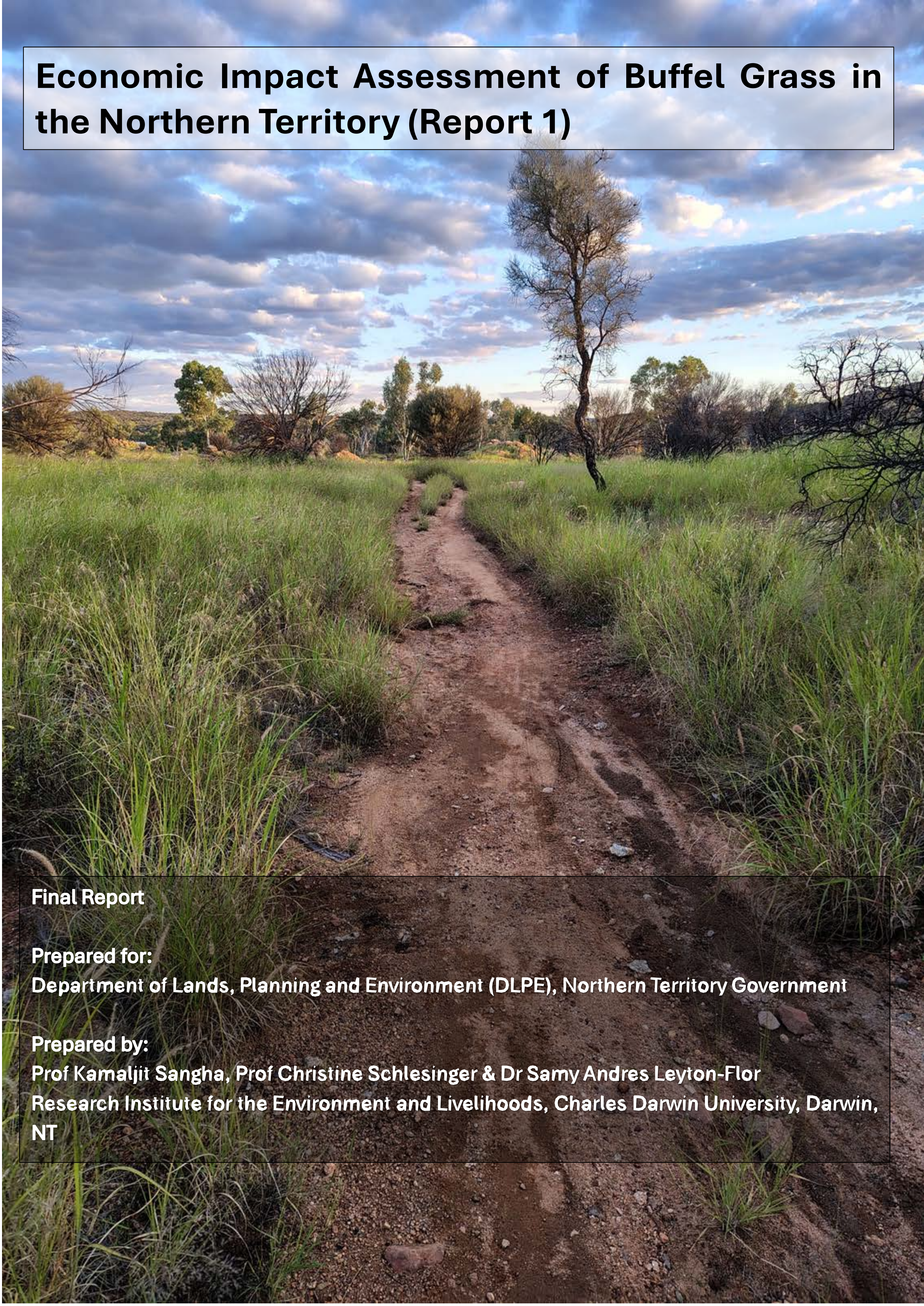
Economic Impact Assessment of Buffel Grass in the Northern Territory (Report 1)



Final Report

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Department of Lands, Planning and Environment (DLPE), Northern Territory Government

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List of Abbreviations

ARC – Annual Restoration Cost
BCC – Buffel Control Cost
BVT – Basic Value Transfer
CBA – Cost–Benefit Analysis
CRC – Cultural Restoration Cost
CV – Contingent Valuation (non-market valuation method)
DCF – Discounted Cash Flow
FMC – Fire Mitigation Cost
GRASP – Grassland Production Simulation Model (used in NT pasture modelling)
MPC – Monitoring and Prevention Cost
NPV – Net Present Value
NT – Northern Territory
SA – Sensitivity Analysis
TEV – Total Economic Value
WTP – Willingness to Pay

1 Executive summary

This report provides an integrated economic impact assessment of buffel grass (*Cenchrus ciliaris* and *C. pennisetiformis*) in the Northern Territory (NT), with a particular focus on central Australia. Buffel grass has historically delivered substantial tangible benefits to the pastoral sector by improving forage availability, carrying capacity, drought resilience and, in some disturbed settings, erosion control. However, buffel grass has also become a major invasive transformer species, now associated with intensified fire regimes, biodiversity loss, cultural-site degradation, scenic amenity decline, increased public management costs, along with growing burden on Indigenous communities, conservation agencies, tourism operators, local government and fire-management services. The NT declared buffel grass a weed in July 2024 under the *Weeds Management Act 2001* (DLPE, 2026, p. 5), and this assessment is directly relevant to implementing the Buffel Grass Weed Management Plan and to future decisions about containment, exemptions, permitted uses, and the protection of high-value areas.

The central policy question addressed by this report is not whether existing buffel pastures have value to pastoral enterprises as they do, but whether allowing further spread or deliberate establishment of buffel grass creates net economic benefits for the NT once broader public, ecological, cultural and economic costs are factored. To answer this question, the assessment uses an incremental Net Present Value framework. This means the analysis focuses on the marginal consequences of an additional 1,000 hectares of buffel grass expansion beyond its current distribution, rather than valuing all existing buffel grass across the NT. This is an important distinction for policymakers to focus on how to manage buffel grass spread from causing further degradation. Our analysis does not deny the historical value of buffel grass to pastoral production, but it tests whether further expansion is economically justified from a whole-of-society perspective or not, giving a holistic picture including various stakeholders' perspectives.

Incremental buffel grass expansion is expected to result in large net economic losses for the NT, with costs approximately sixty times greater than benefits. The benefits of forage provision and erosion-control are estimated at just AU$112.3/ha/year, whereas the corresponding per-hectare external costs are at AU$6,328/ha/year, driven predominantly by biodiversity loss, cultural-site degradation, fire-regime intensification, buffel grass management burdens, and scenic amenity decline. Thereby, each additional hectare of buffel grass-dominated landscape imposes close to AU$6,216/ha/year in external costs. These findings are consistent across all scenarios, time horizons, and discount rates.

A critical distributional finding underlying these estimates is that pastoral benefits accrue almost entirely to private operators, while fire, biodiversity, cultural, and scenic amenity costs are borne predominantly by public agencies, Traditional Owners, conservation bodies, and the broader community. Together, these findings constitute a market failure that provides a direct economic justification for the 2024 weed declaration and for the effective implementation of the *Buffel Grass Weed Management Plan 2026–2036*. The AU$80/ha/yr forage benefit reflects only the marginal gross margin from new buffel grass establishment; it does not represent the total enterprise-scale value of existing buffel pastures, which is tangible, market value, but involves significant environmental externalities. The direct market value of buffel grass is embedded in current enterprise structures and independent of any externalities and/or losses associated with future buffel grass spread.

We conducted both quantitative and qualitative analyses (Part 1 and Part 2, respectively) of various buffel grass-related benefits and costs. The qualitative analysis strongly reinforces the quantitative findings by showing that the costs of buffel grass are already being experienced across multiple sectors and communities in central Australia. Survey and interview participants consistently identified fire regime intensification, biodiversity loss, cultural site degradation, and declining scenic and visitor values as the most significant impacts, and expressed widespread dissatisfaction with the current management approach. The qualitative data also demonstrates that these impacts are not only ecological and economic, but also social and cultural, as respondents described restricted access to Country, reduced availability of bush foods, health effects from smoke and pollens, and increased operational burdens for community and government organisations and land managers. While pastoral participants confirmed that buffel grass improves carrying capacity and drought resilience in their context. The overall pattern of evidence supports the report's conclusion that the broader public, cultural, and environmental costs of further buffel grass expansion far outweigh its private production benefits.

Several limitations of this report must be acknowledged. In the absence of NT-specific primary data on buffel grass spread and extent in central Australia, we relied on area-based estimation, using per-hectare as the unit, to apply conservative values from benefit-transfer methods or proxy valuations. Fire cost parameters are adapted from gamba grass studies in NT savannas, with contextual adjustments to account for the substantially lower fuel loads and different fire return intervals characteristic of arid zone systems. Cultural site costs are based on a single representative riparian site type. The absence of a comprehensive spatial distribution map of buffel grass across the NT prevents the disaggregation of costs and benefits by land type.

Due to time limitations of this report, our consultation approach relied heavily on online surveys, which constrained engagement with remote Indigenous community members, particularly those with barriers to internet access, English literacy, or awareness of survey processes. While the survey approach was adopted under the given circumstances, this limitation is significant, as the Indigenous group often experiences some of the most severe impacts of buffel grass. To partially address this, we supplemented the online surveys with six semi-structured expert interviews selected to capture perspectives closely connected to Country, land management, and community well-being. While this expert-led approach does not substitute for community-wide, on-Country engagement, it provided some critical qualitative insights grounded in Indigenous land management practice and culturally informed perspectives, and strengthened the interpretation of impacts where direct participation from remote communities was not feasible within the project timeframe.

An important consideration for decision makers is that the benefits from buffel grass in the pastoral sector are largely private, while the costs are predominantly borne by society, including tourists, local residents, Traditional Owners, government agencies responsible for the management of public lands, including fire and the wider Australian public through the loss of biodiversity and the costs of remediation.

In conclusion, the report finds that further buffel grass expansion would impose high, persistent, and partly irreversible costs on the NT. While existing buffel grass pastures remain economically important to parts of the pastoral sector, the marginal benefits of additional spread are very small relative to the public costs. This economic assessment suggests that prevention, containment and targeted control are economically justified and should be prioritised over reactive management. Strategic investment, particularly in high-value cultural and biodiversity areas, fire-risk zones, transport corridors, town boundaries and buffel grass-free or low-density landscapes, can avoid much higher future costs and better protect Country, biodiversity, community safety, tourism values and public finances. For that, we emphasise that there is a need to look for a range of cost-effective, sustainable, long-term solutions, collectively, that will help address the problems associated with buffel grass spread, and it is not an easy task. Addressing such a problem requires collective action from all stakeholders so as to deliver sustainable landscape management across NT.

2 Introduction

Buffel grass (*Cenchrus ciliaris* and *C. pennisetiformis*) is one of the most influential plant introductions in Australia's arid and semi-arid landscapes. Widely promoted for its drought tolerance and soil-stabilising properties, buffel grass has become a cornerstone of pastoral production, significantly increasing carrying capacity and reducing erosion risks in rangelands (Friedel et al., 2006). Today, it underpins livestock enterprises across large areas of the southern Northern Territory (NT), delivering substantial economic benefits through improved forage reliability and resilience to climatic variability (Bowen & Chudleigh, 2018). However, these advantages have come at considerable cost. Buffel grass is now recognised nationally as a transformer species that alters fire regimes, displaces native biodiversity, and threatens cultural heritage sites (Australian Government, 2015) and by the Commonwealth's Threatened Species Commission as a novel biota and a key threatening process, presenting a major threat to biodiversity in Central Australia. In the NT, buffel grass has been assessed as a *very high weed risk* (the highest category) based on its invasiveness, impact and potential distribution (NTG, 2022), a ranking that remains unchanged from when the initial assessment was undertaken in 2010 (NTG, 2022). Recognising the extent of ecological and social costs and the detrimental economic impacts outside the pastoral estate, buffel grass was declared a weed in the NT in July 2024 under the *Weeds Management Act 2001*, requiring landholders to prevent its spread and comply with statutory management plans (DLPE, 2026, p. 5). The NT Buffel Grass Weed Management Plan (WMP) requires clear decisions about zoning, including identifying exclusion areas for high-value ecological and cultural assets and defining management zones where control, containment, or prevention measures differ across land tenures. These zoning decisions are considered essential for implementing the 2024 weed declaration and ensuring that regulatory settings align with the diverse ecological, cultural, and economic impacts outlined in the assessment (DLPE, 2026). Buffel grass has been listed as a Key Threatening Process under national legislation and was nominated as a Weed of National Significance in early 2025 (decision pending) due to its severe impacts on biodiversity and cultural sites, increased fire risk, and its declaration as a weed in South Australia in 2015. Despite this, economic analyses remain fragmented and are heavily skewed toward assessing pastoral benefits (Bowen & Chudleigh, 2019). Few studies have quantified non-market costs of losses related to buffel grass, such as cultural impacts or tourism losses, and fire-related infrastructure risks, which are rarely incorporated into cost-benefit frameworks (Australian Government, 2015; Cook & Grice, 2013). Moreover, existing evaluations often overlook long-term management scenarios and cross-sectoral trade-offs, thereby limiting their utility for policy decision-making and management programs. This gap constrains decision-makers' ability to weigh buffel grass's dual role as both an economic asset and an ecological and economic liability outside the pastoral estate.

Buffel grass has reshaped large parts of arid and semi-arid Australia, including large areas of the southern NT, creating a policy dilemma. This report provides the first integrated economic assessment of buffel grass impacts in the NT, evaluating benefits and costs to the pastoral sector, the environmental/conservation sector, cultural heritage, tourism, fire management, and infrastructure. By combining market valuation with non-market approaches, the study captures not only the direct financial benefits to pastoralists but also the broader societal costs associated with biodiversity loss, cultural site degradation, and increased wildfire risk (Bonney et al., 2017; Read et al., 2020; Schlesinger & Westerhuis, 2021). We trust that this analysis will inform policy decision-makers on strategic resource allocation under the Buffel Grass Management Strategy 2024–2030 and will support evidence-based decisions for government, industry, and community stakeholders.

In the NT, a key question for policy decision-makers is whether further expansion, through deliberate seeding or unmanaged spread, should be allowed in pursuit of pastoral gains, despite mounting ecological, cultural, and cross-sector costs? This report addresses that question using an Incremental Net Present Value (NPV) framework that isolates the marginal benefits and costs of spreading buffel grass beyond its current distribution. Specifically, we standardise per-hectare annual flows (benefits and costs), then project them over realistic time horizons and discount rates to assess whether incremental benefits exceed incremental social-environmental costs under a range of scenarios.

The analysis integrates: (i) standardised per-hectare values for forage/erosion benefits and for biodiversity, cultural, fire-related, scenic, and management costs; (ii) multi-parameter scenario testing (central, optimistic, pessimistic, and cultural-valuation variants); and (iii) one-way sensitivity analysis to identify the parameters that most strongly influence economic outcomes. A live tornado chart and scenario visualisations are provided to support transparent, decision-ready interpretation of uncertainty and risk. Collectively, these methods allow NT policy decision-makers to evaluate the marginal value of further buffel grass expansion with clarity about associated losses and benefits, and to prioritise prevention, containment, and investment where the net public return is strongest.

3 Methods

3.1 Study design and analysis framework

This study adopts a sequential explanatory mixed-methods design to quantify and explain the economic impacts of buffel grass in the NT. Quantitative analyses estimate the magnitude of market and non-market impacts, while qualitative inquiry, via literature review, semi-structured interviews and a multi-stakeholder workshop, explains mechanisms, contextualises trade-offs, and validates model assumptions (Braun & Clarke, 2008; Creswell & Poth, 2016). The economic evaluation follows the Total Economic Value (TEV) framework, integrating market values (e.g., pastoral production benefits, management and fire costs) with non-market values (e.g., biodiversity, cultural heritage, and scenic amenity) to derive social net losses across management scenarios (Costanza et al., 1997b; Costanza et al., 2014).

Ecological change is represented using a state-and-transition logic that captures pathways from native vegetation to buffel grass-dominated states, along with associated feedbacks (fuel accumulation, competition for water, or disturbance of soil processes). Economic valuation is then overlaid to estimate changes in net social well-being, the aggregate gains and losses accruing to all affected sectors, under different management regimes (Friedel et al., 2011; Grechi et al., 2014; Grice et al., 2012).

Despite the comprehensive mixed-methods approach, several data constraints limit the precision of the economic estimates. Major gaps exist in quantifying impacts on non-pastoral industries, particularly tourism, Indigenous cultural heritage, and infrastructure, where impacts have been identified as potentially high but robust economic data remain limited or absent. These data deficiencies include the lack of long-term fire-cost records specific to buffel grass-affected arid regions, incomplete valuation studies for cultural sites, and limited empirical measurements of tourism losses associated with scenic degradation and access disruptions. As a result, several parameters in the TEV framework rely on conservative assumptions, benefit-transfer methods, or proxy valuation approaches, and the analysis explicitly acknowledges these constraints in interpreting model outputs. Another limitation is the lack of spatial information on the spread of buffel grass in the NT. However, our qualitative evaluation using surveys and semi-structured interviews offers insights into various impacts of buffel grass across different sectors and provides authentic supporting evidence for our quantitative analysis.

3.2 Literature review approach

The literature review combines a systematic search with targeted harvesting of grey literature. Databases searched included Scopus, Web of Science, and Google Scholar, complemented by the publicly available resources from the NT Government repositories and agency reports (e.g., Weed Management Branch, Bushfires NT, Tourism NT). Search strings combined terms for species and domains (e.g., “buffel grass” OR Cenchrus ciliaris AND “economic” OR “cost” OR “benefit” OR “biodiversity” OR “fire” OR “tourism” OR “cultural”). Inclusion criteria prioritised empirical or modelling studies relevant to arid/semi-arid Australia; exclusion criteria removed non-relevant species, non-empirical commentary, and studies lacking transferable parameters. Reference screening occurred at the title/abstract and full-text stages. The review outputs informed parameter ranges, transfer values, and scenario design (following Whitehead et al., 2015).

3.3 Stakeholder consultation strategy

Stakeholder consultation formed an important component of this economic impact assessment. We tried to capture on-ground experiences, Indigenous knowledge values, operational realities, and cross-sectoral trade-offs associated with buffel grass. The consultation framework followed established principles of participatory environmental management and mixed-methods inquiry, which emphasise inclusiveness, transparency, and triangulation across stakeholder types (Reed, 2008). The purpose of our consultation process, mainly through online questionnaire surveys and grey literature review, was fivefold:

- Validate ecological and economic assumptions drawn from the literature.
- Identify localised, experiential knowledge not captured in scientific or government reports.
- Quantify property-level impacts where possible, including direct expenditures, losses, and risk perceptions.
- Document cultural, social, and non-market values associated with Country, biodiversity, and landscape amenity.
- Ensure Indigenous cultural values and concerns were meaningfully incorporated into the study design.

3.3.1 Stakeholder categories and sampling approach

A purposive sampling strategy was employed (Guest et al., 2013; Mack et al., 2005) to capture a diverse range of perspectives across sectors affected by buffel grass, including pastoral production, conservation, Indigenous land management, tourism, fire management, infrastructure, local government, and other relevant government agencies.

The survey was distributed widely and received responses from individuals representing or affiliated with a range of agencies, organisations, and stakeholder groups, including government agencies, local government, conservation and Landcare organisations, Indigenous organisations and ranger groups, tourism operators, pastoralists, environmental organisations, and residents. These survey responses therefore reflect a cross-section of organisational and community perspectives, but respondents should not necessarily be interpreted as official spokespersons for their agencies unless explicitly stated.

By contrast, the semi-structured interviews were conducted with selected individuals for their specialist knowledge, lived experience, or direct operational involvement in buffel grass management. These interview participants were not interviewed as formal representatives of their agencies or organisations. Rather, they contributed expert, professional, or experiential perspectives to help interpret the quantitative findings, validate assumptions, and identify impact pathways not captured in published data or the survey instrument.

