Department of **Agriculture and Fisheries**
Biosecurity Queensland

Invasive plant risk assessment

Gamba grass

Andropogon gayanus

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Contents

Summary

Gamba grass (*Andropogon gayanus*) is native to the tropical savannas of Africa. It was imported into Queensland as early as 1942 but was not sold commercially on a large scale until about 1983.

Currently, gamba grass exists as relatively small populations scattered across Queensland, with the majority of populations scattered across Cape York south to the Atherton Tableland. These populations include areas that are grazed and well managed, grazed but not well managed and wild, non-grazed stands. While there is no accurate data on the total area of gamba grass in Queensland, it has been estimated that at least 18 000 ha might have been sown with seeds of gamba grass over the past 30 years. The evidence presented in this study suggests that gamba grass is well adapted to Queensland's tropical savannas and could gradually spread over much larger areas, particularly within Cape York.

Gamba grass can provide valuable feed for cattle and is generally not considered to be a problem within fenced, well-managed cattle paddocks. However, it can have significant negative impacts when not heavily grazed or when it invades non-grazed parcels of land, such as conservation areas, semi-urban residential land and mining leases. On non-grazed land, gamba grass can replace native grasses, thereby reducing natural biodiversity. Moreover, its high biomass can fuel intense bushfires, leading to loss of tree cover and the potential for long-term transformation of woodland into grassland. Each dry season in the Northern Territory, high-intensity gamba grassfires pose a threat to human safety and property.

Introduction

Identity and taxonomy

Species:	*Andropogon gayanus* Kunth
Family:	Poaceae (alt. Gramineae)
Sub-family:	Panicoideae
Tribe:	Andropogoneae
Common names:	Gamba grass (Australia), bluestern (Africa, Australia), Rhodesian andropogon (southern Africa), Rhodesian bluegrass (Zimbabwe), onga, tambuki grass (nor th-west Africa), sadabahar (India).

Taxonomy

A. gayanus is a polymorphic species which was divided into three varieties by Stapf (1919) as follows:
(1) var. *gayanus* (syn. var. *genuinus* Hack.)
Joints and pedicels ciliate on one margin; pedicelled spikelets glabrous; callus beard scanty; awn 1–2 cm long.

(2) var. *squamulatus* (Hochst.) Stapf
Joints and pedicels ciliate on both margins; pedicelled spikelets scaberulous and puberulous; callus beard dense, frontal and lateral; awn 2–3 cm long.

(3) var. *bisquamulatus* (Hochst.) Hack.
Joints and pedicels ciliate on both margins; pedicelled spikelets hairy to villous; callus beard dense, frontal and lateral; awn 2–3 cm long.

Other authors have split off further taxa from var. *bisquamulatus*. For example, Bor (1960) cites as var. *argyrophoeus* a more hair y form with pedicelled spikelets plumosely villous and basal leaves villous. Clayton (unpubl. cited in Bowden 1964) recognises as var. *tridentatus* a largely diploid form, with joints and pedicels ciliate on one side and sessile spikelets 6–8 mm long. *A. gayanus* var. *squamulatus* appears to be used synonymously with var. *polycladus*.

Singh and Godward (1960) made chromosome counts of gamba grass from Nigeria, where three varieties occur, although they did not distinguish between them. They found that specimens from the south of Nigeria were mainly diploid, 2n = 20, while those from the north of Nigeria were mainly tetraploid, 2n = 40. Aneuploids were also recorded, 2n = 35, 42 and 43. Moffat and Hurcombe (1949) recorded 2n = 40 for var. *squamulatus* in South Africa. These chromosome counts fit the view of Gould (1956) that basic chromosome number of the Andropogoneae is n = 10. Var. *bisquamulatus*, as described by Stapf (1919), comprises both diploid and tetraploid individuals (Clayton, unpubl. cited in Bowden 1964).

Gamba grass in nor thern Australia is an ar tificial cultivar, known as cv. 'Kent', and was developed specifically for use as cattle fodder in the Northern Territory by crossing material considered to be var. squamulatus and a second unknown variety (Oram 1990). Overseas, more than 10 cultivars have been developed for commercial use as cattle fodder (e.g. 'Carimagua 1', 'Planaltina', 'Sabanero' and 'Gamba'), mainly in South America (Cook *et al.* 2005). Dwarf types have been bred in Colombia.

Description

Gamba grass is a large, perennial grass reaching 1–4 m in height at maturity.

Gamba grass forms dense, hemi-spherical tussocks up to 1 m in diameter. Morphologically, it is a variable species. Plants can have many or few tillers, thick stems and wide leaves or fine stems and thinner leaves. Culms arise from freely branching rhizomes with very short internodes (Hepper 1972). Leaf laminae are linear, acute, up to 1 m long, 1.5–5 cm wide, with a prominent mid-rib. Laminae may be glabrous or pubescent on both sides. The adaxial surface of the sheath is pubescent, especially when young. Leaves are almost unribbed and tend to fold when dr y. Ligules are usually present and are membranous. The inflorescence is a large spathate panicle with up to six groups of primary branches, 2–18 in a group, final branches filiform, 5–8 cm long, terminating in a pair of racemes. The spathes suppor ting the primary branches have well-developed blades. Spatheoles supporting the rays have somewhat inflated sheaths, with blades reduced or absent. Racemes are 4–8 cm long, with 10–14 joints that are 4–5 mm long, inflated, usually hair y on sides, each bearing a pair of spikelets. The sessile spikelet of the pair is 7–9 mm long, bisexual, with a kneed and spirally twisted awn 1–4 cm long. The pedicelled spikelet is male, its pedicel similar to the raceme joint. Joints and pedicles are ciliate on one (var. *gayanus*) or both sides (var. *squamulatus*). The pedicelled spikelet is glabrous or puberulous in var. *bisquamulatus* (Bowden 1964). The species is cross-fertilised (Bogdan 1977).

