

Spatial prioritisation for management of gamba grass (*Andropogon gayanus*) invasions: accounting for social, economic and environmental values

Vanessa M. Adams and Samantha Setterfield

Northern Australia National Environmental Research Program Hub, Charles Darwin University,
Darwin, NT 0909, Australia
(vanessa.adams@cdu.edu.au)

Summary The social, economic and environmental impacts of invasive plants are well recognised. However, the social and economic costs of managing and eradicating invasive plants are rarely accounted for in the spatial prioritisation of funding for weed management. Gamba grass (*Andropogon gayanus* Kunth.) is one of five species of tropical invasive grasses that have been listed as a Key Threatening Process (KTP) and it requires urgent strategic management. The aim of this project is to develop a spatially explicit prioritisation framework to identify optimal budget allocations to both eradication and control measures of gamba grass to minimise the costs (including management costs as well as loss of social, cultural and environmental assets) and likelihood of reinvasion. Our framework extends recent approaches to systematic prioritisation of weed management to account for spatially variable environmental, social and cultural assets that are threatened by gamba grass including: biodiversity, areas of conservation significance and cultural sites of significance such as aboriginal sacred sites.

Keywords Gamba grass, systematic spatial prioritisation, management costs.

INTRODUCTION

The impact of invasive species on natural values can be significant however the economic costs of control or eradication of these species can be vast. Therefore, while the need to control the spread of invasive species is recognised, the financial budget to support such actions may be limited. When resources are limited, it is necessary to schedule management actions across space and time as it is not feasible to fund all required management actions immediately (Possingham *et al.* 2009). Scheduling management of invasive species requires an understanding of the spatial distribution of infestations as well as the costs and benefits of management which are spatially variable. Despite the widespread acceptance of systematic conservation approaches around the world, and the demonstrated cost-effectiveness and accountability of these methods, application to regional weed management in Australia has only just begun (Januchowski-Hartley

et al. 2011). Furthermore, the recent application of a systematic prioritisation approach to weed management by Januchowski-Hartley *et al.* (2011) was limited to a single time step, with the authors highlighting the need to extend this approach to scheduling actions across both time and space. Therefore, we adapt the approach presented by Januchowski-Hartley *et al.* (2011) to a multi-year scheduling approach. Two iterative heuristics commonly applied to scheduling problems include minimising loss (MinLoss) and maximising gain (MaxGain) with studies finding that MinLoss outperforms MaxGain for retaining conservation features when habitat loss is considered (Wilson *et al.* 2006). Future spread of invasive species can be considered to be a threatening process resulting in habitat loss and therefore a key feature of our framework is that we explore both MaxGain and MinLoss approaches to compare results when including spatially explicit spread of invasive species.

STUDY SPECIES

Gamba grass (*Andropogon gayanus* Kunth.) is a perennial C4 grass that forms large tussocks in excess of 3 m high and displaces the much shorter native vegetation (Brooks *et al.* 2010). Gamba grass is one of five species of tropical invasive grasses that have been listed as a Key Threatening Process (KTP) and has recently been listed as a Weed of National Significance (WONS). Significant ecological impacts have been associated with gamba grass invasions including increases in fire severity leading to a reduction in tree canopy and severe impacts on the understory (Rossiter *et al.* 2003, Brooks *et al.* 2010, Setterfield *et al.* 2010). Rapid spread of gamba grass has been observed from initial source paddocks in northern Australia and suggests explosive rates of spread analogous to highly invasive plants elsewhere (Petty *et al.* 2012).

STUDY REGION

Gamba grass is abundant in the Darwin rural region and is estimated to cover 1 – 1.5 million ha of the Northern Territory (NRETAS 2010) including a core infestation in Litchfield National Park. It is estimated to have the potential to invade 70% of northern Australia's

upland savanna communities (Petty *et al.* 2012). The current known extent of gamba grass infestations in the Northern Territory extends south approximately 350 km from Darwin to Katherine in the Daly River Catchment. We selected our study region to include the northern- most portion of the Daly catchment which encompasses Litchfield National Park as well as the Daly River, Nauiyu and Robin Falls areas (Figure 1). The study region covers ~1.2 million ha. Within the study region there are 7 significant stakeholders who control 99% of the land area including stakeholders such as national parks, aboriginal land trusts, pastoral properties and crown lease land. The remaining 1% of land area is held predominantly by small landholders in Robin Falls and Daly River with an average parcel size of 150 ha. The Daly catchment is approximately 5.2 million ha, extending from the coastline south-west of Darwin to 250 km inland. The Daly River and its main tributaries are themselves important conservation features, the Daly being one of northern Australia’s largest rivers with unusually consistent year-round flow. Riparian strips contain some of the most extensive

gallery (rainforest) vegetation in the Northern Territory. The catchment also contains five recognised sites of conservation significance (NRETAS 2009) and is seen as a priority for both conservation and development. While the catchment has experienced low levels of clearing (~5%), changes in fire regimes have been dramatic and increased weed infestations threaten native species. These changes, together with long-term grazing, have been implicated in the decline of the region’s mammals and granivorous birds (Franklin *et al.* 2005, Woinarski *et al.* 2010, Woinarski *et al.* 2011).