Participants were drawn from the following broad stakeholder categories:

- Pastoral industry: pastoralists, NT Cattlemen's Association representatives, and NT Farmers Association members.
- Conservation practitioners: government park managers, conservation NGOs, and ranger groups.
- Indigenous landholders and Traditional Owners: including Indigenous Rangers and cultural advisors from the southern parts of the NT.
- Tourism sector: tour operators, regional tourism organisations, and protected-area visitor managers.
- Fire management agencies: Bushfires NT, Fire and Rescue NT, volunteer brigades, and specialist fire-behaviour experts.
- Local government: representatives from Alice Springs Town Council and MacDonnell Regional Council.
- Government agencies: Northern Territory agencies, including the Weed Management Branch, Parks and Wildlife, and the Department of Agriculture and Fisheries (DAF), as well as relevant Commonwealth agencies where appropriate, such as Parks Australia / Uluṟu-Kata Tjuṯa National Park staff.

Given the project's mandate, this broad cross-section was required because buffel grass generates sector-specific benefits and costs, and the economic assessment must reflect the distribution of these impacts across society. Consultation with a few Indigenous rangers/experts was prioritised due to identified severe impacts on cultural sites, culturally important plant and animal species, and access to Country (Batty & Walsh, 2012; Caron et al., 2021; Kulitja, 2024; Read et al., 2020), consistent with best-practice principles for ethical Indigenous research engagement as set out in the AIATSIS Code of Ethics for Aboriginal and Torres Strait Islander Research (AIATSIS, 2020).

3.3.2 Engagement phase

An initial Engagement Phase was undertaken between October and November 2025 to understand the project scope, clarify data needs, and gather preliminary insights into the perceived impacts of buffel grass across pastoral, environmental, cultural, and tourism sectors. This phase preceded the formal questionnaire survey described later, which served as a critical foundation for refining research questions, economic assumptions, and the overall analytical framework.

The engagement process began with the Buffel Grass WAC Workshop in October 2025, convened to discuss the Scope of Requirements for the Buffel Grass Economic Impact Assessment. This workshop provided the authors with a platform to understand the project objectives and to discuss methodological approaches with representatives from government, pastoral industry bodies, conservation organisations, and Indigenous stakeholder groups. While the purpose of this workshop was not to collect formal data, it enabled the research team to map out key domains of impact, identify data gaps, and determine the most appropriate consultation pathways for different stakeholder groups.

Following the workshop, a series of in-person meetings was held on 22 October 2025 with representatives from the NT Department of Agriculture and Fisheries (DAF), the Arid Lands Environment Centre (ALEC), and plant ecologist Margaret Friedel, who has previously published on the costs and benefits of buffel grass. These meetings provided early understanding of the ecological mechanisms, management cost structures, and cross-sectoral trade-offs that would later underpin model parameterisation.

Subsequently, online meetings were conducted on 10 and 13 November 2025 with staff from the Department of Climate Change, Energy, the Environment and Water, Desert Knowledge Australia (DKA), and one pastoral company. These early discussions offered perspectives from conservation managers, regional organisations, and pastoral industry representatives, enabling the team to refine assumptions about the benefits of pastoral productivity, biodiversity and cultural losses, and fire-management challenges associated with buffel grass.

Collectively, this engagement phase served three methodological functions:

1. Scoping and refinement: clarifying domains of impact and the appropriate valuation approaches for each.
2. Identification of local data sources, such as fire-response budgets, control-cost records, and cultural-site management plans.
3. Contextual validation: ensuring that the subsequent stakeholder consultation strategy was culturally appropriate, sector-relevant, and aligned with the lived experience of land managers and Traditional Owners.

These preliminary engagements informed us to cover diverse aspects in relation to buffel grass in the NT.

3.3.3 Consultation methods

Prior to data collection, an ethics permit was obtained from the Charles Darwin University Human Research Ethics Committee to ensure compliance with their procedures (H25132). The semi-structured interviews and survey were conducted online due to the limited time.

3.3.3.1 Semi-structured online interviews

Buffel grass presents a particularly complex research context because its economic effects are distributed across multiple sectors: pastoral, conservation, tourism, fire/land management, and Indigenous sectors, and the impacts vary substantially depending on land tenure, ecological condition, geographic location, and the values of those affected. Quantitative modelling, while essential for generating the standardised per-hectare estimates and scenario projections that underpin this assessment, cannot capture this heterogeneity without local calibration. Semi-structured interviews provided the mechanism for that calibration by enabling participants to articulate their direct experience in their own terms, identify cost and impact dimensions not represented in the published literature, and challenge or confirm the assumptions embedded in the quantitative model.

Six online semi-structured interviews (60–90 minutes) were conducted with key stakeholders from some sectors listed earlier, identified through snowball sampling (Denzin & Lincoln, 2018). These stakeholders were selected for their extensive knowledge and experience with buffel grass in the Alice Springs region.

We developed and refined two semi-structured discussion guides (Appendices A and C), one for non-Indigenous participants and the other for Indigenous participants, by adapting the five-phase framework proposed by Kallio et al. (2016) to ensure methodological rigour, internal consistency, and alignment with the project's mixed-methods design. In the context of this economic impact assessment, the five phases were operationalised as follows: (1) confirm the suitability of the semi-structured format; (2) development of preliminary interview content informed by literature and early engagement; (3) critical review of the question set for coherence, clarity, and relevance; (4) pilot testing and refinement; (5) finalisation of the semi-structured guide for systematic use (for details, see appendices).

Indigenous consultation was conducted in accordance with the AIATSIS Code of Ethics for Aboriginal and Torres Strait Islander Research (2020), which establishes principles of respect, reciprocity, equality, responsibility, survival, protection, and spirit and integrity. This consultation focused on the impacts of buffel grass on Country, culture, sacred sites, bushfoods, medicines and fire.

3.3.4 Online survey

The study employed an online survey design to systematically collect both quantitative and qualitative data about community and stakeholder perceptions of buffel grass in Central Australia.

The survey questionnaire (Appendix B) was structured using a combination of closed-ended and open-ended items, in line with best-practice guidance in survey research, according to Denzin and Lincoln (2018). Closed-ended questions, including multiple-choice, Likert scale, ranking, and rating items, support efficient quantification of perceptions, attitudes, and experiences, and are standard in descriptive and analytical survey designs aimed at understanding participant views and identifying relationships between variables. Open-ended questions were included to capture richer qualitative insights into respondents' lived experiences, trade-off views, and reflections on the impacts of buffel grass.

For this study, anonymity was emphasised in the survey introduction, aligning with ethical research requirements and encouraging candid responses from diverse groups, including Indigenous respondents, pastoralists, land managers, environmentalists, tourist operators and general community members.

3.4 Economic impact assessment framework (Part 1)

We applied market and non-market methods (Appendix D) to estimate positive and negative impacts of buffel grass on pastoral production, environmental values, cultural values, tourism and recreation, and fire management, including both roadside-corridor fire-prevention activities and broader landscape-scale suppression and asset-protection costs, as well as infrastructure management (Figure 1).

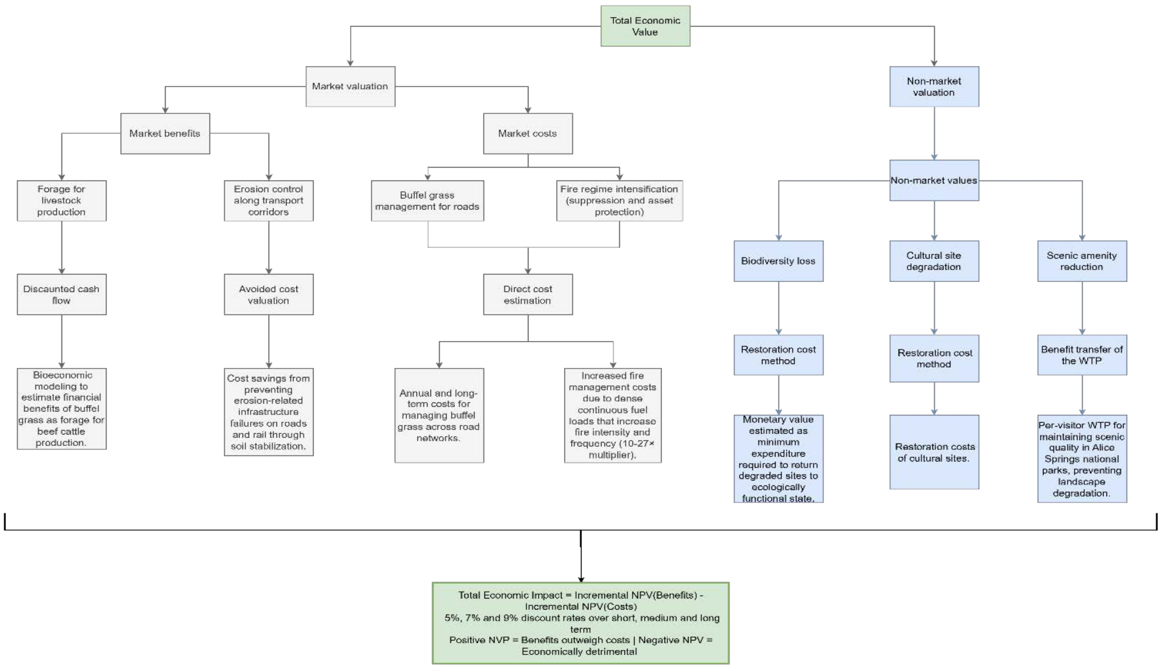

Figure 1. Valuation methods to estimate the economic impact of buffel grass

3.4.1 Market benefits

3.4.1.1 Forage for livestock production

The partial discounted cash flow (DCF) analysis is a standard economic method for estimating an enterprise's profitability over time by discounting future costs and benefits to their present value. In the context of pastoral production, DCF captures how changes in forage availability, livestock performance, and production costs translate into long-term financial returns. To generate these estimates, we used enterprise-level bioeconomic modelling, which links pasture growth, herd dynamics, land condition, and market prices into an integrated framework for evaluating grazing systems (Bowen et al., 2021; Watt et al., 2023). This approach allows the analysis to account for both annual profitability and long-term net present value (NPV) of buffel grass-based forage production under NT conditions.

The partial DCF estimation begins with calculating the annual net benefit for each year of the investment period. This is done using the expression:

$$Annual\ Net\ Benefit = (Area\ \times Stocking\ Rate\ \times Average\ LW\ Gain\ \times Beef\ Price) - (Variable\ costs) - (Fixed\ Costs\ [annual\ recurring\ overheads])$$

Equation 1

Where:

- Area (ha) = total buffel pasture area.
- Stocking Rate (steers per 1000 ha) = number of animals supported per unit area.
- Average LW Gain (kg/head/year) = liveweight gain per animal.
- Beef Price (AU$/kg) = market price for liveweight.
- Variable Costs = costs per head (feed, health, freight).

- Fixed Costs = costs per hectare (annual recurring incremental overheads attributable to an additional 1,000 ha of buffel grass expansion)[1].

This equation yields the net financial return in year *t* and serves as the core of the DCF analysis. In this context, DCF is the method used to estimate the long-term NPV of buffel grass-based forage production by accounting for changes in annual net benefits over time. The year-to-year variability in net returns, driven by fluctuations in pasture condition, stocking strategies, rainfall, animal performance, and market prices, is incorporated through enterprise-level bioeconomic modelling that simulates herd dynamics and pasture productivity over multi-decadal timeframes. This is done following the modelling approach employed in long-term grazing system evaluations in northern Australia, including the multi-year DCF budgets used in Bowen et al. (2021) and Watt et al. (2023).

Once annual net benefits are projected for each year of the planning horizon (often 20 to 30 years in rangeland beef modelling), the DCF method applies a discount rate that reflects the time value of money. The value of future benefits is lower than that of immediate benefits because of risk, inflation, and forgone earning opportunities. To account for this, each year's net benefit is divided by $(1+r)^t$, where r is the discount rate and t is the year number. This discounting process ensures that distant returns, such as productivity gains or costs emerging from pasture-condition changes, are appropriately weighted, as seen in long-term grazing pressure and land-condition analyses for buffel grass pastures in the NT (Watt et al., 2023).

The discounted values are then summed over the entire investment period to produce the NPV, the central output of the partial DCF method. NPV represents the total economic value of adopting a particular forage or grazing strategy, expressed in today's dollars (Watt et al., 2023).

An NPV greater than zero indicates that the strategy yields a net financial gain over the long term, while comparing NPVs across alternative management scenarios reveals which option is most profitable. This approach enables robust evaluation of grazing systems, including assessments of buffel grass utilisation, forage innovation trials, and grazing-management strategies, all of which rely on discounted cash-flow modelling to capture both annual profitability and long-term economic performance in northern Australian beef enterprises (Bowen et al., 2021; Watt et al., 2023).

3.4.1.2 Erosion control along transport corridors

This valuation component estimates the economic benefit of buffel grass in reducing erosion and dust-related infrastructure maintenance and operational delays along transport corridors (roads, rail, and airstrips). Buffel grass's dense ground cover stabilises soil and minimises wind erosion, thereby reducing the need for frequent grading, re-sheeting, and dust mitigation measures (Arafura Resources Ltd, 2016; Friedel et al., 2006; Friedel et al., 2009c). These avoided expenditures were quantified using a cost-

[1] Amortisation was not applied; therefore, fixed costs are treated as annual recurring overheads rather than capital items requiring amortisation.

saving analysis based on historical maintenance records and operational logs (Bureau of Infrastructure and Transport Research Economics, 2025; Infrastructure Australia, 2020). We acknowledge that in some areas, such as Uluru-Kata Tjuta National Park, buffel grass is indeed responsible for causing erosion of walking tracks by holding soil on the sides of the tracks, making them small water channels, which incur significant management costs; however, these costs are not included in the assessment.

It is important to note that the erosion-control benefits attributed to buffel grass occur only where the starting condition is already degraded. In landscapes that retain healthy native groundcover and soil stability, particularly those not subjected to historical overgrazing or disturbance from cattle, feral herbivores, or repeated fire, buffel grass provides little to no additional erosion-mitigation benefit. Buffel's original use for stabilising disturbed transport corridors (e.g., roads, rail alignments) and heavily degraded surfaces means that avoided-cost estimates must be interpreted as applying exclusively to already compromised systems, not to intact rangeland or Country where native vegetation provides effective soil binding and dust suppression (Friedel et al., 2006; Puckey & Albrecht, 2004).

Avoided-cost valuation is widely used for infrastructure-related ecosystem services because it reflects actual expenditures that would occur in the absence of ground cover (Zandebasiri et al., 2023). In the context of buffel grass, this approach captures its original rationale for introduction, erosion and dust control on degraded lands and transport corridors.

We applied a reduction factor that represents the proportionate decrease in maintenance events, costs, or operational disruptions attributable to buffel grass improving soil stability and reducing dust generation along transport corridors. It is a modelling parameter used to translate ecological effects (e.g., reduced erosion or dust formation) into quantifiable economic benefits. The scientific literature emphasises that vegetation effects vary across scales and time, requiring parameters to be applied carefully and conservatively (Jafari et al., 2022; Liu et al., 2018).

The following equation for erosion control was estimated for the previous washouts and culvert cleaning parameters:

$$Annual\ Erosion\ Control\ Benefit = (Washouts\ per\ year\ \times Repair\ Cost\ per\ Washout\ \times Reduction\ Factor) + (Culvert\ Cleaning\ Frequency\ \times Cost\ per\ Cleaning\ \times Reduction\ Factor)$$

Equation 2

Where:

- Washouts per Year: Average number of erosion-related failures.
- Repair Cost per Washout: Cost to restore road or rail embankments.
- Culvert Cleaning Frequency: Number of sediment-clearing events annually.
- Cost per Cleaning: Unit cost for culvert maintenance.

- Reduction Factor: Proportionate decrease in events due to buffel grass stabilising soil (0.35 reduction)[2].

3.4.2 Market costs

3.4.2.1 Buffel grass management costs for roads

The management component estimates the annual and long-term costs of managing buffel grass to reduce its ecological, cultural, and fire-related impacts. This component recognises that buffel grass management occurs across several domains: road networks, culturally and ecologically significant areas, and operational practices intended to prevent further spread. As such, the total annual management cost comprises three primary elements: road buffer maintenance, hygiene (washdown) measures, and scheduled control activities across broader management areas (Box et al., 2025; Buffel Grass Weed Advisory Committee, 2024).

Together, these three components provide a comprehensive estimate of the annual cost required to manage buffel grass effectively. The equation integrates ongoing maintenance needs, annual prevention measures, and periodic large-scale control, enabling planners and land managers to assess the financial implications of sustained buffel grass management over both short- and long-term timeframes (Biosecurity SA, 2019).

$$Annual\ Buffel\ Management\ Cost = (Road\ Buffer\ length \times Buffer\ Maintenance\ Cost) + Annual\ Hygiene\ Cost + \frac{Control\ Area \times Control\ Cost\ per\ ha}{Control\ Cycles}$$

Equation 3

Where:

- Road Buffer Length (km): Total length of roadside buffers (e.g., 10 m either side of sealed roads).
- Buffer Maintenance Cost per km per year: Cost for slashing, spraying, and upkeep.
- Annual Hygiene Cost: Washdown facilities, gravel sourcing protocols, compliance monitoring.
- Control Area (ha): Infested area targeted for herbicide or mechanical control.
- Control Cost per ha: Unit cost for treatment (including follow-up).
- Control Cycle (years): Interval for repeat treatments (e.g., 10 years).

3.4.2.2 Fire regime intensification (suppression & asset protection)

Detailed estimates of increased fire-management costs associated with invasive grasses in the NT have been developed primarily for gamba grass, a major transformer species in the wet–dry tropics and one of Australia's highest-risk invasive grasses (Beaumont et al.,

[2] This parameter represents the proportionate decrease in erosion-related maintenance events (washouts and culvert cleanouts) that occurs when ground cover, such as buffel grass, stabilises soil surfaces and reduces sediment movement. A 0.35 reduction factor indicates an estimated 35% decrease in event frequency, consistent with Jafari et al. (2022), which shows that increased vegetative cover substantially lowers runoff velocity, soil detachment, and sediment transport along transport corridors.

2018; Setterfield et al., 2013). Equivalent region-specific fire-cost studies do not yet exist for buffel grass in the arid and semi-arid interiors. However, the gamba-based estimates are somewhat relevant and informative because buffel grass drives a comparable ecological transformation: both species greatly increase fine-fuel loads, create continuous fuel beds, and produce faster and more frequent fires compared with native vegetation systems (Friedel et al., 2014; Schlesinger et al., 2013).

However, the transfer of gamba grass fire-management cost multipliers is not appropriate without adjustment. Ecological and fire-behaviour evidence clearly indicates that:

- Gamba grass produces extremely high fuel loads, often >10× native savanna grasses in the wet–dry tropics (Setterfield et al., 2013).
- Buffel grass fuel loads, while still transformative, are substantially lower, typically 2–5× greater than native desert grasses, not an order of magnitude higher (McKenna et al., 2017; Miller et al., 2010).
- Pre-existing fire regimes differ sharply: tropical savannas have high ignition frequency and rapid biomass turnover, whereas arid grasslands burn less frequently and accumulate fuel more slowly (Schlesinger & Westerhuis, 2021).

Because the fuel load differential between buffel and native grasses is significantly smaller than the gamba-to-native contrast, using gamba multipliers without modification would overstate fire-suppression and asset-damage costs. To correct this, we adjusted the gamba estimates for the central Australia area and fire frequency, and applied a conservative cost estimate for aerial response, as described below.