Cultivar 'Kent' grows to 4 m high and has pubescent leaves. Pedicels are 4–5 cm long and conspicuously ciliate on both margins. The pedicelled spikelets are 5–7 mm long, whereas sessile spikelets are 5–8 mm and glabrous. The awn of sessile spikelets is 15–30 mm long, and of pedicelled spikelets 5–10 mm long. Pedicelled spikelets are puberulous or villous, hence cv. 'Kent' cannot be assigned to either var. *squamulatus* or var. *bisquamulatus*, but resembles the latter in height. The car yopsis (seed) is 2–3 mm long and 1 mm wide. There are about 890 000 seeds/kg. Seeds are light brown to brownish black (description from Bogden 1977; Bowden 1964).

Reproduction and dispersal

Gamba grass reproduces from seeds. It has spread over long distances as a consequence of being sold and planted as a commercial pasture plant. Other vectors of spread include transport as hay and possibly roadside slashing machinery.

Since the seeds of gamba grass are light (about 890 000 seeds/kg), fluffy, and are produced at a height of 2–4 m above the ground, they can be spread by wind. Ninety percent of gamba grass seeds fall within 5 m of the parent plant and less than 1% fall more than 10 m away (Barrow 1995). Rates of spread of between 110–333 m per annum have been recorded for gamba grass in the Northern Territory (Barrow 1995). Most authors seem to agree that gamba grass spreads slowly across undisturbed woodland, but much more rapidly in areas where the natural vegetation has been disturbed.

Seeds of gamba grass (Photo: John Clarkson, EPA).

Phenology and seed production

Gamba grass is a short-day plant with a critical day-length for flowering of 12–14 hours (Tompsett 1976). Around Darwin, cultivar 'Kent' flowers from April until August (Oram 1990; Smith 1995). In Bolivia and Brazil (16–19oS), flowering is well synchronized in April, but synchronization is poor at lower latitudes (Cook *et al.* 2005). Breeding behaviour is allogamous. Gamba grass reproduces sexually with wind-assisted cross-pollination (Cook *et al*. 2005).

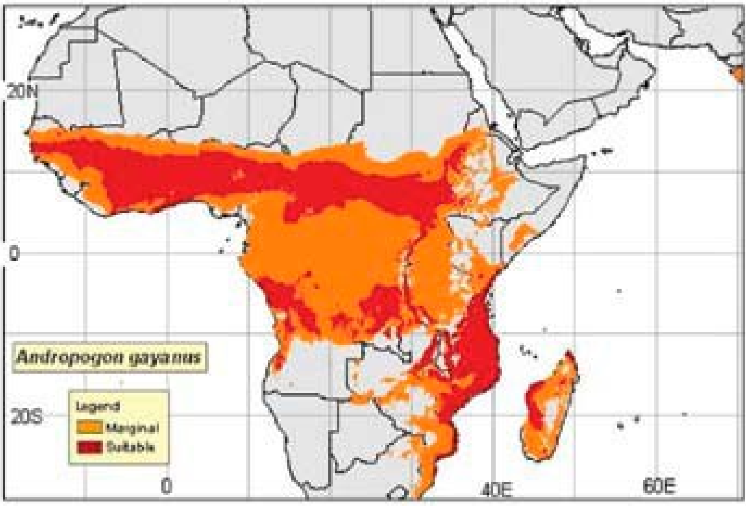
Most seed production occurs from May to June and later in the dry season if soil moisture is available. Some seeds are produced in October/November after early wet season storms (NTDBIRD 2005). Seeds usually mature by late May. Time from first flowering to full seed production (harvest) is 36–44 days (Cook *et al.* 2005). If it is non-grazed, gamba grass can produce between 15 000 to 244 000 seeds per plant per annum, with up to 65% initial viability (Flores *et al.* 2005). By comparison, seed production of native grass species within habitats being invaded by gamba are in the order of 100–900 seeds/m2 for Sorghum intrans (Andrew 1986), *Astrebla* spp. (0–750 seeds/m2) and 50–6300 seeds/m2 for *Heteropogon contortus* (Orr 1998).

Seed longevity

Seed longevity is short, with rapid decline in seed viability at the onset of each wet season. Setterfield *et al*. (2004) found that freshly produced seeds, collected in June, were 80% viable. This declined to less than 1% by the star t of the wet season in December. The maximum viable seed-bank occurs in the dry season, soon after seed production and fall. Seed-banks of 2100 seeds/m² in June have been found to decline to 20 seeds/m² by December (Setterfield *et al*. 2004). Similar densities and seasonal patterns were reported by Barrow (1995).

Origin

The native range of gamba grass extends across the tropical and subtropical savannas of Africa, from Senegal on the west coast to Sudan in the east, south to Mozambique, Botswana and South Africa. Like savannas elsewhere, extended dry seasons are a feature of much of this region.



Areas of Africa considered suitable for growth of gamba grass as a pasture (Cook *et al.* 2005). The red and orange zone broadly reflects the species' native range (as published by Bowden 1964).

Gamba grass grows most vigorously below an altitude of 980 m and seldom forms a significant part of the vegetation above an altitude of 1970 m, though var. squamulatus has been collected in the Sudan at 2300 m (Bowden 1964). Almost all known locations of gamba grass lie between the 400 mm and 1500 mm annual rainfall isohyets (Bowden 1964).

Within its native range, several varieties of gamba grass exist and each occupies a slightly different habitat type (Bowden 1963, 1964).

- Var. *bisquamulatus* 'dominates vast areas of the tropical savanna belt (xerophytic grasslands) from Senegal to the Sudan becoming less abundant in the drier Sahelian belt and the derived savanna' (Bowden 1964). This variety grows best on well-drained sandy clays of medium to high fertility (Cook *et al.* 2005). Bowden (1964) commented that 'within its natural range, var. *bisquamulatus* gives the impression of being more vigorous and aggressive than the other two varieties. Var. *bisquamulatus* shares a similar range to var. squamulatus north of the equator, but is absent south of the equator' (Bowden 1964).

