RPAS PLANNING AND MANAGEMENT FOR GAMBA GRASS FIRE REGIMES

I. Introduction: Gamba Grass and Fire Regimes in Australia

In the context of fire regimes in Australia, Gamba grass (Andropogon gayanus) has emerged as a significant ecological and environmental concern. This invasive grass species, originally hailing from Africa but introduced to Australia, has found a welcoming home in the northern regions of the country, notably the Northern Territory and Queensland. While Gamba grass can be a valuable source of cattle feed within well-managed, fenced paddocks, it becomes a substantial threat 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 outcompete and replace native grasses, leading to a reduction in natural biodiversity. Furthermore, its high biomass makes it highly flammable, thus fuelling intense bushfires that pose a significant risk to the Australian landscape. Each dry season in the Northern Territory, high-intensity Gamba grassfires jeopardize human safety and property, making it a critical concern for the region (Csurhes, S., & Hannan-Jones, M. (2008)).

Gamba grass, with its propensity for forming dense, continuous fuel loads, contributes to the escalation of fire events. These fires not only threaten biodiversity but also endanger human communities, infrastructure, and the overall health of ecosystems. In this context, the management of Gamba grass, as well as its detection and mapping, plays a crucial role in mitigating the risk of bushfires and safeguarding the unique Australian landscape.

Figure 1 shows three maps indicating the possible changes in the distribution of Gamba grass in response to three different climate change scenarios. The mean temperature increases in each scenario, from top left to bottom right, by either 1°C, 2°C or 3°C. In all three scenarios, there is a 20% decrease in summer rainfall and a 20% increase in winter rainfall. The dark red areas on the maps indicate where the climate is highly suitable for the growth of gamba grass, while the white areas indicate where the climate is unsuitable for its growth.

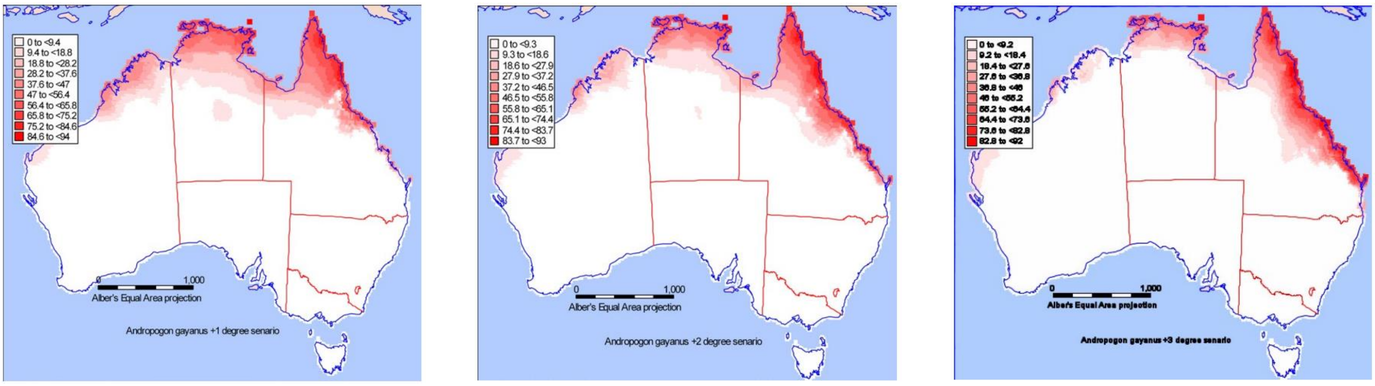

Figure 1. Potential changes in the distribution of gamba grass under different climate change scenarios
Source Csurhes, S., & Hannan-Jones, M. (2008).

II. Pre-Burn Planning with RPAS

RPAS FOR GAMBA GRASS DETECTION AND MAPPING IN PRE-BURN PLANNING

In the realm of pre-burn planning, RPAS have demonstrated their utility as invaluable tools for detecting and mapping Gamba grass infestations. These maps aid in prioritizing burn areas, optimizing resource allocation, and enhancing overall fire management strategies. Gamba grass's role in promoting more intense bushfires emphasizes the importance of early detection and mapping to inform effective control and mitigation efforts.