This buffel grass–fire cycle drives up the cost of fire management in three main categories:

- Pre- and post-invasion wildfire suppression costs per event (excluding broader mitigation activities).
- Standby days and cost per day
- Annual asset repair

The annual fire cost was estimated by applying the following equation:

$$Annual\ Fire\ Cost = \left[\left(C_{post} \times F_{post}\right) - \left(C_{pre} \times F_{pre}\right)\right] + \left(D_{standby} \times C_{standby}\right) + C_{asset}$$

Equation 4

Where:
Fire frequency component:

- F_{pre} = pre-invasion wildfire frequency (historically low, tied to high-rainfall intervals)
- F_{post} = post-invasion wildfire frequency, increased due to buffel grass-driven fuel continuity and reduced fire-return times

Per-event cost component:

- C_{pre} = suppression cost per event in native grass

- C_{post} = suppression cost per event in buffel grass-invaded landscapes

Standby component:

- $D_{standby}$ = number of fire-ban/standby days per year
- $C_{standby}$ = cost per standby day

Asset damage:

- C_{asset} = annual fire-related asset repair cost (fences, bores, signage, utilities)

The assumption of 1,000 ha of buffel grass-prone fire area is used solely as a standardisation unit to convert annual fire-management expenditures into per-hectare costs for economic modelling, consistent with the uniform framework applied across all impact categories in this assessment (Table 12). It is not an estimate of total buffel grass distribution or predicted annual burn area; rather, it reflects the modelling unit at which individual cost components are rendered comparable and aggregable. By applying a consistent 1,000 ha unit across all categories, the analysis ensures that per-hectare fire costs are directly comparable to biodiversity, cultural, and management cost estimates without distortion from differential area scaling. Because the relationship between total fire cost and affected area is linear, this unit also allows for straightforward sensitivity analysis; outcomes can be rescaled proportionally to any alternative area assumption while maintaining full internal consistency across all valuation components.

3.4.3 Non-market values

3.4.3.1 Cost of restoration of land for biodiversity conservation

The monetary value of biodiversity loss associated with buffel grass was estimated by using a direct ecological restoration cost method. Under this approach, biodiversity loss is valued as the minimum expenditure required to return degraded sites to an ecologically functional state. Cost-based valuation is an established method in situations where biodiversity lacks a market price and restoration costs serve as reasonable proxies for the value of lost ecological functions (Bainbridge, 2023).

Buffel grass invasion is known to cause substantial and multi-layered ecological impacts, including reduced native plant richness, competitive exclusion of native grasses and forbs, long-term declines in shrubs and trees, altered ecohydrological processes, and associated declines in invertebrate and vertebrate assemblages (Abella et al., 2012; Bonney et al., 2017; Read et al., 2020; Ryan-Colton et al., 2024; Schlesinger et al., 2020). Importantly, a major mechanism not always explicitly noted is the reduction in recruitment of native plant species. Buffel grass suppresses seedling establishment through altered microclimates, increased fuel loads and fire frequency, and competition for moisture and nutrients, leading to long-term declines in plant abundance and structural diversity (Edwards et al., 2019; Schlesinger et al., 2013; Wright et al., 2021).

According to the economic comparisons in Schlesinger et al. (2020), specifically as detailed in Read et al. (2020), the mean annual cost for a management regime involving slashing and spot spraying in the West MacDonnell Ranges is $1,832 per hectare (2020 value). This figure represents a more intensive "Control to Zero Density" objective. For comparison, the average cost for long-term restoration at the Alice Springs Desert Park is documented at $5,500/ha (Friedel et al., 2009a). Adjusting the former to 2025 values yields a mean annual restoration cost of AU$2,250/ha, which is adopted as the unit cost parameter for this assessment.

Restoration costs are applied to a representative area of 1,000 ha, drawn from the approximately 66,000 ha of Tjoritja / West MacDonnell National Park burnt in a single buffel grass-fuelled wildfire in 2019 (Schlesinger & Westerhuis, 2021). This event is not an isolated occurrence; the conditions that produced it, continuous fine fuel loads along creek lines enabling fire spread even under low temperatures and wind speeds, combined with extensive buffel grass dominance across the arid zone, are predicted to drive more large and unpredictable fires of comparable magnitude across central Australia (Schlesinger & Westerhuis, 2021). The 1,000 ha modelling unit is therefore a conservative and bounded proxy for what is likely a recurring and escalating pattern of buffel grass-fuelled fire disturbance. It is adopted for consistency with the standardised per-hectare framework applied across all impact categories in this assessment (Table 12), rather than as a cap on the total affected area.

The monetary value of biodiversity conservation was calculated by multiplying the per-hectare restoration cost by the total affected area:

$$V_{biodiversity\ conservation} = C_{restoration/ha} \times A$$

Equation 5

Where:
- $C_{restoration/ha}$ is selected depending on the restoration objective (conservative ecological restoration).
- A is the mapped area (hectares) affected by buffel grass invasion.

This approach yields a conservative lower-bound estimate because it accounts only for financially quantifiable restoration for practical purposes, not for irreversible loss of species, ecosystem collapse risk, or non-market ecological values.

3.4.3.2 Cultural site degradation

Caring for Country is a central concept in Indigenous Australian cultures, reflecting a holistic and reciprocal relationship with the land, waters, and all living and non-living entities within a place (Kingsley et al., 2009). Country is understood as a living being with its own spirit and agency, an entity that supports life, provides knowledge, and requires care in return (Russell et al., 2020). From this perspective, Indigenous peoples hold both the responsibility and the inherent right to nurture and manage their lands and natural resources using traditional knowledge and cultural protocols, ensuring environmental sustainability and cultural continuity (Garnett et al., 2009; Sangha et al., 2024).

Restoration of cultural sites impacted by buffel grass in the Alice Springs municipality requires a structured, defensible method that incorporates ecological, cultural, and financial dimensions. The following multi-stage framework estimates annual restoration cost (ARC) by integrating the direct cost of buffel grass control, site-specific restoration needs, cultural protection requirements, and long-term maintenance obligations, each reflecting externalities generated by buffel grass invasion.

All calculations use conservative (low-end) cost assumptions to avoid overestimating costs.

$$Annual\ Restoration\ Cost_{Site} = BCC + CRC + FMC + MPC$$

Equation 6

Where:

- BCC = Buffel Grass Control Cost per ha
- CRC = Cultural Restoration Cost per ha
- FMC = Fire-Mitigation Cost per ha
- MPC = Monitoring & Prevention Cost per ha

Although BCC include some activities that reduce fire risk, such as removing buffel grass biomass and maintaining access, these components do not fully capture the dedicated and ongoing FMC required at culturally significant sites.

Targeted fire management is critical here, as riparian fuel loads can reach 47 t/ha, posing an existential threat to mature gums (NTG, 2019). This covers the maintenance of strategic firebreaks and "hazard reduction" near iconic trees (Read et al., 2020).

CRC represents a conservative placeholder for Indigenous cultural values transferred from Stoeckl et al. (2023). For the Todd River, this would specifically fund the "resurgence of attractive native vegetation" and the maintenance of Dreaming ancestor sites along the riverbed (NTG, 2019).

First, buffel grass invasion around cultural features, particularly waterholes, creek lines, and riparian corridors, tends to occur as broad, continuous bands extending well beyond the immediate cultural feature itself (Ryan-Colton et al., 2024; Schlesinger et al., 2013). These areas require control buffers that are substantially larger than the feature footprint in order to remove seed sources, reduce recurring reinvasion, and prevent high-intensity buffel grass-fuelled fires from reaching the site. Fire behaviour studies in buffel grass-invaded arid river systems show that once ignited, buffel grass fires can spread rapidly along riparian channels and kill large old trees that define cultural landscapes (Arid Lands Environment Centre, 2023; Schlesinger & Westerhuis, 2021).

Second, restoration case studies, including Schlesinger et al. (2020), demonstrate that effective buffel control requires multiple herbicide passes and significant manual labour across areas extending well beyond the immediate cultural asset. While these studies focus on smaller experimental plots, they confirm that the effective management footprint must be large enough to interrupt fire pathways and remove extensive seed banks.

Third, Indigenous ranger groups routinely apply 10–200 m weed-control and fire-protection buffers around sensitive locations in riverine corridors, including fencing lines, slashing corridors, firebreaks, and culturally guided exclusion zones, because buffel grass invasion and fire behaviour extend well beyond the immediate cultural feature (Desert Support Services, 2018; Puckey & Albrecht, 2004). When these buffers are extended around an irregularly shaped cultural zone, such as a waterhole complex with multiple access paths, associated vegetation, and cultural features, the effective operational area consistently approaches tens of hectares, especially in riparian systems where buffel grass forms continuous fuel beds (Ryan-Colton et al., 2024; Schlesinger et al., 2013).

We chose the Lhere Mparntwe (Todd River) and Anthelke Ulpeye (Charles River) corridors as a case study because they are of profound significance to the Mparntwe Aboriginal custodians, representing a living cultural landscape that defines the identity of Alice Springs (NTG, 2019). Therefore, a 100-hectare area of cultural restoration was calculated based on a 10 km stretch and a 100 m buffer; this area provides a realistic and conservative estimate of the combined area needed for buffel control, cultural-plant restoration, access maintenance, and fire-mitigation works in these culturally and ecologically sensitive landscapes (Caron et al., 2021; Kulitja, 2024).

Accordingly, the annual restoration cost is calculated for a 100-ha operational footprint because this represents the practical minimum area required to:

- remove buffel from the cultural site and its immediate surroundings,
- treat upstream and downstream reinvasion sources,
- construct and maintain fire-breaks, and
- ensure culturally safe access and long-term monitoring.

3.4.3.3 Scenic amenity reduction

While scenic amenity is an important component of non-market value, focusing on visual landscape change alone substantially understates the full set of tourism- and visitor-experience impacts associated with buffel grass invasion. Buffel not only homogenises ground-layer vegetation and reduces the distinctiveness of arid-zone landscapes, but it also alters wildlife presence, disrupts culturally meaningful vistas, and increases fire risk, all of which influence visitor experience, safety, site access and tourism sector performance. Studies and stakeholder consultations across central Australia highlight that buffel grass reduces opportunities for wildlife viewing, modifies iconic lookouts and long-distance views, and affects the integrity of cultural landscapes valued by Traditional Owners and visitors alike (Department of Lands Planning and Environment (DLPE), 2025a; Read et al., 2020).

In addition to altering scenic character, buffel grass-driven fire regime changes pose direct operational costs and reputational risks for the tourism industry. Buffel grass increases the frequency and severity of wildfires (Ryan-Colton et al., 2024; Schlesinger et al., 2013), leading to temporary park closures, loss of infrastructure, decreased visitor safety, and reduced access to trails and lookouts, including major tourism drawcards such as the Larapinta Trail (Arid Lands Environment Centre, 2024). These impacts extend beyond visual amenity to include lost visitor days, reduced regional revenue, disrupted tour operations, and heightened maintenance responsibilities for park agencies, none of which are captured in a scenic-amenity-only valuation.

Furthermore, buffel grass degrades culturally significant landscapes, diminishing both Aboriginal cultural values and the cultural tourism experiences that rely on intact Country. Traditional Owners emphasise that buffel grass-driven vegetation change affects the visibility and integrity of cultural sites, Dreaming tracks, and culturally significant plants and animals (Caron et al., 2021; Kulitja, 2024). These impacts are also highly relevant in the context of joint management of national parks, where Traditional Owners share responsibility for maintaining the cultural and ecological values of Country. As buffel grass invasion increases maintenance burdens, alters culturally important landscapes, and reduces scenic amenity, it can constrain both current joint management arrangements and Traditional Owners' future capacity to assume a greater or sole management role over park estates. Because cultural tourism is a central pillar of the visitor economy, these impacts represent additional, non-market losses that overlap with, but go well beyond, scenic amenity.

For these reasons, scenic amenity is treated in this assessment as one measurable component within a broader suite of tourism-related externalities. The Willingness To Pay-based estimate applied here, therefore, captures only a fraction of the total non-market tourism cost associated with buffel grass invasion. Broader impacts, including fire-related closures, cultural landscape degradation, wildlife loss, and safety risks, are acknowledged qualitatively and incorporated into the wider Total Economic Value framework, though robust NT-specific valuation studies for these additional domains are not yet available.

To estimate a per-visitor WTP for maintaining scenic quality and preventing landscape degradation caused by the spread of buffel grass in Alice Springs national parks, a Basic Value Transfer approach was used.

Basic Value Transfer (BVT) is appropriate in the absence of primary stated-preference valuation studies for central Australian desert parks, and when suitable study-site analogues and non-market valuation evidence exist elsewhere in Australia, particularly in National Parks (Zandebasiri et al., 2023). This analysis applies a value transfer (direct transfer of monetary estimates) combined with contextual adjustment using national parks as nationally significant assets, following the Lamington National Park, Queensland study that quantifies public or visitor preferences for protected-area environmental quality (Tisdell, 2012).

The BVT approach relies primarily on Tisdell (2012), which synthesises empirical visitor-survey evidence on Australians' willingness to pay national-park entry fees and demonstrates that visitors consistently express modest but positive WTP for maintaining conservation outcomes and scenic quality in protected areas. These values are directly relevant to buffel grass-affected landscapes in central Australia because they represent park-specific, visitor-based WTP rather than broader household-level environmental preferences.

This study was selected because it examines protected-area management in relation to scenic and natural landscape attributes, employs stated-preference or inferred-preference economic valuation methods, and is based on Australian populations, thereby reducing cultural transfer bias (Whitehead et al., 2015). Together, they directly value natural scenery and conservation quality in ways that closely align with the environmental attributes being assessed for the southern NT.

Adjustments were made using judgmental scaling, which is appropriate when the environmental good is similar, but the ecological and demographic contexts differ (Whitehead et al., 2015). Adjustments were made for:

(a) Scenic uniqueness

National parks in the southern NT, particularly Tjoritja/West MacDonnell National Park and Uluṟu–Kata Tjuṯa National Park (UKTNP), hold exceptionally high scenic, geological, cultural and biodiversity values, and these landscapes form the core of the NT's tourism identity and economy. Their dramatic landforms, intact desert vistas, and globally recognised cultural significance draw large numbers of interstate and international visitors each year, making the region one of the NT's most important tourism destinations (Arid Lands Environment Centre, 2024; NTG, 2024).

Because visitor expectations in these parks are strongly tied to experiencing iconic, distinctive desert scenery, any degradation caused by buffel grass, such as homogenisation of the ground layer, reduced visibility of geological features, loss of native vegetation colour and texture, native flowers, and post-fire scarring, has a disproportionately large impact on visitor experience and perceived landscape quality. In turn, this elevates the WTP for maintaining or restoring these high-value scenic landscapes relative to subtropical or temperate parks, where scenic value might be more resilient to vegetation change. The uniqueness of these desert parks, therefore, justifies using a higher contextual WTP adjustment, reflecting their pivotal role in the NT tourism sector and the heightened sensitivity of visitors to landscape degradation in these world-renowned destinations.

(b) Threat severity

Buffel grass poses a severe and highly visible threat to scenic quality by homogenising the ground layer, increasing the extent and continuity of fuel, and producing more frequent and intense fires that leave long-lasting visual scars. These effects are particularly pronounced in the southern NT arid zone, where post-fire recovery is inherently slow due to low and variable rainfall. For example, following the 2019 fires in Tjoritja/West MacDonnell National Park, rainfall was minimal for several years, resulting in large areas of bare, burnt ground that persisted long after the fire, a pattern unlikely in higher-rainfall regions where vegetation regrows more rapidly (Ryan-Colton et al., 2024; Schlesinger et al., 2013).

This prolonged post-fire barrenness amplifies the visual severity of buffel grass-driven degradation: blackened soils, exposed erosion surfaces, dead shrubs and trees, and extensive fire scars remain visible to visitors for multiple seasons and, in some locations, multiple years. Such slow recovery intensifies the perceived loss of wilderness character, naturalness, and cultural landscape integrity, all of which influence visitors' WTP to maintain or restore scenic quality (Molina et al., 2019).

(c) Visitor composition
Alice Springs receives large numbers of international and interstate nature-tourists, who typically show higher WTP for conservation and scenic amenities compared with local day-users (NTG, 2024).

Based on these factors, a slight upward contextual adjustment from the baseline "few-dollars" WTP range in Tisdell's study was justified.

Following these adjustments, the transferred WTP for protecting the scenic quality of Alice Springs national parks was set at AU$5.00–AU$10.00 per visitor, with AU$7.00 (2025 value) adopted as the central estimate for modelling. This value is consistent with Tisdell's findings that Australian national-park visitors are typically willing to contribute modest amounts, ranging from a few dollars to low double-digit figures, for conservation and landscape maintenance. Assuming that 250,000 people visit Uluṟu-Kata Tjuṯa National Park annually (Australian Government, 2026), we applied the WTP to 50% of tourists, as not all of them will pay AU$7.0. Therefore, the WTP was applied to 125,000 visitors.

It is also conceptually supported by national-level evidence from Ambrey and Fleming (2012), who demonstrate strong public WTP for enhanced environmental quality in protected areas across Australia. Moreover, the selected range aligns with trends identified in global meta-studies, which show that small per-visitor payments for scenic and landscape protection are common in protected-area valuation worldwide (Gross et al., 2023).

(d) Habitat composition
We used Uluṟu-Kata Tjuṯa National Park as a case study. Based on Box et al. (2025), we estimated that the buffel grass covers approximately ~2.1% (~3,000 ha) of Sandplains and Dunefields and Sandstone Ranges habitats in Uluṟu-Kata Tjuṯa National Park.

However, scenic impact is not uniform because buffel grass is concentrated in high-visibility, high-visitor-traffic locations (run-on zones, creek lines, foreground viewing areas). These areas influence visitor experience more than remote sandplains. To reflect this, we applied a 5x exposure multiplier[3] rather than a simple area ratio. Thus, the effective scenic degradation is 2.1% × 5 = 10.5%.

The following equation represents the annual scenic-amenity loss:

$$S = V \times WTP \times \left(\frac{A_b}{A_p} \times E\right)$$

Equation 7

Where:
A_b = Buffel-affected area (ha)

[3] A 5× multiplier recognises higher visibility but avoids overstating the effect. This was calculated based on landscape quality studies of landscape features (Daniel, 2001).

A_p= Total park area (ha)
V = Annual visitors
WTP = Average per-visitor willingness-to-pay to avoid scenic degradation
E = Scenic exposure factor (dimensionless), e.g., 5×
S = Annual scenic-amenity loss (AU$)

3.5 Inflation adjustment method

All historical cost figures were converted to constant Australian dollars using the All Groups Consumer Price Index (weighted average of eight capital cities) published by the ABS (2025). Following standard practice, updated values were calculated as:

$$Cost_t = Cost_{base} \times \frac{CPI_t}{CPI_{base}}$$

Equation 8

When only the publication year (not the month/quarter) was reported, the annual average CPI for that year was used as CPI_{base}. We used the September 2025 quarter (CPI_t = 143.6, index base 2011–12 = 100) as the current period because it is the latest fully published quarterly CPI at the time of analysis (December 2025). All CPI indices and methodology follow the ABS Concepts, Sources and Methods and the Reserve Bank of Australia (RBA) inflation calculator convention (RBA, 2024).

3.6 Conceptual economic model

This model represents the net economic effect of buffel grass by aggregating all measurable benefits and subtracting all measurable costs. It aligns with Total Economic Value (TEV) frameworks commonly used in environmental economics for invasive species (Greiner et al., 2023).

A positive net impact suggests that the benefits outweigh the costs; whereas a negative net impact indicates that buffel grass is economically detrimental when externalities are considered.

$$Total\ Economic\ Impact = \sum Benefits - \sum Costs$$

Equation 9

Where:

$$\sum Benefits = B_{forage} + B_{erosion\ control}$$

$$\sum Costs = C_{biodiversity} + C_{cultural} + C_{scenic} + C_{fire\ management} + C_{buffel\ management}$$

Buffel grass management costs are treated as a distinct cost component because they arise independently of and apply across all four valuation domains: biodiversity, cultural sites, scenic landscapes, and fire-related impacts. Management costs include prevention, containment, hygiene protocols, roadside control, slashing, herbicide treatments, follow-up monitoring, and compliance requirements (Buffel Grass Weed Advisory Committee, 2024). These activities are required regardless of whether a site is valued primarily for conservation, cultural significance, tourism/scenic amenity, or pastoral production.

We standardised the buffel grass impacts to a per-hectare, per-year metric because buffel grass spreads non-linearly and affects landscapes unevenly, costs and benefits differ widely between land types (pastoral, cultural, conservation, municipal), and policymakers must compare incremental expansion areas to understand marginal impacts.