- Var. *squamulatus* (syn. var. *polycladus*) is the most widely distributed of the three varieties of gamba grass. North of the equator it extends in a wide belt between the Sahara and the equatorial rainforests, from Senegal in the west to the Sudan and northern Uganda in the east. South of the equator it extends through the savannas, which form a semi-circle to the south of the Congo equatorial rainforests, from Gabon and Angola in the west, through the Rhodesias [the area of land now occupied by Zimbabwae and Zambia] to central Tanganyika in the nor th and to Mozambique and the Transvaal in the south (Bowden 1964). It shares a similar range and habitat type with var. *bisquamulatus* but tends to be subordinate to var. *bisquamulatus*, dominating a much smaller area by comparison. However, var. *squamulatus* is locally dominant in some of the Miombo savannas of central Africa and the coastal savannas of Angola (Bowden 1964).
- Var. *gayanus* is better adapted to waterlogged soils, compared to the two varieties above, and dominates large areas of the seasonal swamps over much of the African savanna belt from Senegal to Sudan (Bowden 1964). It can sur vive in areas with an annual rainfall of less than 400 mm, but only in the periodic wetlands of riverine flood plains or seasonally flooded valley floors where the soil remains moist for longer periods than the surrounding terrain (Bowden 1964).

The spatial extent and abundance of gamba grass in Africa has increased in response to changes in fire regimes imposed by agricultural practices. In Nigeria (western tropical Africa), gamba grass and stab grass, together with scattered, fire-hardy gnarled trees, fill the 20 000 km^2 grassland of the Cross-Niger River 'transition forest' eco-region, much of which was previously covered with forest before agriculture and frequent burning transformed the vegetation into grassland (National Geographic 2005).

History of introduction

The earliest record of gamba grass in Queensland is a specimen collected from a CSIRO plant introduction garden near Rockhampton in 1942 (Table 1). By about 1951 gamba grass was being grown at the Bureau of Tropical Agriculture at South Johnstone (now South Johnstone Research Centre) (Graham 1951). The first naturalised specimen of gamba grass was recorded by the Queensland Herbarium at Bamaga (Cape York) in 1992, but gamba grass was probably naturalised elsewhere in Cape York by that time, possibly by the early 1980s.

The CSIRO Division of Land Research introduced gamba grass seeds to the Northern Territory in 1931. CSIRO conducted preliminary trials on gamba grass at the Katherine Research Station, Northern Territory, from 1946, using two introductions—CPI 2312 (supplied in 1931 by CP Taylor from Zaria in Nigeria, Africa) and CPI 9207 (supplied in 1944 by Ramos de Otero, Division of Agrostology, Deodora, Brazil, as var. *squamulatus*).

The original source of CPI 9207 in Africa is not known. Residual material of gamba grass from these introduction trials was grown by Mr Frank Kent of the Northern Territory Administration at Berrimah Experiment Farm in the mid-1950s. Progeny of this material was used to establish a larger area on Berrimah. This stand existed until 1981 and formed the basis of the present cultivar 'Kent' (Oram 1990). The exact introduction(s) from which cv. 'Kent' originated are now unclear, but as the species is cross-fer tilised and several generations have been produced since the original introductions, it probably has been derived by natural selection following crossing within and between CPI 9207 and CPI 2312.

Gamba grass was released through the Northern Territory Herbage Plants Liaison Committee in 1978 and listed in the Register of Australian Herbage Cultivars in 1986. Commercial quantities of gamba grass seeds first became available in 1983, when approximately 1 tonne of seeds was produced (Cameron 2000). From 1983–93 gamba seeds were produced in the Northern territory each year and areas were sown for pasture (Catalyst 2004).

In the 1996–97 CSIRO Northern Australia Beef Producer Sur vey, 4% of respondents in the central Queensland coastal region, 4% in north Queensland and 18% in the Northern Territory stated that they had planted gamba grass in pasture improvement programs (Bor tolussi *et al*. 2005).

Worldwide distribution

From its native range over much of Africa, gamba grass has been introduced to many parts of the world, particularly tropical America, for use as improved pasture. It has naturalised in South America (Brazil and Venezuela) and northern Australia.

Distribution in Australia

The exact area of gamba grass in Queensland is unknown. Probably the best estimate is supplied by John Rains (owner of Southedge Seeds) who estimates that, based on seeds sale data, there may be up to 18 000 ha planted with gamba grass (Pressland & Watson 2008). A sample of sites where gamba grass is known to exist (both as planted pasture and naturalised populations) is provided below:

- sites to the nor th and south of Weipa (including Comalco rehabilitation sites)
- Bamaga
- Cooktown area (e.g. road to Hopevale)
- Lakeland Downs area
- Sudley (just east of Weipa)
- Kalinga Station (80 km north of Laura)—about 400 ha planted
- Koolatah (on the Mitchell River near Kowanyama)
- Kendell River (west of Coen)
- Batavia Downs
- the Northern Peninsula Area (NPA) (Aboriginal land)
- near Mareeba (R. Graham, pers. comm.; J. Clarkson, pers. comm.)
- Mt Zero-Taravale Nature Refuge, west-north-west of Townsville.

From this information, it is reasonable to assume that gamba grass currently exists as scattered populations across north Queensland, with most sites located within Cape York.

Queensland Herbarium records for gamba grass are presented in Table 1.

Table 1. Sites where specimens of gamba grass have been collected in Queensland (Source: Queensland Herbarium).