The methods derived from Russell-Smith et al. (2009) and Yates et al. (2015) for assessment plots provide crucial information for understanding the fire dynamics in a particular region and for developing effective fire management strategies. Here are some key points:

Fuel Age Distribution: The assessment plots in the study were established based on Landsat-derived time-since-fire mapping. This information can be critical for pre-burn planning because it helps identify areas with different fuel age conditions. Knowing the fuel age distribution can assist in prioritizing areas for controlled burns, as older fuels are often more flammable and pose a higher fire risk.

1. *Vegetation Structural Properties:* The data collected on vegetation structural properties, including grass cover, shrub/tree densities, and tree canopy cover, are essential for understanding the fuel load and vegetation structure in the landscape.

RPAS can be used to monitor these properties and detect changes over time. For example, RPAS can provide up-to-date information on grass cover and shrub densities, which can be used to assess fuel loads and assess the potential fire risk.

2. *Fuel Components:* The data also includes information on various fuel components, such as grass, leaf litter, coarse woody debris, and heavy woody fuels. Accurate knowledge of the composition and quantity of these fuel components is crucial for pre-burn planning. RPAS can help in mapping and monitoring the distribution and amount of these fuel components, aiding in identifying high-risk areas that require fire management interventions.

3. *Shrub Biomass:* The data provides detailed information on shrub biomass, categorized by height classes and form classes. RPAS can be used to monitor changes in shrub biomass and assess the impact of different management strategies on shrub populations. Understanding the biomass of different shrub species can inform decisions about controlled burns and fuel reduction efforts.

4. *Early Detection and Mapping of Gamba Grass:* In the context of pre-burn planning, the data described above can be valuable for detecting and mapping invasive species like Gamba grass. RPAS can be employed to detect and monitor the spread of Gamba grass infestations in areas with specific fuel characteristics or vegetation structures that Favor its growth. This early detection can aid in prioritizing control efforts to mitigate the risk of intense bushfires, as Gamba grass is known to contribute to more severe fires.

5. *Optimizing Resource Allocation:* By combining the data on fuel characteristics and vegetation structure with RPAS-based mapping of Gamba grass, fire management authorities can optimize resource allocation for controlled burns. Areas with high fuel loads and invasive species infestations can be prioritized for mitigation efforts.

THE ROLE OF SENSOR TECHNOLOGIES IN GAMBA GRASS DETECTION

The accuracy of Gamba grass detection greatly depends on the type of sensor technology used. Multispectral and hyperspectral sensors have been found to be more effective as they can detect the spectral signatures of Gamba grass. RPAS equipped with LiDAR technology have made it possible to create 3D models that provide information about the height and density of the grass. Thermal cameras are also promising tools for identifying Gamba grass patches based on their temperature profiles. These technologies provide crucial data for planning controlled burns and determining which areas need to be prioritized.

MACHINE LEARNING AND GROUND TRUTH DATA FOR ENHANCED ACCURACY

The integration of ground truth data and machine learning algorithms has indeed proven to be a significant advancement in the accuracy of Gamba grass detection models. In the work of Rist et al. (2019), a ResNet-based U-Net model was utilized to map the presence of gamba grass in satellite images, highlighting the potential of machine learning techniques in this domain. Furthermore, Ramirez et al. (2020) conducted research that compared the performance of various models, including DeepLab-v3, SegNet, and U-Net, and found that DeepLab-v3 achieved superior classification accuracy when using class balanced data with greater spatial context. This synergy between remote sensing technologies like RPAS (Remote Piloted Aircraft Systems) and advanced data processing techniques, as highlighted by these studies, holds the promise of enhancing the reliability of Gamba grass detection and mapping during pre-burn planning. This can significantly contribute to more effective fire management by providing more accurate information about the presence and distribution of Gamba grass, thereby aiding in fire prevention and control efforts.