3.7 Sensitive analysis

To evaluate whether additional buffel grass expansion beyond its current distribution (i.e. such as if sowing of buffel grass into new areas and continued expansion within the pastoral estate is permitted) provides net benefits to the NT, this assessment adopted an Incremental NPV framework (Appendix D8). Although current policy proposals restrict future expansion primarily to the pastoral land, the incremental externalities associated with new spread, particularly biodiversity loss, cultural-site degradation, increased fire risk, and deterioration of scenic and tourism values, remain highly relevant, as buffel grass readily disperses along roads, drainage lines, and fire scars into non-pastoral landscapes where these impacts are most severe (Arid Lands Environment Centre, 2024; Read et al., 2020).

Under the proposed legislative framework, eradication of existing widespread buffel grass stands is neither feasible nor required, and management focuses on containment, preventing further spread, and protecting high-value areas. Accordingly, the modelling does not evaluate the costs or benefits of removing existing infestations; instead, it isolates the marginal (incremental) impacts of enabling an additional 1,000 hectares of buffel grass establishment relative to a no-expansion baseline.

This approach allows the analysis to capture the true net public consequences of further incremental spread, recognising that even when expansion originates on pastoral land, the associated externalities are borne disproportionately by conservation areas, tourism landscapes, Traditional Owners, and public land managers. Although these findings were not available in time to inform the initial weed declaration or the details of the initial Buffel Grass Weed Management Plan, they remain directly relevant to the implementation of the Plan and ongoing decisions about exemptions, containment, and protection of high-value areas, as well as informing future Plans. The sensitivity analysis, therefore, evaluates whether incremental pastoral benefits outweigh incremental social and environmental costs across a range of ecological, economic, and valuation scenarios (Equation 10).

$$Incremental\ NVP = \sum_{t=0}^{T} \frac{\Delta B_t - \Delta C_t}{(1+r)^t}$$

Equation 10

Where:

- ΔB_t = incremental pastoral benefits from new buffel establishment in year t
- ΔC_t = incremental cost of externalities in year t, including:
    - fire-related suppression, damage, and risk

    - biodiversity loss
    - cultural-site degradation and reduced cultural access
    - scenic and tourism losses
    - infrastructure and transport impacts
    - long-term ecological change
- r = discount rate
- T = analysis time horizon (typically 20–50 years for ecological change)

A recurring concern in applied invasive species economics is whether incremental benefit and cost parameters are compared on a consistent analytical basis. It is important to be explicit about how this framework achieves that consistency. Both sides of the ledger are expressed as per-hectare annual flows associated with an additional 1,000 ha of buffel grass establishment beyond the current distribution, and both are then discounted over identical time horizons at identical discount rates. The pastoral benefit is the incremental gross margin generated by new buffel grass-supported production on previously uncolonised land. The cost parameters are structured the same way that the fire cost is explicitly calculated as the difference between post-invasion and pre-invasion suppression expenditure (Equation 4); the biodiversity cost represents the per-hectare annual restoration liability incurred on each newly invaded hectare; the cultural site cost is the per-hectare annual restoration cost applied to a representative 100 ha proxy site; and the scenic amenity cost is scaled proportionally to the fraction of affected park area relative to total park area. No cost parameter embeds the historical accumulated liability of existing buffel grass infestations; all are expressed as the annual per-hectare consequence of one additional hectare of new spread. The comparison is therefore symmetric at the margin, consistent with best-practice benefit-cost analysis for invasive species (Greiner et al., 2023). What the framework does not include on the benefit side is the total, historically accumulated carrying-capacity value of existing buffel pastures; a deliberate exclusion, because that value is already embedded in current enterprise structures and is irrelevant to the policy question of whether further spread should be permitted. Including it alongside marginal costs would produce the asymmetric comparison, not avoid one.

3.7.1 Scenario analysis of buffel grass expansion

A structured sensitivity analysis was undertaken to evaluate how uncertainty in key ecological, economic, and non-market valuation parameters affects the estimated NPV of buffel grass impacts in the short (1-5 years), medium (6-20 years) and long term (20+ years). All recalculations used the annuity-based discounting of annual benefits/costs, consistent with best practice for cost–benefit appraisal in Australian agriculture and environment programs (Greiner et al., 2023; Hone et al., 2022).

Two multi-parameter scenarios were developed using the base values, equations, and evaluation horizons defined in the economic analysis. These include:

Scenario A – No further buffel grass expansion (Baseline)

- Buffel grass remains within its current distribution.
- No deliberate seeding is permitted.

- Spread prevention measures (e.g., corridor management, hygiene protocols) limit unintentional expansion.
- Existing pastoral benefits continue unchanged (i.e., locked-in benefits from historical establishment).
- Pastoralists incur ongoing boundary-management obligations to prevent buffel grass spread onto neighbouring conservation areas, cultural sites, road corridors, and tourism estates. These obligations include maintaining firebreaks, monitoring fencelines, and applying localised control or hygiene measures, costs that persist even without further expansion.
- Fire, biodiversity, cultural, tourism, and infrastructure impacts remain at current levels.

Scenario B – Continued buffel grass expansion

- Buffel grass spreads into new areas due to deliberate or unregulated seeding, or failure to control further spread via disturbance corridors, or in areas of high value where occurrence is currently low.
- Incremental pastoral benefits occur only on land not yet dominated by buffel grass.
- Externalities (fire intensification, biodiversity loss, cultural harm, landscape degradation, and infrastructure damage) increase relative to Scenario A across all land tenures.

The incremental change (B – A) represents the net effect of additional buffel grass expansion and serves as the basis for NPV estimation. Both scenarios were evaluated at discount rates of 5%, 7%, and 9% (Hone et al., 2022).

3.8 Qualitative assessment (Part 2)

For the qualitative information, detailed questionnaire surveys (Appendix B) and semi-structured interviews (Appendix A) were conducted with key stakeholders across pastoral, conservation, Indigenous land management, and community health sectors. The online open-ended surveys allowed participants to express their views in detail and share their experiences. We received responses from 102 participants from diverse backgrounds. The surveys were complemented by detailed semi-structured interviews with six interviewees representing all key stakeholder groups, including pastoral, environmental, indigenous, and public stakeholders. This exercise helped gather on-the-ground information from a diverse range of participants and verify the quantitative results.

3.8.1 Qualitative thematic analysis

The qualitative component of this assessment (Part 2) employs thematic analysis of semi-structured interview data and open-ended survey responses to contextualise, validate, and extend the quantitative findings reported in Part 1 (Braun & Clarke, 2008). Interview transcripts were analysed inductively, with themes generated from the data rather than imposed a priori, consistent with reflexive thematic analysis methodology (Braun & Clarke, 2008). Codes were first generated at a semantic level, capturing explicit meanings in participants' accounts, before being developed into broader analytical themes that cut across individual sectors and land tenures (Creswell & Poth, 2016).

Thematic saturation was assessed iteratively as additional interviews were transcribed and coded; while the small sample size prevents claims of formal saturation, the consistency of key themes across participants with different sectoral affiliations strengthens confidence in the analytical patterns identified (Guest et al., 2013). Open-ended survey responses were treated as a complementary qualitative data source and coded using the same framework, allowing triangulation across interview and survey modalities (Denzin & Lincoln, 2018).

3.8.2 Qualitative and quantitative integration

Quantitative modelling outputs (e.g., discounted net benefits, annualised costs, sensitivity analyses) were then compared with qualitative insights using a side-by-side convergence matrix to assess agreement, complementarity, or divergence (Creswell & Poth, 2016). Convergent findings, such as broad consensus on buffel grass's role in fire intensification, strengthened the confidence placed in parameter choices. Divergent findings, for example, mixed views on the scale of pastoral benefits, were interpreted through the lens of contextual variation (e.g., property size, rainfall, management intensity) and handled through scenario analysis rather than single-value estimates.

4 Economic Impact Assessment (Part 1)

4.1 Market benefits of buffel grass

4.1.1 Forage for livestock production

Buffel grass provides high-quality pasture in arid and semi-arid regions, increasing carrying capacity and liveweight gain for cattle. This benefit was estimated using enterprise-level partial budgeting and DCF models (Bowen & Chudleigh, 2018; Bowen et al., 2021; Friedel et al., 2009a).

The economic analysis was based on a representative 1,000-hectare block of buffel grass pasture. This area was selected as a standard modelling unit commonly used in pastoral enterprise assessments because it provides a practical scale for estimating carrying capacity and costs while remaining adaptable to larger property scenarios. The assumption aligns with previous economic modelling studies of northern Australian grazing systems, which often use 1,000-hectare increments for comparative analysis (Bowen & Chudleigh, 2018; Friedel et al., 2009a).

A stocking rate of 300 steers per 1,000 ha (equivalent to 0.3 steers per hectare) was adopted to reflect conservative grazing pressure on buffel grass-based pastures under semi-arid NT conditions. This figure is consistent with enterprise-level models by Bowen and Chudleigh (2018, 2019), which report stocking rates ranging from 161 to 384 steers per 1,000 hectares depending on pasture utilisation. It also accords with NT extension guidelines and grazing trials that demonstrate similar carrying capacities for buffel grass and buffel grass–legume systems (Cameron, 2013; Dixon et al., 2020).

The average liveweight gain was assumed to be 170 kilograms per head per year. This value represents moderate performance achievable on buffel pastures supplemented with legumes and minimal additional feed inputs. It is supported by NT grazing trials reported by Dixon et al. (2020), which recorded annual gains ranging from 159 to 209 kilograms per head, as well as by modelling studies that predict comparable growth rates under similar conditions (Bowen & Chudleigh, 2018).

The beef price was set at AU$4.10 per kilogram liveweight for feeder steers, based on the National Feeder Steer Indicator published by Meat & Livestock Australia (MLA). This price reflects MLA's seven-day rolling average of feeder-steer saleyard transactions, accessed via the MLA Prices & Markets platform and current as of early 2026 (MLA, 2026). MLA's Australian Cattle Industry Projections indicate feeder steer prices around 390–430 ¢/kg liveweight in February 2026, reflecting tightening supply and improving seasonal conditions (MLA, 2026). Using AU$4.10/kg liveweight therefore represents a reasonable central estimate for forward-looking economic projections in central Australia, while acknowledging that realised prices vary by region, timing, and cattle specifications (Table 1).

Feeder-steer variable costs were estimated using benchmark figures for central Australian production systems, drawing on MLA's national and regional market reporting. MLA's feeder-steer indicators, based on a seven-day rolling average of saleyard transactions across Australia, provide regionally relevant pricing and contextual cost information for northern (which includes central Australia) and rangeland producers (MLA, 2026). These data, together with northern production notes, show that properties in Central Australia typically face higher operating costs due to lower and more variable rainfall, reduced pasture productivity, heavier reliance on dry-season supplementation, longer freight distances, and higher fuel and animal-health inputs. To reflect these regional realities, a conservative uplift of 10–20% was applied to standard feeder-steer variable-cost ranges reported for northern production systems, producing an estimated cost of AU$290–AU$320 per head per year, with a practical midpoint of AU$305/head/year (Grainshed, 2026) (Table 1).

Fixed costs were set at AU$37.50 per hectare per year to reflect only the incremental overheads attributable to an additional 1,000 ha of buffel grass expansion, rather than the full fixed-cost burden of an entire pastoral enterprise (Table 1). Although northern Australian beef-enterprise studies report whole-of-business overheads equivalent to AU$110–135/ha for extensive pastoral systems when costs are normalised across the entire property area (Wellington, 2018), these figures include labour, depreciation, administration, insurance, and capital servicing allocated across tens or hundreds of thousands of hectares. In contrast, the present analysis incorporates only the marginal share of fixed costs that would scale with new land brought into production, such as incremental labour time, minor repairs, and additional administration, resulting in a substantially lower per-hectare figure. Using AU$37.50/ha therefore provides a conservative and defensible estimate of the overheads associated specifically with the additional buffel grass-supported production area, avoiding over-allocation of costs that would occur if full-property fixed overheads were applied on a per-hectare basis.

Table 1. Input values for forage benefit estimation

Inputs	**Value**	**Unit**	**Reference**
Area	1,000[1]	ha	Bowen and Chudleigh (2018)
Stocking rate	300[2]	steers/1000 ha	Bowen and Chudleigh (2019); Cameron (2013); Dixon et al. (2020)
Average LW gain	170[3]	kg/head/yr	Dixon et al. (2020)
Beef price	4.1[4]	AU$/kg liveweight	MLA (2026)
Variable cost	305[5]	AU$/head/year	Grainshed (2026)
Fixed cost	37.50[6]	AU$/ha/year	Wellington (2018)

[1]This modelling unit reflects the standard incremental-expansion approach commonly used in northern Australian pastoral enterprise analysis, allowing forage benefits to be assessed independently of whole-property structural constraints. [2] This stocking density falls within the empirically observed range for buffel grass-dominated pastures in central Australia and represents a conservative, sustainable carrying-capacity estimate under variable rainfall conditions. [3] The chosen value reflects mid-range annual gains reported in NT buffel grass and buffel grass–legume pasture trials, ensuring that the forage benefit estimate does not assume exceptional seasonal conditions. [4] This value corresponds to MLA's Feeder Steer Indicator (seven-day rolling average) for early 2026 and provides a transparent, time-specific market benchmark suitable for economic modelling. [5] Variable-cost benchmarks include region-specific adjustments for central Australian operations, notably higher transport requirements, episodic supplementation, and terrain-related animal-health management. [6] This cost represents the incremental overhead associated with managing an additional 1,000 ha of buffel grass-supported land and is not intended to reflect total property fixed costs. Its inclusion ensures full cost recovery within the forage-benefit calculation.

The annual net benefit of AU$80,100 per 1,000 ha was derived by subtracting total costs (both variable and fixed) from gross revenue (Table 2). This figure represents a simplified gross margin before interest, depreciation, and tax, providing a clear measure of economic performance under the stated assumptions. Note that, as an operational pastoral enterprise, there will be a significant amount of interest and tax payments.

Table 2. Annual net benefit of buffel grass for pastoral production using a 1,000 ha area

Outputs	**Value**	**Unit**
Beef output	51,000	Kg/year
Gross revenue	209,100	AU$/year
Variable costs	91,500	AU$/year
Fixed costs	37,500	AU$/year
Annual net benefit	80,100	AU$/year

The AU$80,100 annual net benefit reported in Table 2 represents the incremental gross margin attributable to an additional 1,000 ha of new buffel grass establishment and does not represent the total carrying-capacity contribution of buffel grass across existing pastoral holdings in the NT. Buffel grass is well documented as having substantially increased stocking rates across southern NT. Empirical estimates range from 161 to 384 steers per 1,000 ha, depending on rainfall zone and management system, and this productivity uplift constitutes a foundational component of the NT beef cattle sector's financial viability (Bowen & Chudleigh, 2018, 2019; Cameron, 2013; Dixon et al., 2020). Beyond direct forage productivity, buffel grass provides two enterprise-level benefits that are real and recognised in the pastoral economics literature but fall outside the scope of the incremental model applied here. First, its comparatively low detachment rate relative to native annual grasses enables standing dry-season biomass to persist through protracted feed gaps, providing a feed-security buffer that reduces pastoralists' exposure to supplementary feeding costs during drought episodes (Bowen et al., 2021; Watt et al., 2023). Second, this biomass reserve stabilises enterprise cash flow across the extreme rainfall variability characteristic of the arid zone, reducing the financial risk of successive poor seasons (Bowen et al., 2021). Quantifying these enterprise-level benefits within the incremental NPV framework applied here would require primary financial data across a representative sample of NT pastoral properties, which were not available within the time and resource constraints specified in the Scope of Requirements (DLPE, 2025b). The per-hectare figure of AU$80/ha/yr is therefore a conservative lower bound on buffel grass's total pastoral value and is adopted solely for comparability within the TEV framework; it should not be extrapolated to estimate the aggregate pastoral value of existing buffel grass stands across the NT.

4.1.2 Erosion control along transport corridors

The analysis assumes a baseline washout frequency of six per year in the absence of adequate ground cover (Table 3). This estimate is based on observations from infrastructure corridors in arid and semi-arid regions, where intense rainfall events combined with sparse vegetation often result in recurrent washouts (NTG, 2020; NTG, 2026). Washouts typically occur along unsealed roads and drainage lines, causing significant disruption and estimated repair costs of AUD$12,000.

The culvert cleaning frequency was assumed to be eight events per year, reflecting heavy sediment accumulation during major runoff events (Table 3). Culverts in arid regions are prone to sediment and debris blockages following storm events, necessitating frequent maintenance to prevent flooding and structural damage. The cost per culvert clean was estimated at AU$2,500 per event, based on typical charges for vacuum and clearing operations in remote locations (Austroads Ltd., 2018).

A reduction factor of 0.35 was applied to both the washout and culvert cleaning frequencies to account for the stabilising effect of buffel grass ground cover. Vegetative cover significantly reduces surface runoff velocity and sediment transport, thereby lowering the risk of erosion and reducing maintenance requirements (Table 3). This assumption is supported by studies on erosion mitigation through pasture establishment and road ecology guidelines, which report reductions in erosion-related interventions ranging from 30% to 40% under improved cover conditions (Austroads Ltd., 2018).

Table 3. Input values of the roadside for erosion control estimation

Input	Value	Unit	Reference
Washouts per year[1]	6	events/yr	NTG (2020); NTG (2026)
Repair cost per washout[2]	12,000	AU$/event	NTG (2020); NTG (2026)
Culvert cleaning frequency[3]	8	events/yr	Austroads Ltd. (2018)
Cost per culvert clean[4]	2,500	AU$/event	Austroads Ltd. (2018)
Reduction due to the cover[5]	0.35	fraction	Austroads Ltd. (2018)

[1] Represents the expected number of erosion-related road failures occurring annually without stabilising vegetation. [2]Includes cost of earthworks, machinery hire, gravel replenishment, drainage correction, and labour. [3] Culverts require periodic cleaning when sediment accumulates and obstructs drainage. [4] Reflects the standard operational cost for vacuum extraction, manual clearing, and disposal of accumulated sediment, based on national road-maintenance schedules and Austroads unit-cost benchmarks. [4] Indicates a 35% reduction in erosion-related maintenance events (washouts and culvert blockages) attributable to the presence of vegetation that stabilises soil, slows runoff, and reduces sediment mobilisation.

The total annual benefit of AU$32,200 per year represents the combined savings from avoided washout repairs and culvert cleaning interventions (Table 4). This estimate provides a conservative yet realistic measure of buffel grass's economic contribution to erosion control in arid and semi-arid regions. These assumptions are grounded in infrastructure maintenance guidelines, environmental management recommendations, and industry best practices for road and drainage systems in remote areas (Austroads Ltd., 2018).

Table 4. Annual benefit of erosion control provided by buffel grass

Outputs	Value	Unit
Avoided repair	25,200	AU$/yr
Avoided culvert cleaning	7,000	AU$/yr
Annual benefit	32,200	AU$/yr

4.2 Market costs of Buffel grass

4.2.1 Buffel grass management (buffers, hygiene [washdown facilities], control)

The analysis assumes a road buffer length of 60 kilometres, representing priority transport corridors where buffel grass poses risks to fire and biodiversity. Buffers of 10 meters on either side of sealed roads are recommended in NT weed management strategies to reduce seed production and limit off-site spread (Buffel Grass Weed Advisory Committee, 2024).

The buffer maintenance cost was set at AU$1,200 per kilometre per year, covering slashing and spot-spraying along road verges. This figure aligns with NT government estimates for roadside weed control and is consistent with cost benchmarks for integrated buffer management reported in regional weed strategies (Buffel Grass Weed Advisory Committee, 2024; NTG, 2025). These costs include labour, herbicide, and equipment for maintaining low-density buffers adjacent to high-risk assets.

Hygiene protocols, including vehicle and machinery washdown, were estimated at AU$35,000 per year for fleet and contractor compliance. This assumption is based on NT weed management guidelines, which emphasise prevention as the most cost-effective strategy, with hygiene measures reducing long-term control costs by limiting propagule pressure (Ferdinands et al., 2010; Friedel et al., 2009a). Industry case studies confirm that strict hygiene protocols significantly reduce the risk of reinfestation and associated expenditures.