Collection date	Locality	Label description
10 Dec 1942	Fitzroy Vale nr Rockhampton	Fitzroy Vale, near Rockhampton. Cultivated in CSIRO Plant Introduction Garden
1 June 1960	Samford CSIRO	Samford CSIRO
10 July 1963	Samford CSIRO	Samford CSIRO
1 July 1964	Samford CSIRO	Samford CSIRO
13 July 1971	Indooroopilly	Indooroopilly
24 July 1992	4.2 km from Bamaga to Lockerbie Road on Coastal Road to Red is Point	4.2 km from Bamaga to Lockerbie Road on coastal road to Red Island Point. Heavily disturbed woodland marginal to a riverine closed forest. A tall grass. Very common in clumps.
22 June 1994	Coen, Cape York	Coen, Cape York. Open woodland, past cultivation. Tall grass.
7 August 1997	Bamaga	Bamaga. Roadside. Erect grass to 3 m tall.
17 June 1998	Poison Creek Road c. 7 km from Cooktown (GPS 15 27 42 145 09 37) (r)	Poison Creek Road. Dense roadside sward (possibly intentionally planted in adjacent paddock). Observed as occasional roadside weed elsewhere in surrounding district. Tall cane-like grass growing in clumps.
30 July 1998	Batavia Downs, Cape York Peninsula (GPS 12 39 50 141 40 06)	Batavia Downs. Paddock near homestead. Erect cane-like grass to 3 m tall. Leaf material has dried off. Planted as pasture species but occasional plants noted as roadside weeds. Potential major environmental weed—especially due to combustibility.
1 August 1998	Heathlands Reser ve—Connecting Road to Telegraph Track (GPS 11 44 54 142 33 02)	Heathlands Reserve. Occasional plants along roadside. Large sward (many square metres) in former pasture. Tall clumped grass. Inflorescence shatters when mature. Potential environmental weed and fire hazard.
2 August 1998	Main Road to Weipa 5 km North of Sudley Entrance	Main road to Weipa. Along roadside. Tall, cane-like grass to at least 3 m. Some stems branched. Spikelets hairy. Inflorescences shatter as spikelets ripen. Apparently planted as a pasture species on Sudley. Now escaping and becoming weedy along roadside.
21 May 1999	Near Mareeba township	Near Mareeba township. Tall clumped grass with densely silver hairy spikelets. Occasional plants on roadsides leading to Mareeba township (e.g. Kennedy Highway).
27 June 1999	Along roadside betweeen New Mapoon and Bamaga Cape York	Along roadside between New Mapoon and Bamaga. Clumping grass, ver y tall 2+ m. Has been cooked in microwave.

Collection date	Locality	Label description
7 March 2000	Roadside between Bamaga and New Mapoon	Roadside between Bamaga and New Mapoon. Perennial grass that appears to be resprouting from root stock. Leaf blades and sheaths densely pubescent; blades with conspicuous white central veins. Plants with pith-filled culms to 2 m tall, but far from mature.
15 June 2000	Near Cape York, on track to Somerset, North Side of track c. 3 k m from road to Pajinka turnoff	Near Cape York, on track to Somerset, North side of track c. 3 km from road to Pajinka turnoff. Isolated clump. Repor ted to be abundant in Bamaga and frequent as far North as Lockesbie. Robust clumped grass c. 2 m tall. (Presence has been repor ted to Cook Shire).
15 May 2001	Injinoo Community, North end of town	Injinoo community, Nend of town. Scattered plants. Red lateritic soils. Dense roadside infestations along roads through NPA. Clumped grass c. 2–3 m tall when flowering culms develop. Leaves pubescent, dark crimson spots at junction of blade and sheath.
15 May 2001	Western edge of Lockhart River township	Western edge of Lockhart River township. Disturbed road verge. Tall grass flowering later than other species. Recorded at two sites, edge of township, c. 15 plants.
18 May 2001	Punsand Bay	Punsand Bay. One clump of grass adjacent to entrance driveway. Tall clumped grass with culms ›3 m. Leaves softly hairy. Inflorescence pale green spikes. Spikelets silvery hoar y with dark awns. Widespread weed elsewhere in district, probably carried by vehicle.
2 June 2003	Rubbish dump at Evans Landing, Weipa	Rubbish dump at Evans Landing, Weipa. Occasional clumps around peripher y of rubbish dump. More common elsewhere in district. Plants greener and appear to mature earlier later than other native and introduced grasses. Pebbly bauxitic substrate.
21 April 2004	Batavia Landing, Wenlock River	Batavia Landing, Wenlock River. Sandy soil. Themeda arguens and Heteropogon triticens in near vicinity, plus old mango trees. Tall clumped densely hairy grass with culms 3–4 m tall. Culm diameter to at least 1 cm. Sterile. Dense infestation growing at track.
March 2006	Mt Zero-Taravale nature refuge	Deception Ck track, Mt Zero property, 90 km WNW of Townsville.

While some of the largest populations of gamba grass cover hundreds of hectares, the majority of Cape York is still free of gamba grass. The largest populations are associated with proper ties where gamba grass was planted to provide cattle pasture.

Near Mareeba, gamba grass is currently spreading along roadsides, adjacent open woodland and into a nearby section of Hann Tableland National Park. As is occurring in the Northern Territory, spread appears to be occurring most rapidly along disturbance corridors (such as roadsides) and more slowly into relatively undisturbed habitats. Other sites in north Queensland where gamba grass has invaded national parks include Heathlands (where there are two, well separated infestations) and Keating's Lagoon near Cooktown. Both sites are the subject of control action by the Queensland National Parks and Wildlife Service.

In the Northern Territory, gamba grass currently occurs in the Darwin, Palmerston and Litchfield Shires, the Coomalie Community Government, Mary River, Douglas River and Lower Daly River regions (Douglas & Setterfield 2005). It is particularly abundant near Darwin, further south around the township of Batchelor and around the Berrimah Research Station (where it was first planted). In 2000, it was estimated that there was approximately 7000 ha of gamba grass in the Northern Territory (Cameron 2000). Spread from original planting sites is continuing (Whitehead & Wilson 2000; Kean & Price 2003).

