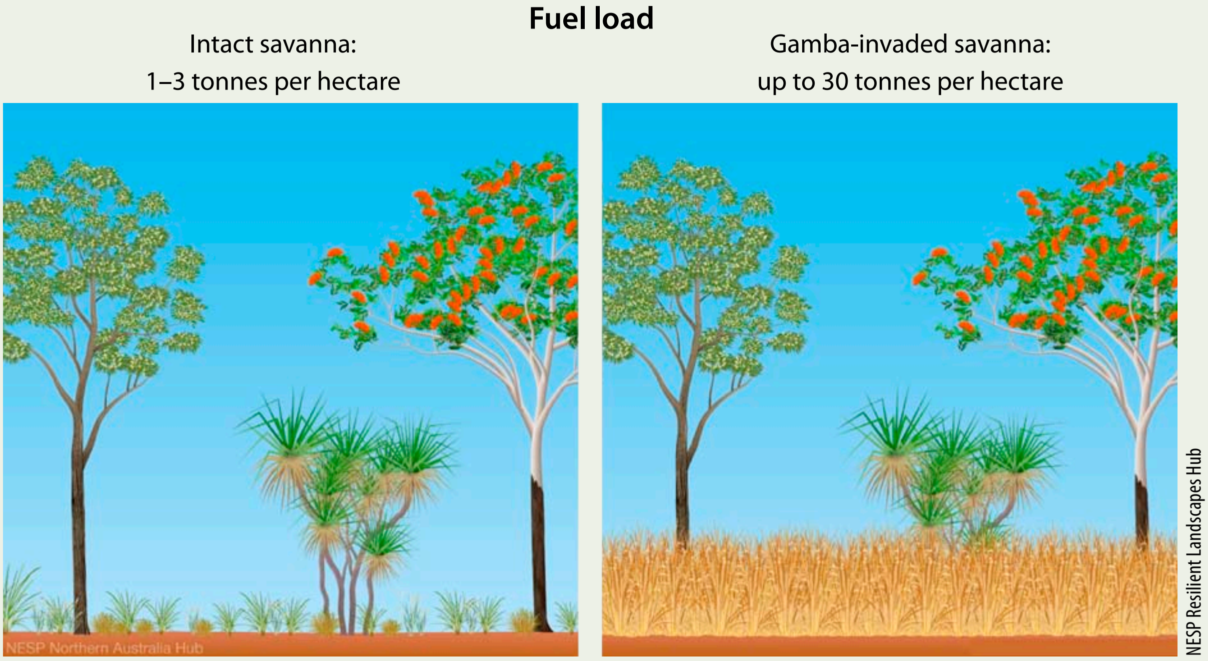

Figure 1.4 Diagrammatic comparison of fuel loads between native savannas and gamba grass-infested savannas. Graphic source: NESP Resilient Landscapes Hub.

A dense monoculture of gamba grass in the Darwin rural area in the late dry season. Note this gamba wasn't planted on this block but invaded from nearby pastoral properties. This infestation has been slashed to ensure the mandatory firebreak.

Gamba fires are more intense, faster moving and have taller flames than native grass fires

Gamba grass fires are up to 8 times more intense than native grass fires (Rossiter et al. 2003). In the first-ever comparison of fire intensity, Rossiter et al. (2003) calculated that, in the early dry season, the energy released per metre of fire front in a gamba grass fire was 15,700 kW/m, compared with a fire intensity in native grasses of 2,100 kW/m (Figure 1.5). A gamba grass fire in the Northern Territory recorded a fire intensity of 43,000 kW/m – the highest fire intensity ever recorded in the region (Setterfield et al. 2010). This grass fire intensity is similar to that of forest fires in southern Australia.

Gamba grass fires have taller flame heights than native grass fires. On average, the flames from gamba grass fires can char leaves 10 m high in the tree canopy – much greater than the 1.5-m char heights typically recorded after native grass fires. Even in low-intensity to moderate-intensity fires, the heat and flame height generated by gamba grass fires can reach up to 13 m and completely incinerate the canopy (Figure 1.5) (Rossiter et al. 2003; Setterfield et al. 2010).

Another consequence of the height and density of gamba grass is that it modifies the structure of the savanna grass fuel layer (Setterfield et al. 2010). Gamba grass leaves can extend from the ground layer to 5 m high, providing a ladder of fine fuels to carry fire into the upper tree canopy and ignite tree crowns (Setterfield et al. 2010). These types of fires didn't occur in northern Australian savannas before gamba grass invasion (Setterfield et al. 2010).