The control area was assumed to be 1,500 hectares, representing targeted spot herbicide treatments and follow-up maintenance in priority conservation zones and high-value cultural sites. The control cost per hectare was set at AU$5,500, reflecting multi-year integrated control programs that include initial herbicide application, mechanical removal, and repeated follow-up treatments to prevent regrowth. This estimate is consistent with South Australian and NT strategic plans, which report average costs ranging from AU$5,000 to AU$10,000 per hectare for large-scale buffel grass eradication in rugged terrain (Biosecurity SA, 2019; Buffel Grass Weed Advisory Committee, 2024). Historical case studies also document similar cost ranges for intensive control in high-value areas (Friedel et al., 2009a).

A 10-year control cycle was applied as the repeat interval for major interventions, consistent with NT weed management planning horizons and the persistence of buffel grass seedbanks, which require long-term monitoring and periodic re-treatment to maintain low-density conditions (Buffel Grass Weed Advisory Committee, 2024; Farrell & Gornish, 2019).

Table 5. Input values for buffel grass management

Input	Value	Unit	References
Road buffer length[1]	60	km	Buffel Grass Weed Advisory Committee (2024)
Buffer maintenance cost[2]	1,200	AU$/km/yr	Buffel Grass Weed Advisory Committee (2024); NTG (2025)

Hygiene protocols (washdown etc.)[3]	35,000	AU$/yr	Ferdinands et al. (2010); Friedel et al. (2009a)
Control area[4]	1,500	ha	Biosecurity SA (2019); Buffel Grass Weed Advisory Committee (2024)
Control cost per ha[5]	5,500	AU$/ha (multi-year)	Friedel et al. (2009a)
Control cycle (years)[6]	10	years	Buffel Grass Weed Advisory Committee (2024); Farrell and Gornish (2019)

[1] Represents the total length of road requiring a 10-m buffer on either side to reduce buffel spread along disturbed linear corridors. [2] Includes the annual cost of slashing, targeted spot-spraying, and small-scale mechanical removal along road verges. [3] Covers the annual operating cost of vehicle and machinery wash-downs, contractor fleet hygiene compliance, and on-site prevention procedures. [4] Refers to the estimated extent of buffel-invaded land requiring periodic herbicide treatment, manual follow-up, and access-control activities. [5] Reflects the average multi-year cost of integrated buffel-control programs, including herbicide application, manual removal, monitoring, and follow-up treatments. [6] Indicates the typical interval between full control treatments, acknowledging buffel's capacity for re-establishment and the need for periodic re-treatment in arid environments.

The total annual cost of AU$932,000 comprises buffer maintenance, hygiene protocols, and annualised control programme costs. This figure provides a realistic estimate of the financial commitment required for a comprehensive buffel grass management strategy for 1,500 ha in central Australia, as recommended in the NT and SA weed management frameworks (Biosecurity SA, 2019; Buffel Grass Weed Advisory Committee, 2024).

Table 6. Total annual cost of buffel grass management

Outputs	**Value**	**Unit**
Annual buffer maintenance	72,000	AU$/yr
Annual hygiene (washdown facilities) cost	35,000	AU$/yr
Control programme (annualised)	825,000	AU$/yr
Total annual cost	932,000	AU$/yr

4.2.2 Fire regime intensification (suppression & asset protection)

The analysis assumes one wildfire event per year as a conservative financial benchmark under pre-invasion conditions[4], representing the baseline frequency in arid and semi-arid rangelands dominated by native grasses (van Etten & Burrows, 2018). This estimate reflects historical fire patterns in central Australia, where fire occurrence is primarily driven by seasonal rainfall and fuel continuity (Friedel et al., 2014; NTG, 2022).

The cost per wildfire event under pre-invasion conditions was set at AU$1,085 (2025 value), reflecting typical suppression costs for low-intensity fires in native grasslands in the NT (Table 7). These fires generally require minimal resources for containment and pose limited risk to infrastructure (Beaumont et al., 2018).

Following the invasion of buffel grass, both the frequency, spatial extent and intensity of wildfire events have increased substantially, and this pattern is now well documented for

[4] By assuming one event per year ($F_{pre}=1$) for native grasses, the analysis establishes a conservative lower bound for the "natural" management liability. Since the actual ecological frequency is often lower (decadal), using an annual baseline ensures that the calculated "Incremental Fire Cost" accurately reflects the additional burden imposed by the invasion, rather than overestimating pre-invasion risk.

central Australia (Miller et al., 2010; NTG, 2022; Weed Management Branch, 2015). Fire return intervals, which were historically long and closely tied to episodic high-rainfall periods, are now much shorter, with fires spreading further and burning into previously unburnt or lightly affected non-buffel grass areas (Schlesinger et al., 2013; Schlesinger & Westerhuis, 2021). This shift reflects the grass–fire feedback loop created by buffel grass: increased fine-fuel loads → more continuous fuels → higher ignitability → more frequent and extensive fire fronts → further buffel grass expansion.

In the Alice Springs municipal area, residents report multiple extensive fires within a single 12-month period in the urban fringes (DLPE. 2025a). Accordingly, we adopted a conservative central estimate of 5 fire events per year under post-invasion conditions, compared with 1 event in native grass systems (Table 7). This estimate is derived through triangulation of (i) reported observations from the Buffel Grass Have Your Say Survey (DLPE, 2025a); (ii) qualitative evidence from stakeholder consultations and survey responses indicating multiple fire occurrences per season; and (iii) consistency with the ecological literature describing buffel grass–driven increases in fire frequency associated with enhanced fine-fuel continuity and reduced fire-return intervals (Miller et al., 2010; Schlesinger et al., 2013; Schlesinger & Westerhuis, 2021).

This central estimate reflects observed local conditions and aligns with the well-established grass-fire feedback mechanism in invasive grass systems, where increases in fine-fuel load and continuity lead to more frequent and extensive fires (Miller et al., 2010; Schlesinger et al., 2013; Schlesinger & Westerhuis, 2021). It is important to note, however, that this value should not be interpreted as an upper bound. Nevertheless, the available ecological evidence (Schlesinger & Westerhuis, 2021) and consistent stakeholder observations (DLPE, 2025a) support a clear shift from infrequent, rainfall-driven fire regimens to more recurrent seasonal fire activity. The increased number of fire events, combined with their extended run lengths and higher flame heights, significantly elevates annual suppression and asset-protection costs.

Buffel grass produces 2–3 times as much combustible material as native grasses (Biosecurity SA, 2019), resulting in fires that are significantly hotter and more frequent. Because of this intensity, these fires require 10 to 20 times the personnel and equipment needed to extinguish a single native grass fire (Beaumont et al., 2018). We used a conservative cost of AU$2,893 (2025 value) corresponding to aerial response costs that include the deployment of water-bombing aircraft (both fixed-wing and helicopters), which are typically not required for standard native grass fires (Setterfield et al., 2013). It should be noted that this cost parameter was derived from gamba grass fire management in the NT's Top End, where aerial suppression infrastructure is operationally established. Full water-bombing capacity has not been routinely deployed in central Australia. During the 2019 West MacDonnell Ranges fire, for instance, large air tankers were not mobilised due to budgetary and logistical constraints (Chlanda, 2019). This estimate should therefore be interpreted as a potential aerial suppression cost under a scenario where adequate infrastructure is in place, rather than a reflection of current operational practice.

The stand-by costs represent the daily burden of maintaining emergency readiness on high-risk days (Table 7). In response to high-intensity grass fires, stand-by costs for fire agencies (including water-bombing aircraft and specialised personnel) have risen to an average of AU$16,000 (2025 value) per day in the NT (Beaumont et al., 2018) for a regional benchmark of 30 fire-ban days per annum (documented for the Vernon region, which mirrors the severe fire-weather requirements triggered by high fuel loads) (Setterfield et al., 2013). A further pressure not quantified here is the growing overlap between southern and northern fire seasons, which may reduce surge capacity across the NT by requiring firefighting resources to be maintained for longer periods and over a wider geographic area.

Finally, the annual asset repair cost covers the damage to property and infrastructure (fences, utilities, outbuildings) caused by more intense fires. The annual property damage from invasive grass fires in the NT is estimated at $1.5 million (Beaumont et al., 2018), a cost parameter justified by comparably high fuel loads and infrastructure exposure in the Alice Springs riparian zone. Scaling the regional benchmark to the municipal level yields an estimated annual repair liability of AU$300,000 (Table 7).

Table 7. Annual cost for fire regime intensification

Input	Value	Unit	Refences
Pre-buffel grass wildfire events per year[1]	1	events	van Etten and Burrows (2018)
Pre-buffel grass cost per event[2]	1,085	AU$/event	Beaumont et al. (2018)
Post-buffel grass wildfire events per year[3]	5	events	DLPE (2025a)
Post-buffel grass cost per event[4]	2,893	AU$/event	Setterfield et al. (2013)
Stand-by days[5]	30	Days/year	Beaumont et al. (2018)
Stand-by equipment cost per day[6]	16,000	AU$/day	Setterfield et al. (2013)
Annual asset repair[7]	300,000	AU$/yr	Beaumont et al. (2018)

[1] One event per year reflects the low baseline fire frequency typical of native-grass arid systems, where discontinuous fuels, sparse ground cover, and long inter-fire intervals suppress ignition spread under natural conditions. [2] One event per year reflects the low baseline fire frequency typical of native-grass arid systems, where discontinuous fuels, sparse ground cover, and long inter-fire intervals suppress ignition spread under natural conditions. [3] The assumed increase to five events per year functions as a starting condition before sensitivity adjustments. [4] Reflects the elevated resource demands associated with buffel grass-fuelled fires, which burn faster and require greater aerial and ground suppression input. [5] Indicates the estimated period each year during which fire-ban conditions necessitate operational readiness. Invasive grasses extend the severe fire-weather season, requiring crews and equipment to remain on stand-by for longer durations. [6] Represents the cost of maintaining aircraft readiness, heavy tankers, grading machinery, remote firefighting bases, and personnel needed for rapid response under elevated fuel-risk conditions. [7] Captures recurring damage to fences, signage, water infrastructure, utilities, and culturally significant sites caused by more frequent fires in landscapes affected by buffel grass.

The annual incremental fire cost under buffel grass-invaded conditions compared to the pre-buffel grass spread is estimated at AU$890,484 under the original baseline frequency assumption (four wildfire events per year), but sensitivity modelling that incorporates increased post-invasion fire frequency shows substantially higher annual costs (Table 8). When wildfire frequency increases by 50–150%, consistent with empirical evidence that buffel grass drives more frequent and extensive fires in central Australia (Schlesinger & Westerhuis, 2021), the annual incremental fire cost rises to AU$873,660–AU$927,180. This escalation reflects the combined effect of higher suppression demand, increased stand-by requirements during prolonged severe-fire periods, and recurrent asset damage.

Table 8. Annual incremental fire cost management of buffel grass with increased fire frequency

Scenario	Post-invasion events	Suppression cost difference (AU$)	Standby cost (AU$)	Asset repair (AU$)	Annual incremental fire cost (AU$)
Base	5	13,380	480,000	300,000	793,380
+50% frequency	7	93,660	480,000	300,000	873,660
100% frequency	9	120,420	480,000	300,000	900,420
+150% frequency	11	147,180	480,000	300,000	927,180

This figure is likely a conservative lower bound. While no equivalent longitudinal data exist for buffel grass-driven fire management in central Australia, the trajectory observed in comparable invasive grass systems is instructive: fire management costs in gamba grass-invaded areas of the Top End increased ninefold over a decade (Setterfield et al., 2013), suggesting that cost escalation under sustained buffel grass expansion could be substantial. For example, if a major fire event impacts high-value cultural assets, such as sacred river red gums, or primary municipal infrastructure, the consequential cost for that single year could significantly exceed the annual average (NTG, 2019).

4.3 Non-market costs of buffel grass

4.3.1 Restoration of land for biodiversity conservation

Biodiversity conservation was valued using an ecological restoration cost method, which estimates the minimum expenditure required to restore degraded sites to an ecologically functional state. This revised assessment uses AU$2,250/ha/yr (2025 value), derived from Schlesinger et al. (2020), the mean annual cost of slashing and spot spraying at the West MacDonnell Ranges, NT (AU$1,832/ha/yr in 2020 dollars, inflated using the ABS CPI). The mean of AU$1,832/ha/yr (range: AU$0–3,848/ha/yr across dry and wet years) reflects sustained management effort over five years, including initial slashing and annual spot spraying.

Restoration costs are applied to a representative affected area of 1,000 ha, a conservative and spatially bounded proxy consistent with the scope of this assessment. This yields an estimated annual biodiversity cost of AU$2,250,000, or AU$2,250/ha/year (Table 9). This figure should be interpreted as a conservative lower bound on the cost of maintaining ecological function in a representative buffel grass-invaded landscape. The true extent of restoration liability across the NT is substantially larger; buffel grass occurs widely across pastoral land, conservation reserves, and Aboriginal land trusts, often at a far greater scale (Puckey & Albrecht, 2004; Ryan-Colton, 2022), but falls outside the quantitative scope of this assessment and is acknowledged as a key limitation (Section 7.6).

Table 9. Annual cost of restoring biodiversity

Input	Value	Unit	References
Buffel grass cover footprint[1]	1,000	ha	This assessment
Restoration cost[2]	2,250	AU$/ha/yr	Schlesinger et al. (2020); inflation adjusted (2025)
Annual biodiversity cost estimate	2,250,000	AU$/yr	This assessment

[1] A standardised unit of 1,000 ha is applied for consistency with the per-hectare framework used across all impact categories in this assessment. [2] Reflects a lower-intensity management regime of slashing and spot-spraying.

4.3.2 Cultural site degradation

We estimated the annual restoration cost of a 100-ha plot, which serves as a proxy for its cultural value. We assumed: (i) buffel grass in Alice Springs creates dense infestations needing repeated control; (ii) cultural sites require fencing, plant restoration and ranger supervision; (iii) buffel grass intensifies fire regimes necessitating fire-breaks and post-fire works; and (iv) municipal corridors and river systems drive persistent re-infestation and inspection workloads (Table 10).

Table 10. Annual restoration cost of cultural sites

Category	Value	Unit	References
BCC (buffel grass control)[1]	2,250	AU$/ha/yr	Schlesinger et al. (2020)
CRC + FMC + MPC (cultural restoration, fire mitigation and monitoring)[2, 3, 4]	10.23	AU$/ha/yr	Read et al. (2020); Stoeckl et al. (2023)
Sacred site area[5]	100	ha	NTG (2019)
Annual restoration cost	226,023	AU$/yr	This assessment

[1] Lower-intensity regime of slashing and spot spraying. [2] Conservative national aggregate for Indigenous cultural values. [3] Targeted sanctuary management. [4] Frequent monitoring and incursion management for a protected sanctuary. [5] 10 km river stretch with a 100 m buffer.

The annual restoration cost of AU$226,000 reflects the severe externalities of buffel grass to cultural sites: fire damage, cultural degradation, access loss, and ongoing reinvasion pressure, documented across central Australia. However, this estimate does not reflect the diverse cultural values of sacred sites, as Lhere Mparntwe (Todd River) and Anthelke Ulpeye (Charles River) corridors are central features in the cultural landscape and are inextricably linked to the spiritual laws and traditions of the Mparntwe people (NTG, 2019), which are irreplaceable.

4.3.3 Scenic amenity reduction

The analysis assumes a conservative figure of 250,000 visitors per year to Uluṟu–Kata Tjuṯa National Park (UKTNP) (Australian Government, 2026). This park is highly valued for its natural scenery and cultural significance, and buffel grass invasion has been documented to diminish visual amenity by creating dense monocultures and altering landscape character (Buffel Grass Weed Advisory Committee, 2024; Department of Lands Planning and Environment (DLPE), 2025a).

The estimation of annual scenic-amenity loss for Uluṟu-Kata Tjuṯa National Park begins with the adjusted park's annual visitation figure of 125,000 visitors, who are WTP to restore buffel grass-related scenic degradation. This number reflects the substantial volume of domestic and international tourists who travel to the region for its cultural, aesthetic, and experiential values (Australian Government, 2026). Given that scenic quality is a core component of the visitor experience, even modest declines in visual amenity can lead to meaningful aggregate welfare losses when applied across such a large visitor population.

To translate this visitor experience impact into economic terms, an adjusted WTP value of AU$7.00 per visitor was applied. This value is intentionally conservative. It incorporates both the proportion of visitors likely to express positive WTP for protecting scenic values and the understanding that not all visitors will directly perceive or respond to buffel grass intrusion. The adjustment follows best-practice non-market valuation methods that recognise heterogeneity in visitor preferences and use benefit-transfer techniques appropriate for protected-area contexts (Tisdell, 2012).
The biophysical basis for the scenic-loss calculation is captured in the estimated 3,000 ha of buffel grass-affected area in Uluṟu-Kata Tjuṯa National Park, i.e. 2.1% of the total park area of 141,000 ha. This figure integrates buffel grass presence across major habitat types, including sandplains and sandstone ranges, as documented in recent remote-sensing and ecological mapping efforts (Box et al., 2025). Although this figure appears small in proportional terms, buffel grass disproportionately affects visually prominent sites such as run-on zones, creek lines, and the base of iconic formations. As a result, its visual impact exceeds its raw spatial footprint. Thus, the 2.1% figure functions more as a landscape-integrated exposure estimate rather than a simple areal proportion.

The final derived metric, the annual scenic-amenity reduction of AU$93,085, represents the aggregated loss in visitor welfare attributable to buffel grass-related degradation of visual landscape quality (Table 11). This estimate reflects both conservative economic assumptions and ecologically grounded exposure estimates. It should be interpreted as a lower-bound valuation, capturing measurable welfare effects without incorporating harder-to-quantify cultural, experiential, or reputational impacts associated with landscape transformation in a World Heritage setting. As such, the estimate is appropriately framed as a financially modest but substantively meaningful indicator of the external costs imposed by buffel grass on nature-based tourism values in the region.

Table 11. Annual cost of scenic amenity reduction

Input	**Value**	**Unit**	**References**
Adjusted visitors per year[1]	125,000	visitors	Australian Government (2026)
WTP per visitor[2]	7.00	AU$/visitor	Tisdell (2012)
Buffel grass cover[3]	3,000	ha	Box et al. (2025)
Total UKTNP area[4]	141,000	ha	Box et al. (2025)
Proportion of UKTNP affected by buffel grass[5]	2.1	%	This assessment
Annual scenic amenity reduction[6]	93,085	AU$/yr	This assessment

[1] Annual visitation estimate of 250,000 for UKTNP, based on Australian Government tourism reporting for the region. [2] A conservative willingness-to-pay value reflecting visitor heterogeneity and partial visibility of buffel-related scenic degradation, derived from protected-area non-market valuation approaches discussed by Tisdell (2012). [3] Represents the estimated area of buffel grass-affected habitat within UKTNP, based on mapped contributions from sandplains and sandstone ranges. [4] Total park area estimate used as the denominator in calculating proportional buffel grass-affected extent, based on spatial analysis from Box et al. (2025). [5] Calculated as the share of buffel-affected area (3,000 ha)

relative to total park area (141,000 ha). This percentage represents a conservative spatial exposure measure and does not capture disproportionate visual prominence of buffel grass in high-use areas. [6] Resulting estimate from multiplying visitor numbers by adjusted WTP and the proportion of the park affected by buffel grass. This figure provides a lower-bound valuation of scenic-amenity loss attributable to buffel grass within UKTNP.

4.4 Total economic impact: marketable and nonmarketable costs and benefits

4.4.1 Standardised buffel grass impacts

The annual estimates across all benefit and cost categories were standardised to a per-hectare basis using conservative 1,000 ha of total affected area values (Table 12).

Table 12. Standardised annual costs and benefits of buffel grass (undiscounted, base-year 2025)

Impact	Annual benefit/cost (AU$)	Buffel grass cover (ha) accounted for this area	Standardised value (AU$/ha/yr)
Benefits			
Forage benefit	80,100	1,000	80
Erosion control	32,200	1,000	32
Total benefits	**112,300**		**112**
Costs			
Buffel grass management	932,000	1,000	932
Fire regime intensification	793,380	1,000	793
Restoration of land for biodiversity conservation	2,550,000	1,000	2,550
Cultural site degradation[1]	226,023	100	2,260
Scenic amenity reduction	93,085	1,000	93
Total costs	**4,294,488**		**6,328**
Net benefits (benefits minus costs)	**-4,482,188**		**-6,216**

[1] Standardised value derived from a representative 100 ha sacred site (10 km river stretch with 100 m buffer). The per-hectare value is carried forward for cross-category comparisons without being rescaled to 1,000 ha.