Preferred habitat and climate

The species in general, including cv. 'Kent', is adapted to the seasonally dry tropics. Typically, the dry tropics has a 6–8 month dry season and a wet season with 750–1500 mm of rainfall. While gamba grass can grow in areas with 400–3000 mm annual rainfall, and a strong dry season of up to 9 months, it prefers more than 750 mm per annum with 3–7 months of dry season (Cook *et al*. 2005). Gamba grass will grow with rainfall up to 2000 mm per annum provided there is a strong dry season.

Best growth is in lowlands of the tropics and warmer subtropics (15–20°S latitude), as growth is restricted where mean minimum temperature of the coldest month is below 4.4°C (Bowden 1964; Cook *et al*. 2005). The leaves are killed by frost. Optimal flowering occurs at 25°C (Cook *et al*. 2005).

Gamba grass is generally considered to require full sunlight, but can grow under light shading or cloudy conditions (Cook *et al.* 2005). In Cuba, significantly reduced yields of gamba grass were attributed to low light conditions under a canopy of *Albizia procera* (Cook *et al.* 2005).

Overseas, gamba grass varieties seem adapted to a wide range of soils (sands to clays, neutral to strongly acid (pH 4–7.5), infer tile to fertile), but generally grow best on loams of moderate fertility (Cook *et al.* 2005). Overseas, some varieties can withstand short-term flooding and waterlogging, but most have poor tolerance (Cook *et al.* 2005). However, there is anecdotal evidence that the variety that exists in Queensland (cv. 'Kent') does not tolerate waterlogging or clay soils. Gamba grass is reported to tolerate soils high in aluminium (greater than 80% saturation) through exclusion of the element, but not salinity. Gamba grass has a relatively low requirement for phosphorus for successful growth (Jones 1979).

Gamba grass seedling recruitment is higher in burnt savanna compared to unburnt savanna (Flores *et al.* 2005), suggesting that the current practice of annual burning over large areas of northern Australia may be accelerating invasion by gamba grass. Observational data over a 20-year period from 1960–80, from a number of sites in the Northern Territory, indicate the ability of mature stands of gamba grass to survive annual fires (Oram 1990). This is an important adaptation that enables gamba grass to persist in the tropical savannas of northern Australia—a region that experiences regular fires.

Gamba grass has three distinct types of roots:

- Fibrous roots close to the soil surface absorb water from the surface of the soil and probably contribute to its early, vigorous regrowth.
- Cord roots are thick, store starch and anchor the tussock.
- Vertical roots are able to extract water well into the dr y season. This root system enables gamba grass to tolerate prolonged dr y periods and to respond vigorously to early rains (Bowden 1964).
- At one stage, the proponents of gamba grass argued that it was a weed of disturbed areas and would not spread into more natural bushland areas. While disturbance corridors such as roadsides have been the major conduits for the spread of gamba grass in the Northern Territory (Barrow 1995; Kean & Price 2003), there is evidence that gamba grass is not restricted to highly disturbed habitats and can disperse over long distances (greater than 500 m) from roadsides and pastoral proper ties into relatively undisturbed areas including conservation parks (Barrow 1995; Whitehead & Wilson 2000; Price, unpublished data; Wilson & Panton, unpublished data). While soil and canopy disturbance are not essential for its establishment, both of these factors will promote establishment. Soil disturbance can increase seedling survival in the first year (Setterfield *et al.* 2005).

Gamba grass can invade a variety of natural habitats from wetland margins through to upland savanna (Flores *et al.* 2005) and is particularly abundant along the banks of watercourses (Kean & Price 2003) and roadsides.

Gamba grass along a roadside in the New Mapoon area of Cape York, Queensland (Photo: B. Waterhouse, AQIS).

History as a weed overseas and interstate

Gamba grass is a serious environmental weed in the Darwin region of the Northern Territory. It is reported to be a major environmental weed in Venezuela (South America) (Smith 1995) and a 'potential weed of concern' in the Pacific Islands (Randall 2002). However, this study was unable to find detailed information on its impacts overseas.

Environmental impacts

In the Northern Territory, gamba grass is currently spreading from pastures into surrounding non-grazed areas, replacing native grasses (Kean and Price 2003). In areas where it has been left non-grazed, gamba grass has become a dominant grass species. Loss of native vegetation assemblages causes a decline in the diversity and abundance of native wildlife.

Research in the Northern Territory suggests that gamba grass is having a long-term impact on native tree cover by increasing fuel loads. Since gamba grass grows to 4 m tall and produces up to 10 times as much biomass as native grasses (gamba grass typically produces a biomass of 11–15 t/ha, but up to 30 t/ha, compared to around 3–5 t/ha for native grasses) (Williams et al. 1998; Rossiter *et al.* 2003), it produces a large amount of fuel for dr y season fires (Barrow 1995; Bowman 1999; Howard 2002).

Compared with sites dominated by native grasses, sites dominated by gamba grass have increased fire intensities by up to eight times (Rossiter *et al.* 2003). Even early in the dr y season, when gamba grass has only just started to cure, fire intensity is more than three times as high as that recorded in adjacent native grass savannas (Rossiter *et al.* 2004). In the absence of gamba grass, early dry season (May–June) savanna fires in the Northern Territory tend to be very low in intensity (c. 2000 kWm-1), patchy and limited in extent. Late dry season fires are more intense (c. 8000 kWm-1) and extensive than early dry season fires (Williams *et al.* 1998). Fire intensities in savanna invaded by gamba grass can reach 24 000 kWm-1 measured in the early dry season (Rossiter *et al.* 2003).

Native grass understorey within a tropical savanna in the Top End of the Northern Territory (Photo: M. Douglas, Charles Dar win Uni, NT).