Gamba grass fires also spread at double the speed of native grass fires. This has significant consequences for native animals attempting to out-run or hide from the fire.

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High-intensity gamba grass fire in the early dry season.

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Gamba grass fires spread at double the speed of native grass fires, which can impact native animals trying to outrun the fire.

Frequently burning gamba grass creates a destructive grass-fire cycle

Gamba grass can sustain repeated fires, year after year. It can even sustain multiple fires within one fire season. This frequent burning benefits gamba grass and creates a 'grass–fire cycle' that is self-perpetuating and can only be halted by actively managing gamba grass.

Repeated fires kill mature savanna trees and prevent the next generation of tree seedlings from establishing. Without shading by the tree canopy and competition for resources from native grasses and woody plants, gamba grass can flourish. After burning, cover of gamba grass increases. A healthy

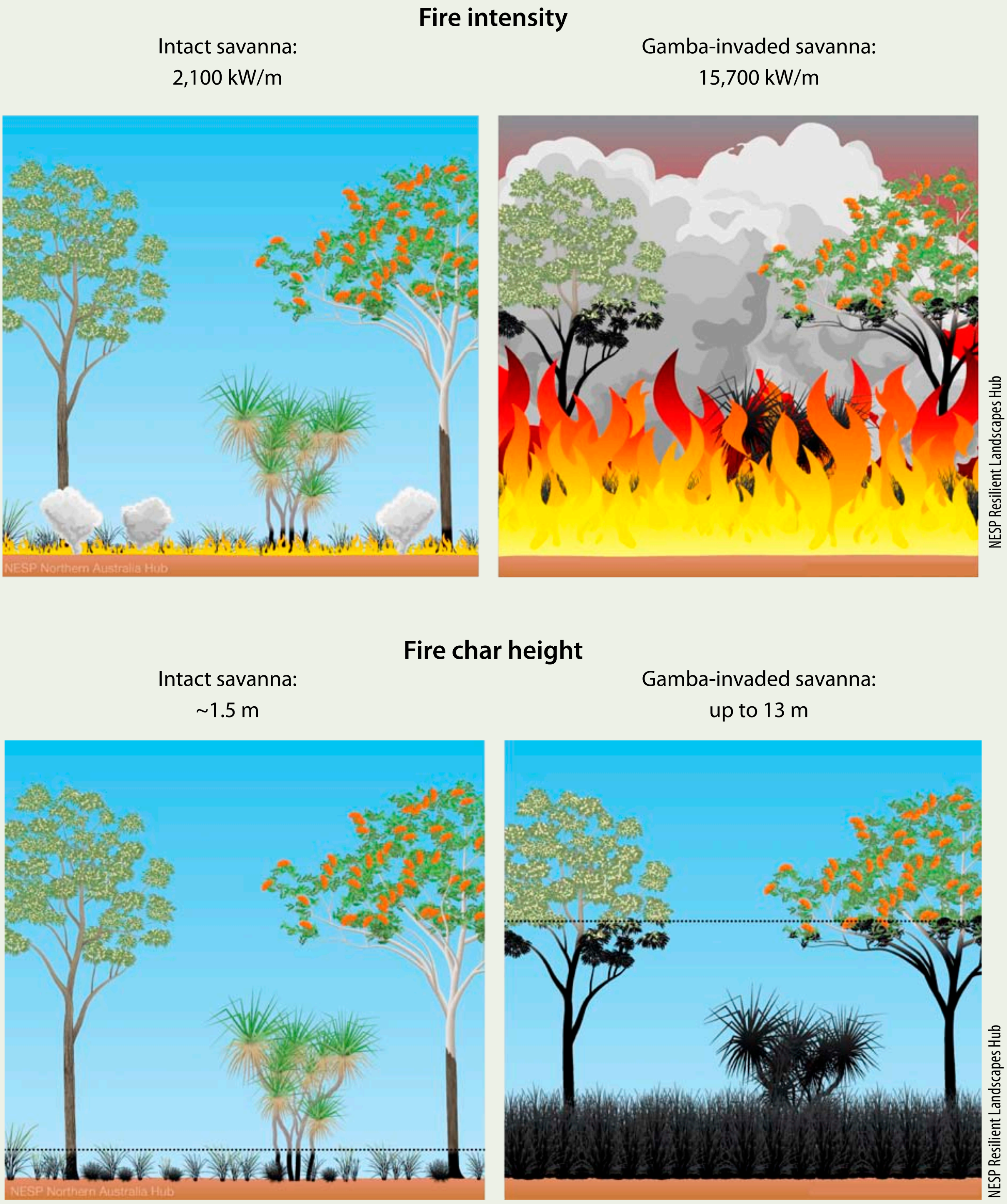

Figure 1.5 Fire intensity (how hot the fire was) and fire char height (the maximum height of leaves that are blackened due to the flames) are both higher in gamba grass fires than native grass fires.

savanna woodland can be transformed into an invasive grassland within a relatively short period of time (Brooks et al. 2010; Rossiter et al. 2003; Setterfield unpublished data).