4.4.2 Net benefit per hectare per year

The comparison between benefits and costs on a per-hectare basis demonstrates a striking imbalance: current estimates indicate that the social, cultural, ecological, and fire-related losses generated by buffel grass invasion outweigh pastoral benefits by roughly 56. In practical terms, this means that each additional hectare of buffel grass-dominated landscape imposes close to AU$6,216/ha/year in external costs, while generating only AU$112/ha/year in grazing and erosion control benefits. This disparity highlights the fundamental asymmetry between private gains, largely accruing to pastoralists, and the public burdens borne by communities, Traditional Owners, conservation agencies, and public land managers.

The negative per-hectare net benefit (costs of buffel grass for other than the pastoral sector) observed in the analysis is not an anomaly but a structural feature of buffel invasion economics. The fact that incremental expansion reliably produces net losses provides an economic basis for prioritising prevention, containment, and strategic control. Rather than framing buffel grass management as a cost to government or landholders, this evidence positions proactive intervention as a financially prudent investment that avoids far larger long-term losses. From an ecological economics perspective, prevention is not only cheaper than large-scale restoration, but also the only strategy capable of avoiding the accelerating externalities caused by the spread of buffel grass.

5 Sensitive analysis of buffel grass expansion

5.1.1 Scenario analysis of buffel grass expansion

The scenario analysis of buffel grass expansion across 1,000 hectares reveals consistently negative economic outcomes across all discount rates and evaluation horizons. The annual net cost, derived from the standardised values in Table 12, is dominated by biodiversity loss (AU$2,250/ha/yr) and cultural site degradation (AU$2,260/ha/yr for the representative 100 ha sacred site), which together far outweigh the modest positive contributions from forage production (AU$80/ha/yr) and erosion control (AU$32/ha/yr). When aggregated across 1,000 hectares, this amounts to an annual net cost of approximately AU$4.18 million, providing the foundation for the net present value calculations presented in Table 13.

Table 13. Incremental NVP of an additional 1,000 ha of buffel grass spread across 5%, 7% and 9% discount rates

Horizon	**5%**	**7%**	**9%**
Short (5yrs)	-18.1M	-17.1M	-16.3M
Medium (20yrs)	-52.1M	-44.3M	-38.2M
Long (30 yrs)	-64.3M	-51.9M	-43.0M
Long + (50yrs)	-76.3M	-57.7M	-45.8M

In the short term (5 years), the incremental NPV remains substantially negative across all discount rate scenarios, ranging from roughly –16.3 million to –18.1 million. Even over this relatively constrained time horizon, the magnitude of annual biodiversity and cultural losses quickly overwhelms any short-term gains from pastoral productivity. This result underscores that, even within a limited planning window often favoured by operational land managers, buffel grass expansion imposes immediate and material costs on ecological and cultural assets that cannot be offset by increased livestock carrying capacity or marginal improvements in soil stability.

Over a medium-term horizon (20 years), the cumulative economic burden of buffel grass intensifies significantly, with NPVs ranging from –38.2 million to –52.1 million dollars, depending on the discount rate. At this timescale, the persistence of annual ecological degradation is particularly influential; the workbook's restoration-based valuation estimates biodiversity losses at a sustained, very high annual cost, which compounds over time despite discounting. Because many ecological, cultural, and fire-related costs accumulate nonlinearly and are not easily reversible, the medium-term perspective makes clear that buffel grass expansion leads to entrenched and escalating losses that are much larger than typically acknowledged in narrow pastoral productivity analyses.

The long-term (30 years) projections deepen this pattern, producing NPVs ranging from –43.0 million to –64.3 million dollars. What is notable at this horizon is the way discount rates moderate, but cannot eliminate, the magnitude of net losses. Higher discount rates (e.g., 9%) substantially reduce the weight of long-term ecological harm, yet even under this economically conservative assumption, the losses remain economically significant. The persistence of fire-related costs, management expenses, and cultural loss valuations ensures that the negative annual net impact does not diminish over time; instead, it contributes to a sustained compounding of losses that reflect the long-lived, landscape-altering nature of buffel grass invasion.

Finally, the long-term (50-year) horizon highlights the lasting and intergenerational implications of buffel grass spread. NPVs range from –45.8 million to –76.3 million dollars, even after substantial discounting. These results illustrate that once buffel grass becomes established across a large area, the cumulative costs, particularly biodiversity impacts, cultural landscape degradation, and elevated fire regimes, persist indefinitely and dominate any initial or ongoing pastoral benefits. The long-term analysis thus indicates that buffel grass is not merely a short- or medium-term management challenge but a deeply transformative ecological disturbance with long-run economic consequences. From a policy and land-use planning perspective, this timescale is highly relevant: it captures the realities of ecological recovery timelines, intergenerational cultural stewardship, and the irreversible nature of major shifts in vegetation structure.

Across all discount rates and time horizons, the results are consistent: incremental expansion of buffel grass beyond its current footprint produces large net economic losses. The reason is structural: incremental benefits are modest and static (AU$112/yr in total), while incremental costs are large (AU$4,294/yr), cumulative, and, in several cases, irreversible.

5.1.2 Incremental change (scenario B – scenario A)

The core purpose of defining two A and B scenarios is to isolate the incremental effects of further spread of buffel grass. Scenario A captures existing locked-in conditions and management obligations, while Scenario B captures the additional impacts, both positive (incremental forage benefits) and negative (ecological, cultural, fire, tourism, and infrastructure impacts), arising solely from expansion into new areas.

Thus, the difference between Scenario B and Scenario A (i.e., B – A) represents the true marginal cost or benefit of allowing buffel grass expansion beyond its current footprint. This incremental change is the appropriate quantity for NPV estimation, because it avoids double-counting baseline impacts and focuses solely on the consequences of future decisions about buffel grass management, containment, or permissive expansion.

Across all evaluation time horizons (5, 20, 30, and 50 years) and discount rates (5%, 7%, and 9%), this incremental NPV isolates the time-discounted economic contribution of expansion:

- In the short term, expansion may yield small pastoral gains, but ecological and cultural losses begin accumulating immediately.
- In the medium and long term, negative externalities dominate overwhelmingly, resulting in strongly negative incremental NPVs.

- At low discount rates, long-lived impacts such as biodiversity loss and cultural degradation weigh more heavily, generating larger negative NPVs.
- At higher discount rates, long-term effects are de-emphasised, but even under 9% discounting, the incremental NPV remains substantially negative.

These scenarios show that the economic consequences of buffel grass expansion depend almost entirely on the incremental externalities generated by Scenario B. While Scenario A requires ongoing management efforts to maintain containment, Scenario B introduces substantial new ecological, cultural, fire-related, and landscape costs that far outweigh incremental pastoral benefits. The incremental NPV framework clearly demonstrates that allowing buffel grass to expand beyond its current footprint results in significant long-term economic losses across all discount rates and time horizons.

6 Qualitative assessment (Part 2)

Part 2 of this assessment presents the qualitative findings from semi-structured interviews and open-ended survey responses, and integrates them with the quantitative model outputs reported in Part 1. Open-ended survey responses[5] were combined with thematically coded material from six semi-structured expert interviews: a botanist (Participant 1), a community health professional and environmental advocate (Participant 2), a community housing and Aboriginal services professional (Participant 3), an Indigenous Ranger Programme Coordinator (Participant 4), a Pastoral Expert (Participant 5) and a Caring for Culture & Country Manager (Participant 6). Themes 1, 2, 3, 5 and 6 correspond to cost and benefit domains identified in the valuation framework. Themes 4 and 8 are emergent themes arising exclusively from the interview and survey data and represent a gap in the current economic estimates of this report.

6.1 Qualitative thematic analysis

The qualitative data corpus comprised transcripts from six semi-structured interviews conducted with key stakeholders across pastoral, conservation, Indigenous land management, and community health sectors, supplemented by open-ended survey responses from 102 participants. Eight themes emerged from this process: fire regime intensification and landscape transformation; biodiversity and ecological decline; cultural site degradation and loss of access to Country; tourism, scenic amenity, and visitor experience; pastoral production benefits and their perceived limits; management challenges, resource constraints, and governance failures; public health and community well-being; and opportunity costs borne by Indigenous town camps and homeland communities. These themes are presented in the sections that follow, with each grounded in direct participant accounts and cross-referenced against the quantitative findings of this report to identify points of convergence, complementarity, and divergence

6.1.1 Theme 1: Fire regime intensification

Fire risk was the most salient theme across all qualitative data sources (102 surveys and six semi-structured interviews) and the domain with the strongest quantitative convergence: 84.3% Likert agreement, 68.3% direct experience, and the top-ranked management priority (mean rank 2.06). Survey respondents described buffel grass as

[5] Refer to Appendix E to see survey data

fundamentally transforming the fire environment of the Alice Springs municipal area, events characterised as more frequent, more extensive, harder to suppress, and increasingly threatening to residential safety, infrastructure, and ecological assets. This perception aligns with the empirical literature documenting that buffel grass creates continuous fine-fuel beds capable of sustaining landscape-scale fire spread under conditions that would not support ignition in native vegetation (Miller et al., 2010; Ryan-Colton et al., 2024; Schlesinger et al., 2013).

"Areas that previously would have experienced fire only during episodic high-rainfall intervals can now 'burn really frequently' as buffel grass provides a persistent and rapidly regenerating fuel source."
Participant 1; interview conducted 24 March 2026

All six interview participants identified altered fire behaviour as one of the most significant observable consequences of buffel grass establishment in central Australia, consistent with the modelled incremental fire cost of AU$793,380/year in this report. Participant 1 described the progressive transformation of mulga (*Acacia aneura*) woodlands, where the dominant species is highly sensitive to repeated burning, into simplified grass-dominated systems, consistent with Ryan-Colton et al.'s (2024) findings on long-term ecosystem state transitions driven by buffel grass-fire feedbacks. Participant 1 observed that dead mulga skeletons in buffel grass-dominated areas would be incinerated in the next fire, leaving no trace: a tipping point beyond which ecological recovery is practically foreclosed. Participant 1 described transitioning from a childhood experience of no fires in Alice Springs to present-day weekly fire events during the season. While this is a subjective lifetime observation rather than systematic monitoring data, it is directionally consistent with documented reductions in fire-return intervals in buffel grass-invaded arid landscapes (Schlesinger & Westerhuis, 2021).

Participant 5, drawing on pastoral experience, provided a nuanced perspective: while acknowledging that buffel grass produces higher and more persistent fuel loads than native arid grasses, he noted that the distinctive burning behaviour of buffel grass, burning slower but longer and hotter than short arid grasses, creates particular difficulties for fire suppression using standard dry-firefighting techniques. This operational dimension is not captured in the current fire cost parameters, which are derived primarily from event frequencies and suppression costs rather than difficulty-of-suppression metrics.

Participant 2 described a direct personal experience of fire risk near residential areas, including a buffel grass-fuelled fire that threatened her property in Ilparpa in 2023 and multiple fire events at Pitchi Richi and Simpsons Gap within the same period. She also reported that smoke from buffel grass-fuelled fires in 2023 generated formal health alerts for the central Australian and Barkley region and increased hospital presentations and admissions, a cost pathway that intersects with the health-related impacts reported in the survey but is not quantified in Part 1. Participant 4 highlighted an occupational health and safety dimension: the tendency of buffel grass to accumulate as seed and dry matter in and under vehicles creates fire risk to vehicles and their occupants, a pathway with direct cost implications for ranger programmes and remote community access that is not addressed in the current cost modelling framework.

Participant 6 provided particularly detailed operational experience from Uluṟu-Kata Tjuṯa National Park, describing the near-impossibility of controlling buffel grass-fuelled fires using dry firefighting methods. Participant 6 noted that buffel grass fires require water suppression rather than the rake-hoe clearance techniques used for spinifex, and that once ignited, buffel grass fires spread so rapidly that standard operational responses are inadequate. This finding is consistent with the conservative approach taken in this report, which applied gamba grass fire cost parameters with a downward adjustment for lower buffel grass fuel loads; the operational evidence suggests that the per-event suppression difficulty in park and cultural site contexts may be underestimated.

Survey open-ended responses (n = 74 respondents) documented fire proximity to residential properties, smoke-affected commuting and outdoor activities, infrastructure damage, and multi-agency emergency response requirements. One respondent described *"Teams and teams of people involved to fight the fires. We have had buffel [grass] fires directly opposite our house. Spouse has at times been unable to attend after-hours commitments due to being called out to fight fires"*. Another noted *"several per year and increasing over the past 5 years. Hotter, larger fires lasting for a much longer period"*. These accounts provide independent experiential grounding for this report's fire cost model (AU$793,380/yr incremental; frequency assumption: 1→5 events/yr), but do not independently establish causal attribution.

One survey respondent who identified as a fire management professional noted: *"Working in fire management, I have seen firsthand the damage buffel [grass] causes to the environment, cultural assets and life"*, and another documented fighting five separate fires in 2023. Participant 3 described multiple fire-related road closures that isolated remote communities and prevented residents from accessing essential services in town. This last observation extends the fire impact narrative beyond direct property damage to include access equity and the disruption of essential services for remote Aboriginal communities.

6.1.2 Theme 2: Biodiversity loss and landscape transformation

Perceived biodiversity loss was the second most strongly endorsed harm category (83.2% Likert agreement), and impacts on plants and animals were the most frequently reported experienced impact (76.2%). Survey respondents and interview participants described widespread and progressive vegetation homogenisation across the Alice Springs region. Participant 1 described unpublished experimental plot data comparing treated and untreated sites on a peri-urban Alice Springs property, noting approximately 40–50 species in successfully weeded plots compared with as few as three to five in buffel grass-dominated controls. While these data remain unpublished and cannot be independently verified, their directional character is corroborated by the buffel grass literature (Bonney et al., 2017; Edwards et al., 2019; Ryan-Colton et al., 2024; Schlesinger et al., 2013; Schlesinger et al., 2020; Wright et al., 2021).

"Alice Springs used to be a hotspot for wildflowers and things. Now you'll only find wildflowers where people have been actively weeding."
Participant 1; interview conducted 24 March 2026

Interview participants unanimously described the observed decline in biodiversity, supporting this report's biodiversity restoration cost estimate of AU$2,250/ha/year. Participant 1 noted that recovery on cleared sites was demonstrable within experimental timeframes, providing direct observational support for the reversibility assumption embedded in Part 1's restoration cost approach and consistent with published research (Schlesinger et al., 2020; Wright et al., 2021). Survey respondents elaborated the biodiversity dimension in several directions: one described *"a massive area of open land… absolutely covered in buffel grass… not all just nice flat land that you can jump on a ride-on mower"*; another documented *"loss of overstory due to fire at Simpsons Gap NP; loss of biodiversity in a study north of Old Telegraph Station"*; and a third noted *"Reduction in the wildflower displays that were once characteristic of central Australia"*.

Participant 4 also reported the loss of spinifex (*Triodia spp.*) from areas now dominated by buffel grass, with consequent impacts on the spinifex ecosystem and associated cultural practices. Spinifex resin (kitty), derived from burning *Triodia pungens*, is a culturally significant material used to produce tools and implements across central Australia. Participant 4 also noted the displacement of native millet grass seeds, used traditionally for grinding into damper, from buffel grass-invaded landscapes, though the specific species identity of these seed grasses could not be confirmed from the interview transcript alone and warrants verification against the primary botanical literature before any taxonomic attribution is made. The loss of these plant resources represents a compound cultural impact, not only the disruption of material culture dependent on spinifex resin, but also of food systems built around native seed harvesting, both of which are documented as foundational practices in arid-zone Indigenous economies.

Participant 6 noted that they had watched repeated burning of buffel grass convert diverse shrubland with bloodwoods, hakeas, and diverse native grasses into virtual monocultures over a decade, a trajectory they attributed to the failure of land managers to follow up burning with herbicide treatment, consistent with the evidence from Schlesinger et al. (2020) that sustained management is essential for the recovery of native vegetation. The broader survey data strongly reinforce these interview findings, with impacts on plants and animals being the most frequently selected experiential item (75%), providing broad public corroboration for the expert assessments.

Survey respondents with on-ground management experience provided cost data relevant to biodiversity restoration. One Landcare-active respondent reported *"1,750 person hours and 4,400 L of herbicide used to manage buffel grass on roughly 10 ha of land within the Alice Springs municipality"*; another reported spending *"over the last 3 years… over $1.2 million on herbicide, contractors and staff"*; a third estimated AU$100,000 per annum for their organisation. These self-reported cost figures, while not independently audited, are of the same order of magnitude as the estimated biodiversity restoration cost of AU$2,250/ha/yr applied to modest treatment areas, providing a plausibility check on the economic parameters without superseding them.

6.1.3 Theme 3: Cultural site degradation

Cultural site threats were endorsed by 81% of Likert respondents, and 44.6% reported direct experience of the loss of culturally important sites. Two Indigenous respondents who completed the cultural questions described qualitatively distinct and grave impacts. One noted: *"We don't go to places we used to go because it is dangerous, roadways are washed out and overgrown with buffel [grass] so you can't see where you can drive, people don't like walking around on country that is covered in buffel [grass] because it is dangerous"*. A second, describing nearly 20 years as a ranger with Parks and Wildlife and the Central Land Council, confirmed direct observation of buffel grass's effects on the environment and native plants and animals, and referenced effects on cultural practice and Country management capacity. In the 'What has changed for you?' item, both respondents who answered identified: harder access to sites; fire impacting important sites, plants, and animals; fewer and harder-to-find bush foods; and teaching young people on Country becoming harder.

"Near-destruction by buffel [grass]-fuelled fire of a sacred River Red Gum that had been a central cultural landmark along the Todd River for generations, attributed to inadequate management buffers around the site."
Participant 2; interview conducted 23 March 2026

Three interview participants provided detailed evidence of buffel grass impacts on cultural sites, access to Country, and intergenerational knowledge transmission, directly corroborating this report's cultural site restoration cost estimate (AU$226,023/year for a representative 100-ha sacred rivers complex). Participant 4 described situations in the region and the southwest of the NT where buffel grass had so thoroughly covered cultural sites, sacred objects, and grave sites that, on every visit, knowledge holders were required to locate features that were once freely accessible. He used the phrase, *“if my ancestors were to come back from 150 years ago and walk this country, they would get lost”*, as a summation of landscape transformation that has direct implications for the intergenerational transmission of spatial and ecological knowledge, a non-market impact that the restoration cost proxy in this report does not fully capture, consistent with the critique of Manero et al. (2022) regarding the limitations of restoration cost approaches for valuing inherently relational and non-substitutable cultural values.

Participant 6 described decades of direct experience with local Indigenous custodians' concerns about buffel grass, including the destruction of a women's sacred site through buffel grass infestation, the choking of springs (now without water), and the documentation of the women's testimony that there are no more pretty flowers anymore, referring to the native wildflower displays that previously characterised run-on zones now dominated by buffel grass. They also recounted a significant incident on a visit with young people to a homeland on the Northern Territory-South Australia border, when immediate distress was evident when the group encountered a landscape lacking the bush foods and cultural markers they associated with country from their childhood experiences. This case is consistent with Caron et al. (2021) and Kulitja (2024), illustrates how buffel grass invasion functions as a mechanism of cultural discontinuity that is not merely a biophysical change, but an erasure of the ecological foundation on which cultural knowledge, ceremony, and identity depend.

Participant 2 reported the destruction of one of Alice Springs's most culturally significant trees, a large River Red Gum, which was identified by Albert Namatjira (Arrernte painter from the MacDonnell Ranges) as a subject of his paintings and surrounded by a protective fence, when buffel grass within the small unmanaged area around the tree ignited in a buffel grass-fuelled fire. This case exemplifies the intersection of cultural heritage, ecological change, and fire regime documented in Section 4.2.3 and illustrates why the AU$226,023/year cultural site restoration estimate is likely a conservative lower bound.