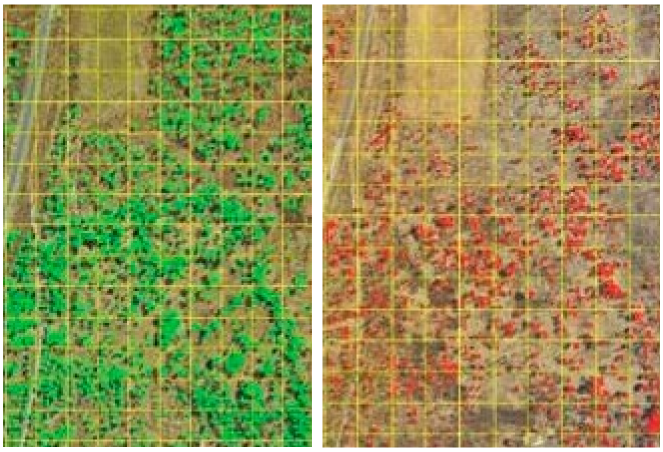
Gamba grassfire in the Northern Territory. Note the person in the lower right corner (Photo: Sue Lamb, Northern Territor y Bushfires Council).

Flame heights of gamba grassfires are higher than those of native grassfires and typically rise higher than the tree canopy (Rossiter *et al.* 2003). These fires could dramatically alter

the structure of the native vegetation (Bowman 1999; Rossiter *et al.* 2003). This prediction is suppor ted by a flame simulation model (Liedloff & Cook, in prep.), which suggests that gamba grassfires could kill most of the overstorey tree layer within a century (Leidloff, unpublished data). However, tree cover can be halved within five years where gamba grass invasion is coupled with poor fire management (i.e. late dry season fires) (Setterfield *et al.*, unpublished data).

Gamba grass invasion can also reduce tree species recruitment, with native tree seedling density 75% lower in invaded sites compared to native grass sites (Clifton *et al.*, in prep.). Changes in fire regimes caused by gamba grass could also threaten the sur vival of rare plants such as cycads (Liddle 2004)—plants that feature heavily in tourism promotions for the Northern Territory.

On areas of non-grazed land, intense fires fuelled by gamba grass have the potential to transform eucalypt-dominated tropical woodlands into tree-free grasslands. Such transformation has been observed in savanna ecosystems elsewhere in the world and is referred to as the 'grass-fire cycle' (sensu D'Antonio & Vitousek 1992).



Tree cover (indicated by green shading in the left-hand image) was reduced by 50% (indicated by red shading in the right-hand image) over five years of annual burning of a woodland infested with gamba grass (Images courtesy M. Douglas, Charles Dar win University, NT).

Trees killed by intense fires generated by gamba grass in the Northern Territory (Photo: M. Douglas, Charles Dar win University, NT).

In addition to modifications to natural fire regimes, gamba grass can reduce available soil nitrate levels by 70%, treble grass water-use and more than halve deep-drainage of water (Rossiter *et al.* 2004). If such changes occur over a sufficiently large area, the potential exists for gamba grass to alter catchment hydrology—to the detriment of downstream wetlands and streams. Such impacts are probably a consequence of the plant's size and growth rate, compared to the more modest requirements of smaller native grass species. Hence, there is evidence that gamba grass could alter a range of basic functional processes within tropical savannas.

Social and economic impacts

Fires generated by gamba grass in the Northern Territory pose a serious threat to human life and property. In the late 1990s the Northern Territory Fire and Rescue Service became concerned at the increasing fire intensities around Dar win and the township of Batchelor. Each dry season in the Dar win area there is considerable community concern expressed in the media at the potential for gamba grass to cause damage to proper ty and possibly loss of life. Bushfires Northern Territory has advised that high intensity gamba grassfires have caused the destruction of building structures (including houses) in the Northern Territory. This has resulted in Bushfires Northern Territory 'mounting a formal case for removal of gamba from the Northern Territory' (Ian Thomas, Regional Manager, Queensland Fire and Rescue Service, pers. comm.).

A substantial infestation of gamba grass exists near the township of Bamaga on Cape York. At this site, the proximity of gamba grass to houses poses a fire risk. It has been reported that a mining company in Cape York spends in excess of $200 000 per annum on gamba grass control in its revegetation areas. The Queensland National Parks and Wildlife Service is also spending money each year trying to keep gamba grass out of its Cape York parks. The cost imposed on local governments is unknown, although there is likely to be an ongoing need to control gamba grass along roadsides in Cape York.

Economic benefits

Well-managed gamba grass can provide valuable feed for cattle in the monsoonal tropical savannas of northern Australia. While young growth of gamba grass is palatable and is well accepted by cattle throughout the year under moderate grazing pressure, it becomes coarse and fibrous if under-grazed (Cook *et al.* 2005). Hence, to be useful, gamba grass needs to be grazed heavily or slashed during the wet season, other wise it grows too tall and palatability declines significantly.

In the Top End of the Nor thern Territor y, fertilised, well-managed gamba grass can carry more than 40 times more cattle than the native pastures of the region. Well-managed gamba pastures can carry up to five head per hectare and increase their live-weight by 25 kg/ head/month during the five months from December to April. In nor thern Australia, animal production on gamba grass pastures over an entire year is in the order of 90–120 kg/ head/ year, a figure that is hindered by weight loss during the dry season (Cook *et al.* 2005). However, addition of a legume can increase this to 150 kg/head/year. In the dry tropics of South America, with a wet season of five months, live-weight gains of 250 kg/head/year have been recorded (Cook *et al.* 2005).

In Cape York, infrastructure development is limited due to costs associated with difficult terrain, poor soils and large areas. Consequently, a need was seen to be able to hold mustered cattle in a small area while normal management practices (vaccinations, weaning, dehorning, marking, sorting sale cattle etc.) were carried out. Gamba grass was recommended for this purpose in Cape York primarily because it had the capacity to produce a large bulk of feed (10–15 t/ha) and could thus support a large number of cattle in a relatively small area (i.e. in a holding paddock) for a limited time.