FRAMEWORK

The importance of allocating sufficient resources from start to finish of an invasive species control program has been recognised as a key feature of success. However, the costs of managing spread and the resulting damage are rarely accounted for when allocating scarce funds to management (Simberloff 2009). Januchowski-Hartley *et al.* (2011) demonstrated the financial benefits of using a spatially explicit planning framework and accounting for the

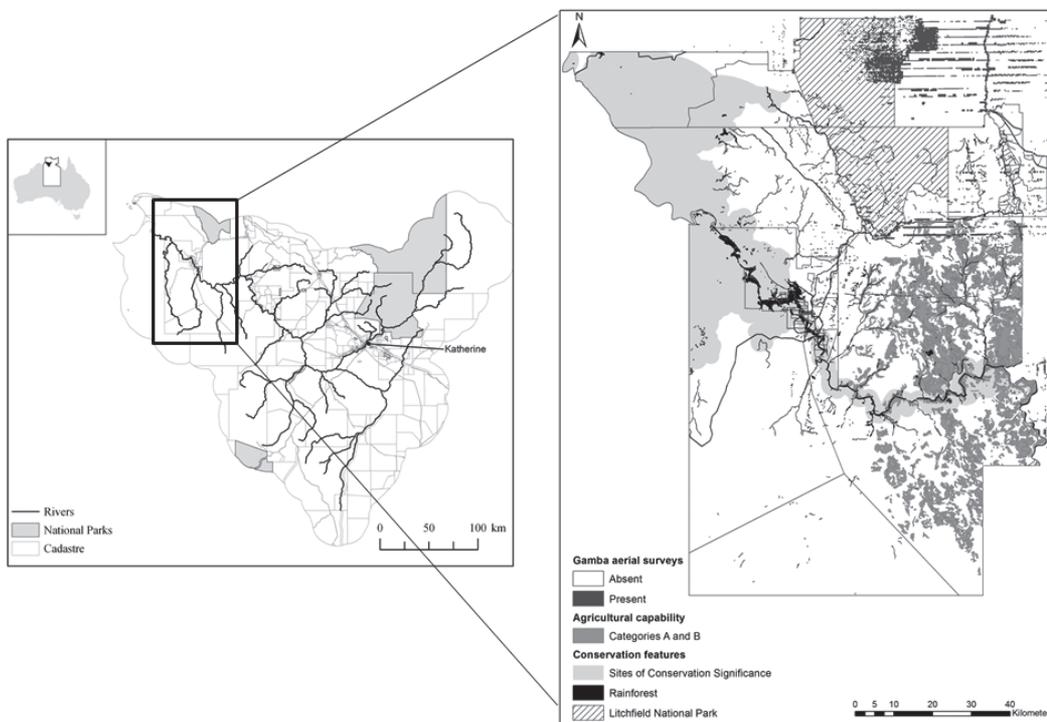


Figure 1. Study area in the northwest portion of the Daly Catchment. This site is being used for the development of a framework for systematic prioritisation of weed management. Mapped assets including areas of high agricultural capability (medium grey), rainforest vegetation (black), Litchfield national park (hatched) and sites of conservation significance (light grey) are shown as well as mapped gamba grass infestations (dark grey) from aerial surveys.

variable costs of different actions. We build upon the framework presented by Januchowski-Hartley *et al.* (2011) by extending the decision making process from a single time step to a multi-year scheduling problem. In addition, we include a spatially explicit growth model of gamba grass including spread and growth of infestations through time. Our draft decision making framework is based on the systematic conservation planning framework (Pressey and Bottrill 2009) and we build our scheduling algorithm on the widely used systematic conservation planning software Marxan (Ball *et al.* 2009). Our framework therefore extends recent approaches to systematic prioritisation of weed management (Januchowski-Hartley *et al.* 2011) to set explicit objectives for management of spatially variable environmental and cultural values currently infested as well as those values threatened by future infestation.

It has been demonstrated that high habitat loss rates can amplify the differences between good and poor approaches to scheduling management actions (Pressey *et al.* 2004; Visconti *et al.* 2010b). Based on estimated spread rates in our study region, we have high rates of habitat loss from infestation. Therefore, a minimum loss approach may provide the best scheduling management of infestations through time depending on the uncertainty levels in the spread model (Visconti *et al.* 2010a). We therefore built our framework to allow us to use both MaxGain and MinLoss approaches and compare results.

FRAMEWORK ALGORITHM AND INPUTS

Our framework relies on an explicit statement of objectives which are summarised in a quantitative objective function to be optimised against a given budget. The required inputs for our framework include the current distribution and density of an invasive species, a spatially explicit spread model, growth rates for infestation density, mapped assets threatened by invasion (in our case environmental and cultural values) and costs of management actions.

We select infestations to manage annually based on an algorithm which will maximise the objective function (we compare both MinLoss and MaxGain objective functions) given an annual budget constraint. The framework then recalculates the distribution and density of gamba grass given management allocations which decrease density and prevent future spread while un-managed sites increase in density and spread to un-infested sites. The algorithm steps are as follows:

1. Define explicit objectives. For example, a MinLoss objective function would be based on a verbal statement such as minimise future loss of environmental assets due to infestation.

2. Define the management actions and respective costs and benefits of these actions.
3. For each spatial feature in the study region calculate the benefits and costs of management.
4. Set an annual budget.
5. Allocate the budget to a set of infestations based on the objective function.
6. Update the state of the study region based on the biophysical growth model, i.e. infestation of new sites occurs through spread and growth occurs within current infestations.

These steps are followed for each annual time step. Summary statistics are calculated at the end of the time period including number of features infested and number of avoided infestations (compared to a baseline of no management).

FUTURE APPLICATION OF FRAMEWORK

We are currently developing and testing the framework algorithm in our study region. Future steps include discussing outputs from our scheduling framework with stakeholders to examine the priorities identified at a local to regional level and to discuss implications for funding as well as how to schedule on-ground action where funding is limited. Emerging trends from our study region include the importance of controlling along property boundaries to reduce infestation into neighbouring properties, putting in place containment borders to reduce expansive spread and loss of assets, and considering when to switch between eradication and control activities.

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