Exotic grass invasion in the tropical savanna of northern Australia: 
ecosystem consequences

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Summary...
invaded the savanna understory of native grass and now dominates many parts of the reserve.

Five paired sites were selected at Wildman Reserve, each paired site consisted of an area of native grass savanna, and an adjacent invaded savanna dominated by gamba grass. Field sampling was undertaken during November 2002–April 2004.

**Fuel loads and fire characteristics** Fuel loads and fire characteristics were measured at Wildman Reserve in June 2001 at a site heavily infested with gamba grass and in 2003 at the five paired sites described above (native grass and gamba grass). For details of the 2001 fire see Rossiter et al. (2003).

Fuel loads were measured by sampling all the above ground biomass from three randomly placed quadrats (2 m²) within gamba grass and native grass dominated sites. The rate of spread was measured following Moore et al. (1995), Byram fire-line intensity (Byram 1959) was then calculated using the fuel load and rate of fire spread data. Average char and scorch heights were measured on the dominant eucalypt species at the sites. Both measurements are post hoc indicators of fire intensity (Williams et al. 1998). The results obtained at Wildman Reserve were compared to the data collected on fire regimes from five years of experimental fires (in native grass sites) at the Kapalga Research Station (See Williams et al. 1998).

**Soil nitrogen availability** Nitrogen (N) availability was measured in situ using mixed ion-exchange resin bags (Dowex-MR3, Sigma). Ion accumulation of resin bags depends on rates of N mineralisation, water movement in the soil and plant and microbial uptake. These are the same factors that determine N availability for plants so resin bags provide an index of uptake. These are the same factors that determine N availability in the soil and plant and microbial load (Dowex-MR3, Sigma). Ion accumulation of resin bags (in situ) using mixed ion-exchange resin bags. Five g of resin was placed into 5 × 5 cm sewn polyethylene bags (Australian filter specialists, 355 µm mesh), which were buried 5 cm below the soil surface and incubated in situ for between 7–14 days. Sampling occurred at three seasonally significant times: November 2002 (dry-wet transition), January 2003 (early wet season) and March 2003 (late wet season). After incubation, the resin was extracted with 1 mol L⁻¹ KCl, and NO₃⁻ and NH₄⁺ in the extract was analysed using an autoanalyser.

Differences in soil nitrate availability between grass types (gamba grass versus native grass) were compared using a three-way ANOVA (with factors Grass type (fixed), Time (fixed) and Sites (random)).

**Canopy water use and soil water dynamics** Patterns of leaf-scale transpiration and soil water uptake were investigated in gamba grass and native grass dominated savanna sites. To compare leaf-scale water use, diurnal patterns of transpiration were measured using a portable photosynthesis system (Li6200, Licor Inc., Lincoln, Nebraska, USA). Measurements were made on mature leaves of gamba grass and native species (Sorghum spp. and Heteropogon triticeus (R.Br) Stapf).

At a canopy scale, water use can be inferred from patterns of soil moisture dynamics. Volumetric soil water content (θv) was monitored at one of the paired gamba grass and native grass sites, on 1 or 2 hourly time scales for approximately two years (2002 to 2004) using TDR sensors (Delta-T Devices, Cambridge, UK). Sensors were installed in replicate pits at each site at depths of 5, 20, 50 and 100 cm. These data were used to calculate total soil water store (S, mm) and during periods of no drainage, changes in S equate to evapotranspiration (ET, mm). Changes in S were examined during rain-free periods at the end of the wet season of 2003 and 2004 (March to April) to calculate evapotranspiration at high canopy leaf area index (LAI). During significant rain events, deep drainage (D, mm) occurs. D was calculated for each grass type using the rapid changes in soil storage at 100 cm depth, which are associated with passing wetting fronts in the soil.

**RESULTS**

**Fuel loads and fire characteristics** In 2003, fuel loads in gamba grass sites were approximately double those in native grass (means 7.2 ± 1.2 versus 3.4 ± 0.1 t ha⁻¹; Table 1). This led to fire intensities in gamba sites more than three times those of the native grass fire intensities. Gamba grass fire behaviour in the early dry season was similar to the late dry season native grass fires at Kapalga. Fire behaviour for the native grass site at Wildman reserve was similar to that recorded at Kapalga for all fire variables measured.

**Nitrogen availability** Soil nitrate availability was significantly lower in invaded gamba grass sites than native grass sites at all three seasonal times (F₂, ₈ = 43.44, P <0.001; Figure 1). This difference between grass species was most evident at the dry-wet transition (November), with reductions of available soil nitrate in invaded sites of up to 70% (means 237 ± 49 versus 732 ± 110 ng NO₃⁻ g⁻¹ resin day⁻¹). There was a significant difference between season due to the substantial decrease in nitrate availability in the late wet season (F₁, ₄ = 87.28, P <0.001; Figure 1). There was also significant variation in nitrate availability at the scale of site (F₄, ₆₀ = 2.76, P <0.05).
Canopy water use and soil water dynamics Under moderate soil moisture conditions, typical transpiration rates were similar for both grass species (Table 2). However, wet season rates of canopy water use would be significantly higher in gamba grass sites given the larger LAI developed by gamba grass canopies when compared to native grass species. Gamba grass canopies typically obtain LAI’s of 4–5 (Rossiter 2001) compared with 1–1.5 for native grasses (Hutley et al. 2000) (Table 2). Assuming these rates of leaf transpiration, this gives a daily water use value of approximately 5.8 and 1.8 mm d⁻¹ for gamba and native grass canopies at typical wet season LAI (Table 2).