This study was unable to find any published information on the total value of gamba grass to Queensland's beef industry. However, a crude estimate of the potential value of 5000 ha of gamba grass, compared to 5000 ha of unimproved (native) pasture, was offered by Bill Holmes (DPI&F) as follows:

For unimproved (native) pasture

Area of unimproved native pasture: 5000 ha
Carrying capacity: 1 AE/20–50 ha
Annual live-weight gain per animal: 80–100 kg

Best scenario: (1AE to 20 ha making 100 kg/year) 250 head x 100 kg live-weight x $1.40/kg = $35 000 per annum

Worst scenario: (1AE to 50 ha making 80 kg/year) 100 head x 80 kg live-weight x $1.40/kg = $11 200 per annum

Maximum benefit: for gamba grass in an improved pasture (cleared and fertilised)

Area of managed gamba grass: 5000 ha
Carrying capacity: 1 AE/4 ha
Annual live-weight gain per animal: 110–140 kg

Best scenario: 1250 head x 140 kg live wt x $1.40/kg = $245 000 per annum
Worst scenario: 1250 head x 110 kg live wt x $1.40 = $192 500 per annum

These figures, however, do not include the extra costs involved with running more cattle. These might include $10/head in husbandry costs on the extra 1000 cattle (1250 less 250) or $10 000 total, and an interest cost on the capital tied up in extra stock ($500/head × 1000 head × 10% = $50 000). This is a total cost of about $60 000 or $12/ha, and excludes the cost of land preparation, pasture sowing and new infrastructure (fences & waters) required by the intensification. If we accept the best case/worst case values and set best against best and worst against worst, we come up with a range of benefits (before costs) of $181 300 ($192 500 less $11 200) to $210 000 ($245 000 less $35 000). Take away the costs for husbandry ($10 000) and interest on extra livestock capital ($50 000) and we are back to $130 000 to $220 000 round figures, before costing off pasture establishment and new infrastructure. Hence, a gross benefit of $24–30/ha is provided by sown gamba grass.

Costs need to be deducted from this figure. The costs of establishing gamba grass pasture could be anything up to $400/ha depending on the amount of preparation—clearing ($30–150/ha); seedbed preparation ($0–25/ha); seed ($17/kg*4kg/ha = $68/ha); aerial seeding ($0–3/ha); fertilizer (100kg/ha*$650/tonne = $65/ha); whether new water points are needed ($90/ha); yards and fencing ($2000/km, assuming 25 km2 blocks and 20 km of fence = $16/ha). Assuming the least amount of input and 10% interest, the establishment costs could be about $20/ha. This would give a total benefit of sown gamba grass of $4–10/ ha (Bill Holmes, DPI&F, pers. comm.).

Commercial gamba grass seed production is not a major industry with only one producer of gamba grass seeds for grazing production in Queensland. Around six tonnes of gamba grass seeds were being sold per annum in 2005, with sales currently increasing by about one-third each year (R. Newman, Southedge Seeds, pers. comm.). Six tonnes of seed is sufficient to grow 1500 ha of gamba grass pasture when sown at a rate of 4 kg/ha.

Grazier support for gamba grass appears to be mixed; some cattle producers wish they had never planted gamba grass due to its propensity to spread and the difficulties associated with managing fire as well as maintaining sufficient grazing pressure to prevent the plant from becoming tall and rank (J Clarkson, EPA, pers. comm.). However, the proponents of gamba grass claim that it is well accepted by graziers. One of Australia's largest cattle producers, Australian Agricultural Company (A ACo), is not interested in using gamba grass in areas where it is an option, as they are satisfied with production from native pastures in such areas (J. White, Rangelands Manager, A ACo, pers. comm.).

For general sown pasture purposes in Cape York, there are a number of alternative sown grass species being used. Urochloa, *Brachiaria* spp. and Rhodes grass are all suitable grasses used in intensively developed pastures, albeit on a small scale. However, these grasses cannot produce the bulk of feed in a small area to fulfil the needs of a holding paddock mentioned above. An area three to four times larger would be needed.

In response to growing community concern at the negative impacts of gamba grass, the Northern Territory Department of Business, Industr y and Resource Development has stopped recommending gamba grass (NTDBIRD 2005). There have been claims that gamba grass has anti–cattle tick (*Boophilus microplus*) properties. However, Mexican studies on reducing the number of cattle tick larvae available to infest calves in pasture did not yield ver y promising results (Fernandez-Ruvalcaba *et al*. 2004; Cruz-Vasquez *et al*. 2000). It was found that only those plants older than six months had a significant effect on the number of larvae af ter four weeks, reducing available larvae by about 20%, while 12-month-old plants reduced available larvae by 50%. Similarly, de Barros and Evans (1989) found that short-term exposure of larvae to *A. gayanus* did not reduce larval numbers. It is difficult to interpret the results of early studies on *A. gayanus* (Thompson *et al*. 1978), although they appear to show a persistent but modest effect of reducing lar val sur vival. Overall, there is poor evidence to suggest that *A. gayanus* could have an important place in integrated control programs for cattle ticks. Its effect on larvae appears to be modest and dependent on the age of the plant (Jonsson 2006).

Pest potential in Queensland

The evidence collected by this study suggests that gamba grass has the potential to cause significant problems in areas where it is not subject to grazing by cattle. Areas at risk appear to include much of our northern tropical savannas (tropical woodland and open forest ecosystems). While gamba grass can provide valuable cattle fodder when fenced and grazed at sufficient intensity to prevent it becoming tall and rank, it has the potential to dramatically increase fuel loads and cause intense fires in areas that are either lightly grazed, or in areas that are outside cattle paddocks. In non-grazed areas, it is predicted to have significant impacts on natural tree cover and flow-on effects to native biodiversity.