Frequent burning of gamba grass to reduce fuel loads only entrenches this grass–fire cycle. Other methods of control are necessary to break the grass–fire cycle. Reducing fire frequency or actively excluding fire in combination with herbicide application has been shown to effectively control the density of gamba grass infestations. Chapter 3 ('Managing gamba grass') has more information on best practice management methods for gamba grass.

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Native trees, such as these Eucalyptus miniata *(Darwin woollybutt), can be killed due to the heat of gamba grass fires.*

Gamba grass invasion increases the fire danger and fire management costs

Most Australians are familiar with the fire danger risk index, which is calculated daily and informs the public of fire risk on a scale from moderate to catastrophic. When gamba grass invades at a regional scale, it increases the fire risk. For example, research by Setterfield et al. (2013) looked at the influence of gamba grass on the Grassland Fire Danger Index (GFDI). It was shown that, depending upon the year, areas with dense gamba grass (average landscape fuel loads of 10 t/ha) had a 6-fold to 8-fold increase in the number of days when the GFDI was high enough to invoke a total fire ban. The length of the severe fire-weather season increased by 6 weeks, with severe fire-risk days commencing in mid-June rather than late July in areas with dense gamba grass.

In September 2022, a new Australian Fire Danger Rating System was implemented across Australia. Regions with extensive areas of dense gamba grass have been accounted for with calculations based on higher fuel loads than nearby regions without this scale of invasion.

Natalie Rossiter-Rachor

A plane water-bombing a gamba grass fire.

Gamba grass increases the cost of controlling bushfires

Mitigating fire risk is difficult and expensive. While native grass bushfires are routinely controlled using equipment carried on the back on a 4-wheel drive ('grass-fire units'), gamba grass fires require more equipment, often including aerial fire-fighting capacity (water-bombing planes and helicopters). This aerial attack capacity is especially important in the Darwin rural area, where the risk to lives and infrastructure is high due to these fires. Fire fighters need personal protective equipment that is rated for attending 'structural fires' (i.e. buildings) and is rated to withstand the intense radiant heat generated by gamba fires (Setterfield et al. 2013).

The costs of fighting fires escalated quickly in the Darwin rural area following gamba grass invasion.

Significant resources are required to control gamba grass fire each year.

Prior to invasion, when total-fire ban days were declared for the day, only 4-wheel drives had to be on standby in case of a fire, with a small number of staff. This involved minimal cost. By 2010, the equipment required to be on stand-by had increased to include a fixed-wing aircraft and 2 water-bombing helicopters (with pilots on standby for the day), water tankers, front-end loaders and multiple fire officers, as well as a Bushfires NT (Northern Territory Government) staff member that could coordinate an aerial fire-fighting campaign (Setterfield et al. 2010).

When a bushfire (or wildfire) occurs, the equipment that was on stand-by becomes operational and is used to control the bushfire. This has dramatically increased the cost of fighting individual fires. Setterfield et al. (2013) compared the costs of fighting fires at 6 sites before and after they were invaded by gamba grass. The cost of fighting a fire burning in native grasses averaged less than $1,000, while the costs of fighting gamba grass fires at the same 6 sites ranged from $6,000 to more than $43,000 (Figure 1.6; Setterfield et al. 2013). To date, the most expensive gamba grass fires to be documented by researchers occurred in a 5-day period in 2017. It cost over $300,000 to control 5 fires burning through dense gamba grass in the rural area around Darwin (Setterfield et al. 2018). The largest of these individual fires burned almost 100 km^2 in one day and cost more than $100,000 to manage for the day (Setterfield et al. 2018). A much smaller fire that burned less than 4 km^2 cost more than $55,000 to manage.

The 2023 Vernon Arafura Regional Bushfire Management Plan by Bushfires NT outlines the risk gamba poses to the region and the fire response to this risk.