Gamba grass sites have had reduced deep drainage in all events examined to date. During February–March 2003, 269 mm of rainfall was recorded in a three-week period which resulted in 56 mm drainage from the gamba grass site compared to 138 mm from the native grass site. During March–April of 2004, 313 mm was received from this rainfall event. Drainage for this event was 71 and 89 mm for the gamba and native grass sites respectively (Table 2).

During March 2003, values of ET at the gamba stand approached 5 mm d⁻¹, although data for native grasses are not available for this period. During March–April 2004, ET for the gamba grass site was 3.1 mm d⁻¹ compared to 2.8 mm d⁻¹ for the native grass site (Table 2).

DISCUSSION

This study demonstrates that gamba grass invasion may significantly alter several key processes in savanna ecosystems.

The fire behaviour results from this study support a previous study on the impact of gamba grass invasion

<table>
<thead>
<tr>
<th>Table 1. Summary of fire behaviour of experimental fires at Wildman Reserve and Kapalga Research Station (in the early and late dry season). Rows are mean values (±SE). Table modified from Rossiter et al. (2003). The Kapalga data are based on five years of fire monitoring. Detailed results are presented in Williams et al. (1998).</th>
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<tbody>
<tr>
<td></td>
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<td></td>
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<tr>
<td><strong>Fuel (t ha⁻¹)</strong></td>
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<tr>
<td><strong>Fuel moisture (% ODW)</strong></td>
</tr>
<tr>
<td><strong>Rate of spread (m s⁻¹)</strong></td>
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<tr>
<td><strong>Fire intensity (kW m⁻¹)</strong></td>
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<td><strong>Char height (m)</strong></td>
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<td><strong>Scorch height (m)</strong></td>
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Figure 1. Soil nitrate availability as determined by in situ ion exchange resin, at three seasonally significant times: dry-wet season transition (Nov.); early wet (Jan.); and, late wet (March). Values are means (± SE).

Table 2. Wet season water use characteristics of gamba grass and native grass dominated sites. ET = evapotranspiration, D = deep drainage.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Gamba</th>
<th>Native</th>
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<tr>
<td>Leaf area index</td>
<td>4–5</td>
<td>1–1.5</td>
</tr>
<tr>
<td>Transpiration (mmol m⁻² s⁻¹)</td>
<td>5.6</td>
<td>4.6</td>
</tr>
<tr>
<td>Canopy water use (mm d⁻¹)</td>
<td>5.8</td>
<td>1.8</td>
</tr>
<tr>
<td>ET (mm d⁻¹) 2003</td>
<td>5.0</td>
<td>–</td>
</tr>
<tr>
<td>ET (mm d⁻¹) 2004</td>
<td>3.1</td>
<td>2.8</td>
</tr>
<tr>
<td>D (mm d⁻¹) 2003 event¹</td>
<td>56.4</td>
<td>138.2</td>
</tr>
<tr>
<td>D (mm d⁻¹) 2004 event²</td>
<td>71.7</td>
<td>88.8</td>
</tr>
</tbody>
</table>

¹ rainfall for this event was 269 mm.
² rainfall was 313 mm.
on fire (Rossiter et al. 2003). Invasion by gamba grass into native savanna will lead to a substantial increase in fuel loads and fire intensity. Even when not fully cured, early dry season gamba grass fires still result in intense fires.

More intense gamba grass fires are likely to lead to larger losses of N via volatilisation. This N loss is further exacerbated by the higher N concentration in gamba grass tissue, which is approximately 50% more than native grasses (Rossiter, unpublished data). This nitrogen loss may also be reflected in the differences in the amount of available soil nitrate in gamba and native grass sites (Figure 1).

Gamba grass invasion will significantly reduce the seasonal availability of nitrate in savannas. The decrease in plant available nitrate was more evident at the beginning of the wet season (the growing season), which coincides with the period of germination, establishment and vegetative re-sprouting of savanna vegetation.

These preliminary data suggest that water use of gamba grass sites is higher than that of native grass species and results in reduced deep drainage. This estimate of native grass ET is consistent with estimates of Hutley et al. (2000) for Sorghum spp. dominated understory, which gave wet season values of ET at 2.8 mm d⁻¹. In addition, transpiration of gamba grass continues until June and July, while for native species, transpiration is greatly reduced by this phase of the dry season (Rossiter 2001).

These patterns suggest that gamba grass infestation will result in increased competition for soil moisture with woody components as water use occurs at a higher rate and for longer periods of the dry season. Deep drainage is a critical reserve of moisture sustaining evergreen tree canopies during the long dry season and gamba grass may reduce the flux of moisture from the upper soil horizons at the end of the wet season further reducing deep soil moisture storage. Catchment scale gamba grass infestation could also result in reduced or the earlier cessation of stream flow.

CONCLUSIONS

This study has demonstrated that gamba grass invasion is likely to have an effect on each of the three key determinants of savanna functioning, fire regimes, nutrient availability and water availability. Gamba grass has the potential to alter not only the amount of resources available, but also the seasonal timing of these resources. These changes are likely to have serious long-term consequences for the structure and functioning of savanna ecosystems.

ACKNOWLEDGMENTS

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REFERENCES