III. Burn-Time Monitoring with RPAS: Leveraging Real-Time Data for Informed Decision-Making During Controlled Burns

Controlled burns are essential for managing the spread of Gamba grass and reducing the risk of uncontrolled bushfires. Real-time monitoring with Remotely Piloted Aircraft Systems (RPAS) plays a crucial role in enhancing the effectiveness of controlled burns by providing valuable data for informed decision-making. This adaptive approach not only ensures the targeted destruction of Gamba grass but also minimizes collateral damage to the environment. In this section, we discuss how RPAS can be used to monitor controlled burns in real-time and the challenges associated with their operation in varying environmental conditions.

REAL-TIME DATA FOR INFORMED DECISION-MAKING:

In the realm of fire management and controlled burns, the utilization of real-time data is paramount for making informed decisions and ensuring the safety of both the environment and the firefighting teams involved. Just as Valencia et al. (2023) demonstrated the significance of specific assessment methods for fire dynamics, the integration of cutting-edge technology such as UAV-based Lidar and real-time monitoring offers invaluable insights into fuel load, fire propagation, fire front movement, Fireline intensity, and flame height. These data-driven insights empower fire management teams to adapt their strategies dynamically, making crucial decisions regarding ignition, tracking fire progression, and assessing fire behaviour during controlled burns. The following points elucidate the implications and importance of such real-time data for effective fire management strategies.

- *Fuel Load and Fire Propagation:* The data acquired before the burn using UAV-based Lidar provides a detailed map of the fuel load in the experimental plot. The fuel structure is heterogeneous, with varying fuel loads across the area. This data is crucial for fire management teams to understand the fuel distribution and make informed decisions about ignition strategies and fire behaviour prediction.
- *Fire Front Monitoring:* The real-time location of the fire front over time, allows fire management teams to track the progression of the fire. The ignition strategy, involving both line-fire ignition and lateral ignitions, is designed to explore spatiotemporal changes in fire behaviour. This information helps in adapting firefighting tactics as the fire progresses.
- *Fireline Intensity Analysis:* The map of Fireline intensity will provide a significant variability within the burn plot. This variability is crucial for understanding the dynamic nature of the fire and its potential impact on firefighting strategies. Fireline intensity is strongly influenced by factors such as fuel load and rate of spread (ROS).
- *Flame Height Analysis:* Flame height data is obtained from in-fire poles and a model that considers variables like fuel load and ROS. The model is found to capture significant variabilities in flame height across the experimental plot. Understanding

flame height is critical for assessing fire behaviour and its potential impact on the environment.

IMPLICATIONS FOR FIRE MANAGEMENT:

The use of RPAS for real-time monitoring during controlled burns provides critical data that allows fire management teams to adapt their strategies as needed. This includes making decisions on ignition techniques, tracking the fire's progression, and assessing the intensity and behaviour of the fire. The variability in Fireline intensity and flame height emphasizes the dynamic nature of controlled burns, requiring constant monitoring and adaptability.

IV. Post-Burn Assessment with RPAS

In the realm of ecosystem restoration, a wide array of strategies is employed, ranging from natural recovery processes to active interventions like controlled burns. Choosing an appropriate strategy is contingent upon several factors, encompassing the local restoration context, potential obstacles, and desired outcomes (FAO and WRI, 2019; Holl and Aide, 2011). Restoration objectives can span from reinstating the original ecosystem structure and species composition to enhancing ecosystem services and socio-economic purposes (Holl, 2012; FAO, n.d.-a).

In the aftermath of controlled burns, Remotely Piloted Aircraft Systems (RPAS) continue to play a pivotal role in post-burn assessment. The data collected through RPAS are invaluable in assisting land managers in making informed decisions about the efficacy of the burn operation and the need for further interventions. This post-burn evaluation is vital to ensure that fire management strategies effectively address the threat posed by Gamba grass and reduce the risk of bushfires.

The persistence of Gamba grass post-burn is a critical aspect that warrants long-term monitoring studies. RPAS, with their ability to efficiently cover large areas, are exceptionally well-suited for conducting these longitudinal studies. This approach allows for a comprehensive and systematic assessment of Gamba grass management strategies over time, shedding light on the effectiveness of controlled burns in mitigating Gamba grass invasions and their impact on local fire regimes.