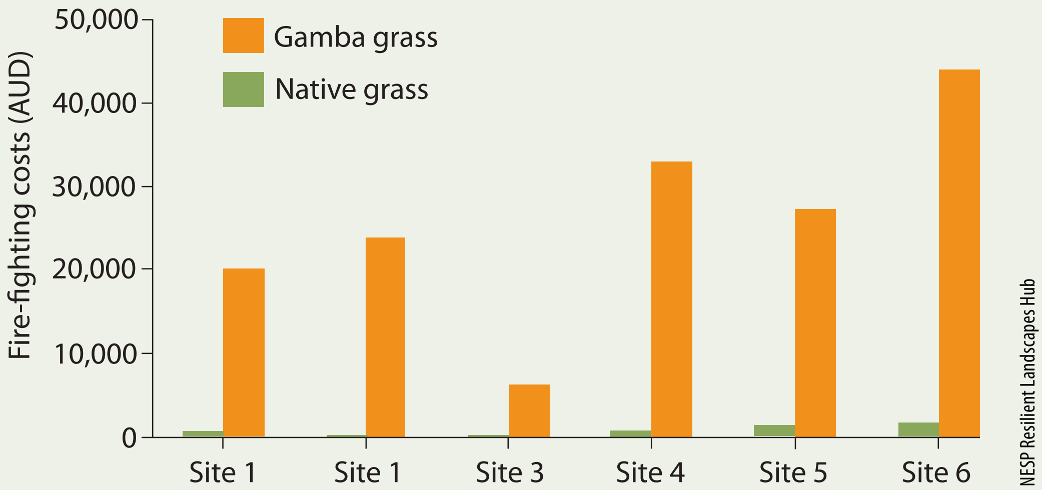

Figure 1.6 The cost of controlling individual fires increased by an order of magnitude following invasion by gamba grass (Setterfield et al. 2013).

Gamba grass threatens biodiversity, including threatened species

Gamba grass poses a serious threat to biodiversity across northern Australia, displacing native plant species and reducing plant biodiversity in the understorey to only 1–2 native plant species (Brooks et al. 2010). In recognition of this serious threat, gamba grass was listed as a Key Threatening Process under the Australian Environment Protection and Biodiversity Conservation Act 1999, with a national Threat Abatement Plan outlining the priority actions to reduce the risk posed by gamba grass. In addition, gamba grass is listed as one of the key threats to Australia's biodiversity in the national Threatened Species Action Plan 2022–2032, with a goal of reducing the area of gamba grass by 2026 to protect biodiversity.

Gamba grass can impact fauna directly through mortality in fires and indirectly through changes to food resources and habitat availability. However, there are still large knowledge gaps about the specific impacts of gamba grass, and particularly gamba grass fires, on a range of native fauna.

Bushfires NT

The intense heat of gamba grass fire can damage horticultural orchards, as demonstrated by the incineration of this mango orchard during a gamba grass fire in the Northern Territory.

Gamba grass fires impact on horticulture

Gamba grass fires impact on a range of land uses, such as primary production and horticulture. For example, primary producers may need to spend money on controlling gamba grass and protecting their assets from fire.

Bushfires NT

Mango orchard burnt during a gamba grass fire, Batchelor, Northern Territory.

Bushfires NT

Gamba grass fires can result in large smoke plumes from the burning of the large amounts of grass and tree biomass, such as the smoke plume of this large gamba grass fire in the late dry season.

Gamba grass fires are a risk to cultural values

Gamba grass invasion transforms native savanna and, consequently, has a dramatic impact on Indigenous cultural values (Setterfield et al. 2018). This is a consequence of the displacement and death of native plants and animals, reduction in the availability of traditional foods, direct impacts on significant and important sites, and restriction of movement through dense infestations (March 2011).

In addition to the impact on Indigenous sites and values, gamba grass invasion has significant economic impact on Indigenous Australians, through the time and effort to manage gamba grass, the loss of resources such as food, and impacts on incomes through carbon credits generated from strategic fire management in tropical savanna, which must exclude defined areas with gamba grass in them (Neale and Macdonald 2019).

The impact and risk to Indigenous cultural values from gamba grass is reflected in Healthy Country Plans. Gamba grass is identified as a key management interest in at least 10 Healthy Country Plans or Plans of Management which include Indigenous Protected Areas located in Western Australia, the Northern Territory and Queensland.

Samantha Setterfield

The intense heat of gamba grass fires can burn native trees, such as this mature Eucalyptus miniata *(Darwin woollybutt).*

Further information on recent research into gamba grass ecology and impacts can be found at gamba-uwa.hub.arcgis.com.

Setterfield SA, Rossiter-Rachor NA, Cramer VA and Thomas JE (2023) *Gamba grass research synthesis*, Australian Government's National Environmental Science Program.

Bushfires NT

Gamba grass fires increase the risk posed to built assets.