This narrative illustrates a mechanism documented in the ecological literature that buffel grass-fuelled fires threaten the large old trees that define cultural landscapes across arid river systems (Schlesinger & Westerhuis, 2021). Survey data reinforce a limitation acknowledged in this report that no primary stated-preference valuation research has been conducted with Arrernte Traditional Owners, meaning the restoration cost proxy is likely to underestimate the true non-substitutable value of affected landscapes.

6.1.4 Theme 4: Health and well-being impacts

Health impacts constituted a recurring and analytically significant theme. Pollen allergies (53.5%) ranked fifth among experienced impacts, above loss of culturally important sites, establishing health as a widespread rather than marginal dimension of buffel grass harm. Survey open-ended responses elaborated the health burden: *"I am an asthmatic and struggle with allergies when the buffel is releasing its pollen. Aboriginal people who are more likely to suffer from chronic illness, have depleted immunity and are more prone to respiratory illness and therefore more impacted"*; *"My hayfever has become acute when I walk our dog around the nearby streets and beside the river"*; *"After big storms a lot of people get hay fever due to the high pollen in the air"*. Survey comments also explicitly called for health cost analysis: *"The health impacts of buffel [grass] must be considered" and "Dust carrying microbiome — impact on human health"*.

Participant 2 drew on professional public health nursing experience to note that the 2023 fire season prompted a formal public health alert across the Central Australian region and that hospital presentations increased during elevated smoke periods. Participant 3 similarly described the health dimension of buffel grass-fuelled fires on Indigenous community residents, noting the absence of coordinated evacuation support during the 2023 season. Participant 3 further observed that the NT lacks a formal animal welfare response to fire events, with no institutional mechanism for euthanising burnt livestock or conducting wildlife welfare assessments in the aftermath of buffel grass-fuelled fires; a governance gap that compounds the broader social and ecological costs of intensified fire regimes.

Participant 1's qualitative estimate of health costs in the hundreds of millions over the medium term cannot be independently verified and should be treated as a directional signpost rather than an empirical finding. From an ecological economics perspective, health costs constitute a cross-sector externality analogous to the fire regime externality modelled in Section 4.2.2: costs are borne by the public health system and affected individuals rather than by those who generate buffel grass biomass accumulation, creating a market failure that strengthens the justification for regulatory intervention.

Participant 4 identified health and well-being impacts at the community level, describing how the physical inaccessibility of Country due to buffel grass density was contributing to reduced engagement with bush-based activities by young people, increased community boredom and social distress, and a deterioration of mental health and cultural well-being that he linked to disconnection from Country, consistent with Garnett et al. (2009) and the Healthy Country, Healthy People framework of the Aboriginal and Torres Strait Islander Health Plan.

6.1.5 Theme 5: Tourism, scenic amenity and visitor experience

Scenic beauty was recognised by 79.4% of Likert respondents, with a mean score of 4.25/5. Both tourism respondents (n=2) strongly agreed across all four tourism-specific Likert items, including scenic quality impact, visitor satisfaction, visitor unawareness, and major business impact, a unanimous response suggesting severe impact on the tourism sector, though the very small sample size precludes generalisation. Participant 1 described Alice Springs as historically a hotspot for wildflower tourism, with diverse native forb assemblages now largely confined to actively managed Landcare sites. Participant 1 characterised extensive buffel grass-dominated sections of the Larapinta Trail as 'depressing' for ecologically informed visitors, a view consistent with research on the impacts of invasive species on nature-based tourism (Molina et al., 2019).

"I had a disorientating flash of not recognising Anzac Hill—a prominent town landmark—on returning after an absence. The hill was now almost completely covered in buffel [grass]".
Participant 2; interview conducted 23 March 2026

Survey respondents described trail inaccessibility, landscape identity loss, and safety concerns: *"Unable to find or navigate trails due to high buffel growth. At times higher risk due to hidden rocks, erosion, drop offs—and even several snakes!"*; *"Buffel grass makes mountain biking and 4WDing around the town particularly dangerous"*; *"The red centre is no longer the red centre"*. A survey comment explicitly framed the tourism stakes: *"Alice Springs is known for its natural environment, First Nations culture and leadership and world-class tourism, buffel grass invasion is an existential threat to this community and the region, transforming the colour, spirit and place into a buffel [grass]-fuelled inferno"*. Section 4.3.3 estimated scenic amenity losses at AU$93,085 per year for Uluṟu-Kata Tjuṯa National Park (UKTNP), explicitly acknowledged as a lower-bound estimate excluding fire-related closures and cultural landscape degradation. The survey data confirm this characterisation and indicate that scenic and tourism impacts extend well beyond UKTNP to encompass town-facing landscapes, the Larapinta Trail, and urban river environments.

6.1.6 Theme 6: Pastoral production and erosion control benefits

The pastoral sector's perspective was more complex than the dominant harm narrative, reflecting buffel grass's dual role as a declared weed and a commercially valued pasture grass. All ten surveyed grazers strongly agreed that buffel grass improves carrying capacity and drought resilience. Pastoral respondents provided liveweight gain estimates ranging from 20% to 100% (mean approximately 50–70% for those who responded), consistent with the enterprise model in Section 4.1.1. Cattle operation scales reported ranged from 2,000 to 50,000 head, confirming that the pastoral sector's relationship with buffel grass is economically material to those operations.

However, pastoral respondents were not uniform advocates for expansion. Several explicitly acknowledged increasing fire management costs on their properties, and one stated*: "Roughly $5,000 annually and might be more if we get a fire, and 1,000 times that if we get a drought and there's no buffel grass to feed the cows"*, an honest acknowledgement of the contingent and volatile nature of the pastoral benefit. Participant 1 challenged the policy equivalence between existing buffel coverage and further expansion: sufficient coverage already exists for pastoral viability, making new seeding into currently native-dominated areas difficult to justify ecologically or economically. Multiple survey comments called for a pastoral levy to offset community costs: *"Pastoralists need to contribute to the management of buffel [grass]... the meat they produce is not to supply the local market... a levy on pastoralists to fund buffel [grass] remedial action"*. This view is consistent with the market failure analysis: private benefits accrue to pastoral operators while public costs are borne across government, communities, and the environment.

Participant 5 provided the most technically detailed pastoral perspective, drawing on primary industries experience. They offered several observations that nuance the binary framing of the buffel grass debate. First, they documented a near-total die-off of buffel grass during the 2017–2019 drought period, estimated at up to 99% of tussock loss on plains and 65% in watercourses, followed by a mass germination event in 2020 that produced denser buffel grass cover than had existed before the drought. This observation, which is not reflected in the current report parameterisation, points to a specific volatility in buffel grass dynamics under prolonged drought. During the dieback phase, buffel grass ceases to function as a forage resource, exposing pastoral enterprises to feed deficits that the current carrying capacity estimates do not account for (Friedel et al., 2014). Following drought-breaking rainfall, buffel grass typically recovers to densities exceeding pre-drought levels, producing heavier and more continuous fuel loads that intensify the grass-fire feedback cycle (Ryan-Colton et al., 2024; Schlesinger et al., 2013). The net effect is that drought does not reset buffel grass to a more manageable state but rather amplifies both its competitive dominance and its fire-related externalities over successive rainfall cycles, a dynamic with material implications for both the pastoral benefit estimates and the fire cost parameters in the current model. Second, they argued that in pastoral contexts where cattle graze regularly, buffel grass remains patchy and co-exists with native species at levels that do not occur in ungrazed national parks, a landscape-level dynamic that supports the mosaic management approach without endorsing unrestricted expansion. Third, he emphasised the importance of not conflating good seasons with buffel grass-related change: the unprecedented five-year run of above-average rainfall since 2020 has increased fuel loads across all grass types, and some of the fire events attributed to buffel grass may reflect climatic drivers as much as invasion dynamics.

The pastoral sector divergence identified in the survey is consistent with the body of literature documenting systematic differences in how pastoral and conservation stakeholders perceive buffel grass costs and benefits (Friedel et al., 2008; Friedel et al., 2011; Marshall et al., 2011). These divergent perceptions do not indicate that one group is incorrect; they reflect genuinely different distributional outcomes from buffel grass in pastoral versus non-pastoral contexts. The incremental NPV framework adopted in this report is explicitly designed to isolate marginal costs and benefits of new expansion, rather than to adjudicate the historical value of existing buffel pastures, a distinction that is critical for policy communication with pastoral stakeholders.

6.1.7 Theme 7: Governance and institutional capacity

The critically low satisfaction with current management (77.2% rating 1 or 2 out of 5) was accompanied by a rich qualitative account of governance failures, resourcing inadequacy, and compliance gaps. Participant 1 identified the absence of systematic buffel grass distribution mapping as a fundamental barrier to strategic prioritisation: without knowing where buffel grass is and where the active expansion fronts are, resource allocation cannot be evidence-based. This corresponds directly to the single highest-priority data gap identified in this and the companion report.

Survey comments were extensive and pointed. Selected verbatim excerpts capture the breadth of governance concerns: *"The NT Draft Buffel Weed Management Plan is a disgrace allowing an exemption for pastoral leaseholders"*; *"Get buffel grass listed as a weed of national significance and get federal funding"*; *"Council be quicker and better at responding to buffel [grass] explosion after rain events when the ground is wet and before it seeds"*; *"The trade off of time — there needs to be more work done to inspire, engage rural residents and find ways for Landcare, NTG Buffel Team and others to better coordinate"*; *"Create pilot buffel [grass]-free zones especially around cultural, touristic sites and biodiversity corridors... Act before seeding"*. Participant 2 raised structural concerns about the independence of biosecurity policy assessment processes and the commercial relationships governing the selection of management approaches.

All interview participants addressed the efficacy of existing management approaches, identifying a consistent set of institutional, operational, and motivational barriers. Participant 1 described the Todd River Landcare site, where years of intensive management had brought buffel grass to near-depletion in the seed bank, only for a single flood event to reintroduce massive quantities of seed from upstream, undoing years of work. They characterised the absence of mapping data as the single largest strategic deficit, noting that effective management requires knowledge of where the fronts are to intercept rather than merely respond to the spread. This observation directly supports the recommendation that comprehensive GIS mapping is the highest-priority data investment.

Participant 6 described a fundamental motivational and institutional failure: that even within a national park with an explicit no-tolerance policy, adequate equipment, and dedicated staff, day-to-day operational management of buffel grass is undermined by a lack of follow-up culture. They documented situations in which months of intensive treatment proved ineffective, where opportunities for follow-up control of regenerating plants were missed in practice. This observation is consistent with Farrell and Gornish (2019), who identify sustained, multi-year follow-up as the non-negotiable requirement for effective integrated buffel grass control, and is directly relevant to the adaptive funding and workforce planning recommendations in Report 2 (Section 8.4). Participant 5, presenting the pastoral sector perspective, noted that the 2024 declaration had generated more regulatory complexity without significantly changing operational reality, and that resources and clear management methods are more important to effective management than legislative instruments.

Participant 2 raised the issue of governance capture, arguing that management decisions are influenced by the herbicide industry through organisations that receive government biosecurity contracts, creating incentives to favour chemical approaches over integrated management. While this claim requires independent verification and is made from an advocacy position, it points to a legitimate policy concern: the independence and transparency of cost-benefit analyses used to justify management approaches, a concern directly relevant to the positioning of this economic assessment as an independent government-commissioned report.

6.1.8 Theme 8: Town camp and community costs

Participant 3, drawing on five years of direct operational experience managing housing and municipal services across Alice Springs's 17 Aboriginal town camps and multiple remote homelands, documented a cost stream entirely absent from this report that the diversion of Aboriginal community essential services budgets to buffel grass management. Participant 3 reported that Tangentyere Council, the resource and advocacy body for Alice Springs's 17 town camps, was operating at 100% of crew time on buffel grass management at the time of the interview, with four crews (each comprising a team leader, supervisor, and six workers) committed entirely to the task. Under normal circumstances, these crews perform a range of municipal services, hard waste removal, infrastructure maintenance, and community training. The opportunity cost of diverting this capacity to buffel grass management was thus: foregone training, foregone infrastructure maintenance, and foregone service delivery, none of which appear in our cost framework presented in Section 3.4.

"They estimated that roughly 75% of their resources go into buffel grass management just normally, and at the moment it's 100%. That's four crews full-time, probably for the next couple of months, just trying to get on top of the buffel grass."
Participant 3; interview conducted 9 April 2026

At the homelands scale, Participant 3 described one large homeland, a former cattle station claimed under the Land Rights Act, deploying 25 workers full-time for two months, at an estimated 50 person-hours per week plus tractor and equipment hire, to manage buffel grass across the property. Core funding of approximately AU$1.8 million per year for municipal and essential services, normally covering a range of housing and community functions, was being consumed entirely by buffel grass management during post-rain periods. Participant 3 further documented town camp communities incurring fire mitigation costs for land adjacent to commercial infrastructure (a large gas facility near Trucking Yards town camp) that the government had declined to fund, despite the commercial operator bearing no such obligation.

Participant 3 also identified a related structural inequity in access: homelands on small excisions from pastoral properties are surrounded by a sea of buffel grass, with pastoral operators under no obligation to manage the buffel grass at boundaries. The communities, many of whom are among the poorest in Australia, must fund their own fire protection and buffel grass management to protect government-funded housing assets worth AU$700,000–$1,000,000 per dwelling. This constitutes a market failure in which the costs of an externality generated by one land use category are borne by adjacent communities that have no capacity to prevent reinfestation from neighbouring unmanaged land.

6.2 Integrating the quantitative and qualitative assessments (Parts 1 and 2): finding convergence and divergence

Table 14 summarises the degree of convergence between survey and interview findings and the quantitative economic outputs of the market and non-market valuation of this study. The matrix follows the side-by-side convergence approach described by Creswell and Poth (2016). Convergence is indicated where both data streams point in the same direction; complementarity is indicated where one stream provides mechanistic or contextual detail that the other cannot; divergence is indicated where the two streams produce potentially contradictory signals. The qualitative assessment reflects thematic correspondence rather than statistical matching.

Table 14. Convergence between stakeholder survey findings, expert interview material, and quantitative economic estimates from the market and non-market valuation assessment

Theme	Quantitative finding (survey)	Qualitative finding (interview)	Assessment
1. Fire regime intensification	84% Strongly agree/Agree; 2nd most frequent experience (n=69)	Unanimous; detailed operational evidence; difficulty of suppression underestimated	**Convergent**
2. Biodiversity loss and landscape transformation	82% agreement on biodiversity decline; most frequent experience	Species richness data; irreversible shrubland-to-grassland transitions documented	**Convergent**
3. Cultural site degradation	81% agreement on cultural site degradation; 44% reported loss of culturally important sites	Extensive evidence: cultural discontinuity beyond physical site damage, loss of bush food, Country transformation	**Convergent**[1]
4. Health and well-being impacts	53.5% of respondents reported pollen allergies; fire smoke and dust were identified as health risks	Participant 1: hospital admissions; smoke events; Participant 4: cultural well-being decline	**Complementary** (survey captures prevalence; interviews explain mechanisms)

5. Tourism, scenic amenity and visitor experience	79.4% agreement on scenic value loss	Impacts on the Larapinta Trail and West Mac Ranges; tourist expectation mismatch	**Convergent**
6. Pastoral and erosion control benefits	40.2% agree buffel grass improves pasture; pastoral grazers (n=10) all strongly agree on carrying capacity and drought resilience, but note fire management costs; ranked lowest management priority by the full sample.	Participant 5: improved carrying capacity is real but context-dependent; drought buffer is important; monoculture risk is acknowledged; some evidence of benefit on degraded roadsides, but not universal	**Complementary**[2] (sector divergence explained by context)
7. Governance and institutional capacity	78% very dissatisfied with the current buffel grass management	Mapping gap; follow-up failure; institutional barriers; adaptive funding needed	**Convergent**
8. Town camp and community costs	Not captured in the survey	Participant 3 interview: 17 town camps with 100% of crews on buffel grass control; 40 person-hours/week for 2 months on one homeland	**Emergent** (qualitative only; estimate gap)

Note. [1]Cultural site convergence is strong within the modelled riparian corridor scope, but survey and interview evidence extends cultural impacts beyond this proxy area to songline paths, ceremonial sites, seasonal bush food areas, and remote homelands. [2]Dust/erosion and pasture benefit convergence is 'Complementary' because the survey population, which under-represents pastoral workers, produces a contested aggregate signal; pastoral grazers (n=10) consistently report the benefits, while the non-pastoral majority disagree or are neutral.

The findings from the stakeholder survey and expert interviews provide broad convergent validation for the economic estimates from the market and non-market valuation assessment. The seven domains quantified in Section 4, pastoral benefits, erosion control benefits, buffel grass management costs, fire regime costs, biodiversity loss, cultural site degradation, and scenic amenity, are all corroborated by the qualitative data, with varying degrees of convergence. The strongest convergence is found in the three highest-cost domains: fire regime intensification, biodiversity loss, and cultural site degradation. This is analytically significant because it is precisely these three domains that drive the negative incremental NPVs across all scenarios in Section 5.1.1, and their qualitative validation strengthens confidence in the overall policy conclusion that buffel grass expansion generates large net economic losses for the NT.

Pastoral workers represent 11% of the survey sample, but their mean scores on cost-oriented items are three to four scale points below all other respondent sectors; a difference large enough to substantially shift aggregate means if the pastoral sub-group were larger or more evenly distributed. This pattern reinforces the conclusion of Friedel et al. (2008; 2011) and Marshall et al. (2011) that the buffel grass debate is structurally resistant to resolution through perception surveys or community consultation alone, because the distribution of costs and benefits across stakeholder groups is fundamentally asymmetric. Policy processes that treat survey data as a simple proxy for net social benefit risk understating the public burden of buffel grass if pastoral sector responses are weighted disproportionately. The incremental NPV framework adopted in this report explicitly separates private pastoral benefits from public externalities, which is the appropriate analytical response to this structural asymmetry.

The identification of town camp and homeland opportunity costs as an emergent qualitative theme, derived from consultation with Participant 5, represents the most significant gap finding of this analysis (see Section 6.1.8). This theme 8 documents the systematic diversion of housing, municipal services, and employment resources in remote areas into buffel grass management, a cost domain captured neither in the economic modelling framework of this report nor in the management cost scenarios of Report 2. The evidence provided by Participant 3 suggests that the total cost of buffel grass management borne by Aboriginal community organisations within and adjacent to the Alice Springs municipal area, estimated at AU$1.8 million per year in core funding alone, before accounting for Remote Area Employment Service wages, may represent a cost stream comparable in magnitude to the Scenario 1 direct management cost estimate of AU$297,500–$535,000 per year in Report 2. This does not mean the estimates are comparable in scope (Report 2 Scenario 1 covers a different operational domain), but it does suggest that the existing quantitative framework is likely to substantially undercount the true public cost of reactive management by excluding Indigenous community sector costs from its scope. This gap warrants explicit acknowledgement as a limitation of both the economic impact assessment and the management cost scenarios report and should be prioritised for quantification in any future assessment of buffel grass impacts in the Alice Springs municipal area.

The health dimension (Theme 7) represents a second significant gap. The high prevalence of self-reported pollen allergies (53% of survey respondents) and the documented association between buffel grass-fuelled fire smoke and hospital admissions (Participant 2, interview data) constitute a cost pathway that is potentially quantifiable through existing health economics methods. The magnitude of this cost is currently unknown, but Participant 2's suggestion that it could reach hundreds of millions of dollars is not unlikely given the scale of the health system in central Australia and the frequency and severity of recent fire events. Future assessments should commission a dedicated health impact study using hospital admission data, emergency department records, and pharmacy-level allergy medication dispensing data to provide an evidence-based lower-bound estimate.