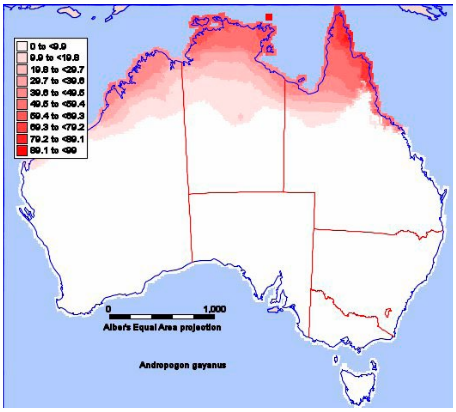
Based on information collected in this study, habitats at particular risk of invasion are predicted to include areas with the following attributes:

- seasonally dry, tropical climate, possibly extending south to a sub-tropical climate (south to about 15–20°S)
- savanna vegetation (open woodland), including relatively undisturbed areas, but perhaps mostly on non-grazed sites such as conservation reserves, margins of townships and roadsides
- mean minimum temperature of the coldest month above 4.4 °C
- annual rainfall of 700–1500 mm, with a strong dry season
- lowland (extending up to 1500 m above sea level)
- well-drained soils that are either sands or loams (not clays), pH 4–7.5, infertile to fertile, with best growth on loams of moderate fertility.

In the Northern Territory, the predicted distribution of gamba grass covers all savanna areas, wetland margins and rainforest ma rgins nor th of Daly Waters (15°S), an area of approximately 380 000 km2 (Douglas and Setterfield 2005). The total area of Queensland at risk of invasion is also substantial, including seasonally dry tropical and subtropical savannas over much of Cape York and northern and central Queensland (from coastal and subcoastal areas west to the 400 mm annual rainfall isohyte), extending south to around 20°S.

This study predicts that consequences of unwanted (non-grazed) gamba grass could include:

- loss of native pasture species
- loss of tree cover (as a consequence of more intense fires)
- loss of wildlife dependent upon natural vegetation
- loss of property and possible loss of human life (as a consequence of intense fires).

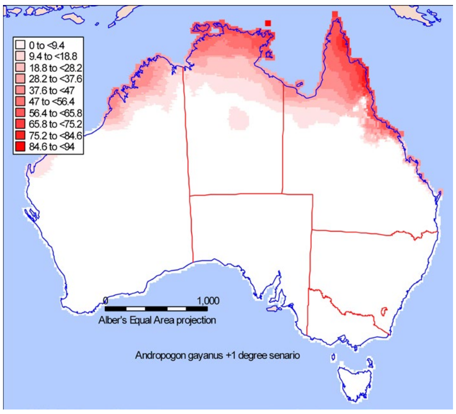


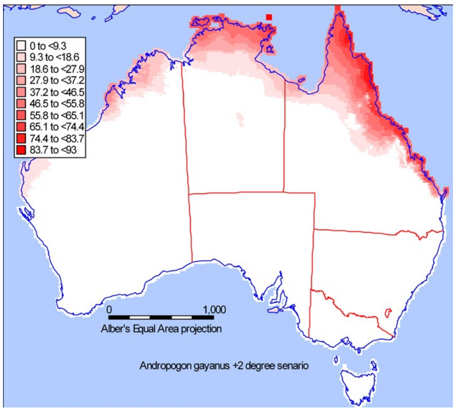
Potential distribution of gamba grass (dark red indicates areas where climate is considered highly suitable for growth of gamba grass; white indicates areas where climate is considered unsuitable for growth of gamba grass) (map generated using CLIMEX climate- matching software).

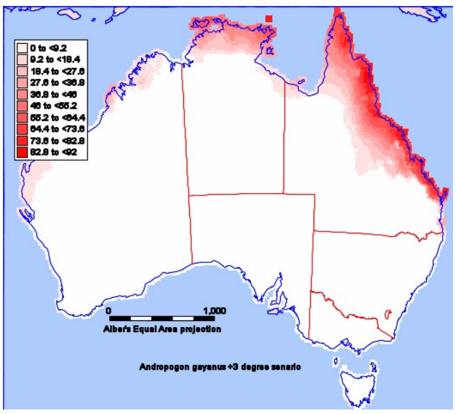
Gamba grass is a serious environmental weed in the Northern Territory; it has a broad natural distribution in Africa and is climatically suited to north Queensland. These three attributes (history as a pest elsewhere, broad natural distribution and climatic suitability) are reliable indicators of pest potential (Bomford 2005).

Climate change

The potential distribution of gamba grass might change in response to global climate change. The predicted effects of increasing mean temperature and changing rainfall are presented in Figure 12. Increasing mean temperature of 1–30 Co is expected to cause a southerly shift in the plant's distribution, perhaps allowing it to grow further south along the Queensland coast.







Three possible changes in the distribution of gamba grass in response to three climate change scenarios (mean temperate increases, clockwise from top left, by either 1°C, 2°C or 3°C). In all three scenarios, summer rainfall decreases by 20% and winter rainfall increases by 20% (dark red indicates areas where climate is considered highly suitable for growth of gamba grass; white indicates areas where climate is considered unsuitable for growth of gamba grass) (maps generated using CLIMEX climate-matching software).

Some studies have highlighted the role of deep-rooted, savanna grasses, such as gamba grass, in sequestering atmospheric carbon and storing it deep within the soil (as organic carbon) (Fisher *et al*. 1994; Mannetie 2007). While all vegetation stores carbon in an organic form, forests store much larger amounts per unit area of land compared to grasslands since they have greater above-ground and below-ground biomass. Hence, the replacement of forests (or woodland) with lower biomass open grassland contributes to rising atmospheric carbon dioxide levels and climate change.

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