7 Discussion

7.1 Interpretation of economic findings

The results of this economic impact assessment provide an unambiguous economic signal that incremental expansion of buffel grass beyond its current distribution in the NT produces substantial net losses across all tested scenarios, discount rates, and evaluation horizons. The standardised per-hectare analysis reveals a structural imbalance in which pastoral and erosion-control benefits amount to approximately AU$112/ha/year, while the combined external costs, spanning biodiversity loss, cultural site degradation, fire regime intensification, management expenditures, and scenic amenity reduction, total more than AU$6,328/ha/year (Table 12). This roughly sixty-fold asymmetry between public burdens and private gains is not a product of extreme assumptions; it persists consistently across all discount rates and time horizons tested. When aggregated across the 1,000 ha modelling unit, the annual net cost amounts to approximately AU$4.18 million, generating incremental NPVs ranging from -AU$16.3 million to -AU$18.1 million over 5 years, -AU$38.2million to -AU$38.2 million to -AU$52.1 million over 20 years, -AU$43.0million to -AU$64.3 million over 30 years, and -AU$45.8million to -AU$76.3 million over 50 years, across discount rates of 9%, 7%, and 5% respectively (Table 13). These findings are consistent with international evidence demonstrating that invasive grasses generate externalities that overwhelm private returns, particularly once fire-regime feedbacks and non-market costs are incorporated (Fusco et al., 2019; Setterfield et al., 2013).

As set out in section 3.7, all benefit and cost parameters are expressed as annual per-hectare flows associated with a common 1,000 ha modelling unit and discounted over identical time horizons; the comparison is symmetric at the margin throughout. What the analysis does reveal, and what may account for the perception of asymmetry, is a distributional asymmetry that is itself a substantive finding that pastoral benefits from new buffel grass spread accrue almost entirely to private operators, while the costs of that spread are borne predominantly by public agencies, Traditional Owners, conservation bodies, and the tourism sector. This structure, in which private benefits are concentrated and public costs are diffuse, is precisely what the TEV framework is designed to make visible. It is not an artefact of the analytical method; it is a property of buffel grass invasion economics that the method accurately captures. The appropriate response to this distributional finding is not to augment the benefit side with historical pastoral values that predate and are independent of any incremental spread decision, but to treat the asymmetry as evidence of a market failure that justifies regulatory intervention, as the NT Government's 2024 weed declaration already reflects (DLPE, 2026).

A key contribution of this study is the integration of non-market values, biodiversity restoration, cultural heritage, and scenic amenity into the cost-benefit framework through the TEV approach (Costanza et al., 1997b; Costanza et al., 2014). Biodiversity loss, valued at AU$2,550/ha/year (Bonney et al., 2017; Friedel et al., 2009a; Wright et al., 2021), for ecological restoration, emerges as the dominant cost driver, accounting for the overwhelming share of total per-hectare losses. This finding aligns with ecological assessments showing that buffel grass drives non-linear, potentially irreversible regime shifts in native plant communities, which are ecologically costly to remediate (Abella et al., 2012; Ryan-Colton et al., 2024). It is important to note that the loss of biodiversity is irreversible, with costs beyond marketable measures that will be borne by present and future generations.

The qualitative–quantitative integration provides an important line of triangulation for these economic findings and shows complementary results. Across the survey and interview material, stakeholders consistently described the same cost domains that dominate the economic model, especially fire regime intensification, biodiversity loss, cultural-site degradation, and declining scenic and visitor values. This convergence is analytically significant because several monetary estimates in this report rely on conservative transfer values and proxy methods; the qualitative evidence shows that these are not abstract categories but lived, repeatedly observed burdens across the region. At the same time, the integration identified additional unquantified costs, particularly health impacts and town camp and homeland opportunity costs, indicating that the negative net results reported here are more likely to be understated than overstated.

7.2 Pastoral benefits and diminishing marginal results

The pastoral sector has historically been the principal beneficiary of buffel grass, which provided transformative productivity gains during its establishment phase in central and northern Australia from the 1970s to the 1990s (Friedel et al., 2006; van Klinken & Grice, 2006). However, this assessment, consistent with the literature, finds that the marginal value of additional buffel grass spread is considerably smaller than these historical gains suggest. The partial DCF model applied in this study, drawing on enterprise-level parameters from Bowen and Chudleigh (2018) and Watt et al. (2023), yields a net annual pastoral benefit of approximately AU$80/ha for additional buffel grass-supported production under the modelled expansion scenario, relative to the no-expansion baseline; this is substantial in absolute terms but dwarfed by the off-property costs. Extrapolating this figure for a pastoral property of 100,000 ha (given that the average property size in the NT is >200,000 ha), applying 50% of the area as productive pasture returns an average benefit of $4,000,000 per annum (which we acknowledge is still an overestimate given that ABARES 2026 data reveals an average farm cash income of $2,036,000 for the beef production in the NT (ABARES, 2026).

The need to distinguish between existing pastoral value and future land-sector opportunity is reinforced by Russell-Smith and Sangha (2019), who argue that beneficial land-sector change in northern Australia is both necessary and feasible. Their response to McLean and Holmes (2019) does not dismiss the pastoral industry, but instead highlights that long-term viability depends on improved business management, sustainable natural resource stewardship, and diversification into complementary ecosystem service markets. These include savanna burning, carbon and biodiversity markets, conservation employment, Indigenous land management, ecotourism, and other multifunctional land uses. For the present assessment, this supports a cautious interpretation that buffel grass benefits and the existing buffel-based production can be economically important for some pastoral enterprises, but this does not automatically justify further spread where the marginal gains are outweighed by fire, biodiversity, cultural, and public management costs.

Several mechanisms explain why incremental expansion produces diminishing returns. First, the most productive and responsive land has already been converted to buffel grass-dominated pasture; expansion now occurs into more marginal areas with lower rainfall, poorer soils, and reduced pasture responsiveness (Friedel et al., 2006; Patidar et al., 2023). Second, nutrient rundown in older buffel pastures progressively reduces soil fertility and pasture quality, requiring costly management interventions to maintain productivity (Bowen & Chudleigh, 2019; Dalal et al., 2021). Third, the homogenisation of groundcover reduces the resilience of pastoral systems to rainfall variability, increasing production risk during drought periods (Elledge & Thornton, 2022; Thornton & Elledge, 2021). Pastoralists themselves recognise these dynamics: qualitative research by Marshall et al. (2011) and Friedel et al. (2009b) documents widespread acknowledgement that fire risk, management costs, and loss of native shade species reduce the net value of further expansion in already buffel grass-saturated landscapes.

The qualitative findings refine this interpretation by showing that pastoral benefits are real but highly context-dependent and do not support a general argument for continued spread. Pastoral respondents and Participant 5 confirmed improvements in carrying capacity and drought resilience in established buffel pastures, but they also acknowledged increased fire-management costs, variable performance across seasons, and the importance of distinguishing between existing productive use and expansion into new areas. This distinction is critical for policy interpretation: the evidence from Section 6 suggests that many of the strongest pastoral benefits are tied to historically established buffel grass systems, whereas the major incremental costs arise when buffel grass expands into native-dominated, culturally significant, conservation, or settlement-adjacent landscapes.

This study deliberately operationalises an incremental NPV framework to isolate the marginal costs and benefits of the new buffel grass spread, rather than assessing the historical total value of existing buffel pastures. This distinction is critical for the policy sector. The question before the NT Government is not whether buffel grass has historically benefited pastoralism, it has, but whether permitting further spread delivers net societal benefits. Framed in this way, the answer is consistently negative. Two pastoral values that fall outside the incremental model merit explicit acknowledgment here to avoid misrepresenting the total economic contribution of buffel grass to the NT pastoral sector. The first is carrying capacity. Buffel grass has delivered substantial increases in stocking rate across southern NT relative to native-grass baselines, with enterprise-level modelling reporting ranges of 161-384 steers per 1,000 ha, depending on rainfall zone and pasture utilisation strategy (Bowen et al., 2021; Cameron, 2013). These gains are concentrated in land already under buffel grass and already contributing to production; they represent the historical, total value of buffel grass to established enterprises, which is a distinct quantity from the marginal value of additional spread assessed here. The second is feed security. The comparatively slow detachment rate of buffel grass relative to native annual species means that standing biomass retains nutritional quality through the dry season, functioning as a reserve feed source that buffers pastoral enterprises against the production risk inherent in years of low or failed rainfall (Bowen et al., 2021; Watt et al., 2023). This risk-management function constitutes a genuine enterprise-scale benefit not captured by the per-hectare incremental estimate, which models consistent annual production rather than the episodic, highly variable production cycles that characterise central Australian beef enterprises.

These acknowledged values do not alter the fundamental conclusion of the incremental analysis. The policy question before the NT Government is specifically whether permitting further buffel grass spread beyond its current distribution delivers net societal benefits at the margin; it is not whether existing buffel pastures provide value to the enterprises that depend on them, which they demonstrably do. At the margin, the evidence remains consistent that the most productive and rainfall-responsive land has already been converted to buffel grass-dominated pasture, so new spread now occurs predominantly into more marginal environments where forage benefits are lower and social-ecological costs are higher (Friedel et al., 2006). The total carrying capacity and feed security contributions of existing buffel grass stands, while real and material, do not alter the cost–benefit trajectory of incremental expansion into non-pastoral and peri-pastoral landscapes, where fire intensification, biodiversity loss, and cultural site degradation are the dominant outcomes.

7.3 Fire regime intensification as a cross-sectoral externality

Buffel grass-driven fire regime intensification constitutes one of the most consequential externalities associated with continued spread. The grass-fire feedback loop documented in the literature, whereby buffel grass accumulates large quantities of dry, continuous biomass that fuels hotter, faster, and more frequent fires, which in turn create space for further buffel grass colonisation, transforms complex native vegetation communities into simplified, fire-prone grasslands (Friedel et al., 2014; Grice et al., 2012; Miller et al., 2010). Studies in central Australia consistently show that buffel grass invasion increases fuel loads and fire intensity, leading to more extensive and costly fire regimes (Friedel et al., 2009a; Read et al., 2020), although precise cost multipliers relative to native grass fires remain under-quantified. Therefore, the annualised incremental fire cost of AU$793,380 estimated for the study area, incorporating suppression cost differentials, stand-by expenses, and asset repair, is likely conservative, given that fire costs are known to escalate non-linearly as buffel grass cover expands.

Importantly, the long-term biodiversity consequences of buffel grass-driven fire regimes extend far beyond ground-storey vegetation. Repeated high-intensity fires lead to the loss of critical habitat components, such as mature shrubs, hollow-bearing trees, and perennial food plants, and are predictive of declines in invertebrate, reptile, bird and mammal assemblages across arid and semi-arid landscapes over time and with continued spread at the landscape scale. Studies in central Australia have shown that buffel grass-fuelled fires kill large old trees, remove structural refuge, and promote ecosystem shifts from diverse native communities to simplified grass-fire systems, meaning that the cumulative biodiversity losses over the coming decades are expected to be substantial (Ryan-Colton et al., 2024; Schlesinger et al., 2013; Schlesinger & Westerhuis, 2021).

A critical feature of fire-related externalities is that they are disproportionately borne by the public rather than by pastoral operators who benefit from buffel grass's forage productivity. Public fire management agencies, local governments, road and utility authorities, tourism operators, and Indigenous communities all bear costs associated with elevated fire frequency and intensity that are not reflected in pastoral enterprise accounts (Friedel et al., 2008; Friedel et al., 2009a; Friedel et al., 2009c). This constitutes a textbook example of market failure, in which marginal private benefits diverge from marginal social costs (Costanza et al., 1997a; Daly & Farley, 2004). From a policy and state/territory perspective, this divergence provides a strong justification for regulatory intervention: without government action, private actors face insufficient incentives to limit buffel grass spread, because the costs of doing so fall largely on society rather than on those who benefit from it.

Section 6 adds important operational depth to this fire externality. Interview participants described buffel grass-fuelled fires as qualitatively different from fires in native arid grass systems: harder to suppress, more persistent, more dangerous for crews, and more disruptive to transport, community access, and public health than standard event-frequency estimates alone can capture. Participants also identified pathways not currently included in the quantified fire equation, including smoke-related health warnings and hospital presentations, fire risk to ranger vehicles from accumulated seed and dry matter, and the isolation of remote communities during repeated fire-related road closures. These qualitative findings reinforce the conclusion that fire costs are one of the most consequential and socially distributed impacts of buffel grass, and suggest that the current annual fire-cost estimates should be interpreted as conservative lower-bound values rather than full social-cost estimates.

7.4 Cultural and non-market costs

Cultural impacts represent a distinctive and ethically significant category of externality that has been systematically undervalued in previous economic assessments of buffel grass (Friedel et al., 2008; Marshall et al., 2011). This study estimates an annual restoration cost of AU$226,023/year for a representative 100-hectare sacred rivers complex in Alice Springs municipality, encompassing buffel grass control, cultural plant restoration, fire mitigation, and monitoring.

The qualitative evidence indicates that these cultural costs extend well beyond the physical restoration of a representative sacred-site footprint. Interview and survey participants described buffel grass as disrupting access to Country, reducing the availability of bush foods and culturally important plants, obscuring sacred features, and undermining Elders' and rangers' ability to teach younger people on Country. In this sense, the cultural cost of buffel grass is not limited to site damage alone, but includes a broader process of cultural discontinuity in which ecological change erodes the material basis of knowledge transmission, ceremony, and identity.

The non-substitutable nature of cultural values makes them particularly difficult to incorporate into standard economic frameworks (Manero et al., 2022; Russell et al., 2020). Indigenous valuation frameworks emphasise that Country and cultural heritage are relational, collective, and intergenerational, and cannot be adequately represented by market-based proxies alone (Sangha et al., 2024; Sangha et al., 2015; Sangha et al., 2019; Stoeckl et al., 2021). The restoration-cost approach adopted in this study provides a defensible minimum estimate of cultural loss, but it necessarily understates the full extent of harm, since no financial expenditure can fully recover lost cultural heritage, access to sacred sites, or the intergenerational transmission of knowledge interrupted by buffel grass invasion (Bowman, 2018).

This limitation reinforces the case for prevention: if restoration costs already yield strongly negative NPVs, the true cost of cultural loss, which by its nature cannot be reversed, is likely higher still. In areas subject to landscape-scale invasion, buffel grass may threaten not only individual cultural sites but the broader conditions that enable people to live on, care for, and maintain connection with Country. These broader harms are not fully captured by restoration-cost proxies, suggesting that the cultural costs estimated here remain a conservative minimum.

Scenic amenity loss represents one of the more subtle but socially significant and meaningful impacts of buffel grass invasion, particularly in landscapes where visual character and naturalness are central to cultural identity, tourism appeal, and public enjoyment. In the economic analysis underpinning this study, scenic loss is quantified at approximately AUD$93,085/year for the affected areas in Uluṟu-Kata Tjuṯa National Park. Although this monetary value appears small compared with the far larger biodiversity and cultural losses, it represents only the measurable portion of more diffuse aesthetic change. Buffel grass fundamentally alters the visual structure of central Australian landscapes: replacing patchy, species-rich native grasslands and open woodlands with uniform buffel grass swards (Read et al., 2020; Schlesinger & Westerhuis, 2021), reducing visual diversity, and eroding iconic red-earth landscapes that visitors and Traditional Owners strongly associate with the character of Country (Buffel Grass Weed Advisory Committee, 2024; DLPE, 2025a; Kulitja, 2024).

The qualitative integration also suggests that the tourism and amenity impacts of buffel grass are broader than those associated solely with scenic degradation. Respondents linked buffel grass to trail inaccessibility, increased hazards for walking, mountain biking and four-wheel driving, loss of wildflower displays, altered town-facing landscapes, and a diminished sense of place in iconic settings such as the Larapinta Trail, Anzac Hill, and the West MacDonnell Ranges. These accounts support the interpretation already noted in Section 4.3.3 that the scenic-amenity estimate is only a lower-bound component of a broader tourism-related externality, which also includes fire-related closures, reduced wildlife-viewing opportunities, and the degradation of culturally significant landscapes valued by both visitors and Traditional Owners. This means that scenic loss should be read not as a minor isolated cost category, but as one visible indicator of a deeper transformation of place-based value in central Australia.

7.5 Implications for policy and management

The consistency of negative incremental NPVs across all scenarios and discount rates is consistent with, and provides strong economic support for the NT Government's July 2024 declaration of buffel grass as a weed and is directly relevant to implementation of the *Buffel Grass Weed Management Plan 2026–2036* (DLPE, 2026). The Plan explicitly prioritises the protection of environmental and cultural assets and the reduction of spread along transport corridors, while allowing continued pastoral use under a permit system, subject to conditions, including assessment of site characteristics, proximity to conservation areas, and the risk of further spread. It also recognises grazing as a "reasonable measure" for managing buffel grass on pastoral land and treats some small-scale within-region pastoral uses as lower-risk, while still requiring landholders to take reasonable measures to prevent spread onto adjoining land, particularly where conservation areas or active management occur nearby (DLPE, 2026). In this context, permit decisions play a critical role in determining whether incremental spread is allowed or constrained.

Against this policy setting, the results of this assessment suggest that any permitted uses that facilitate further buffel grass expansion on pastoral land should be interpreted cautiously. While the private incremental benefits to pastoral production are modest, the associated externalities to biodiversity, cultural sites, tourism landscapes, fire management, and public land administration are large, cumulative, and disproportionately borne outside the pastoral estate. The analysis therefore supports a strict interpretation of the Plan's spread-prevention and containment requirements, especially at boundaries with conservation areas, transport corridors, and other high-value lands, where the social costs of additional spread are likely to exceed any incremental pastoral gain by a wide margin.

More specifically, the analysis provides evidence-based guidance for prioritising prevention and containment over reactive management. Because buffel grass management costs, biodiversity loss, cultural site degradation, and fire regime intensification accumulated over time are largely irreversible once threshold dynamics are triggered (Grechi et al., 2014; Ryan-Colton et al., 2024), early intervention delivers far greater net returns than delayed action. This is consistent with the principle that preventing biological invasions is substantially cheaper than controlling or eradicating them after they have established (Rossiter-Rachor et al., 2023). Hence, a cost-effective, holistic approach is required to manage buffel grass spread across the central Australian landscape.

Beyond the direct ecological and management costs quantified in this assessment, buffel grass invasion is also likely to generate substantial opportunity costs by reducing future access to emerging environmental markets and land-based income opportunities. As invasive grasses simplify native ecosystems, reduce biodiversity, and intensify fire regimes, they reduce the ecological condition and management flexibility needed to access biodiversity repair, carbon abatement, and other nature-based financing opportunities (Russell-Smith et al., 2018; Sangha et al., 2020; Sangha et al., 2021). In central Australia, this is particularly relevant because buffel grass-driven shifts in vegetation structure (Read et al., 2020) and fire behaviour (Schlesinger & Westerhuis, 2021) can undermine the integrity of landscapes that might otherwise support restoration investment, cultural land management, cultural and nature-based tourism, and the potential adaptation of savanna-burning carbon abatement approaches (i.e., shifting fire regimes to reduce emissions) to arid-zone conditions. These foregone opportunities are difficult to quantify at present and, for that reason, are not included in the formal economic model; however, their omission means the current estimates are likely conservative. In effect, buffel grass not only imposes direct costs through biodiversity loss, cultural damage, and fire management burdens, but may also restrict the NT's capacity to realise future economic benefits from healthy, functioning ecosystems and Indigenous-led land stewardship.

The relatively minor influence of pastoral benefit parameters on overall NPV suggests that arguments for permitting further spread on economic grounds are unlikely to be justified by plausible revisions to forage or erosion-control values. This does not imply that pastoral benefits should be disregarded, but it does indicate that they are insufficient to offset the societal costs of expansion, and that bioeconomic and DCF models that exclude externalities systematically overstate buffel grass's net value (Friedel et al., 2008; Friedel et al., 2009a).

The integrated findings also provide clearer guidance about management priorities and implementation barriers. Survey respondents ranked reducing fire risk, protecting biodiversity, and protecting cultural sites and water places as the highest priorities, while active control at high-value sites, fuel-load reduction with herbicide follow-up, and improved hygiene and buffer management were preferred over passive or one-off responses. Interview materials further showed that management effectiveness depends not only on funding levels but also on institutional follow-up, coordination across land tenures, and the availability of strategic mapping to identify invasion fronts and priority assets. These findings suggest that policy effectiveness will depend on shifting from reactive, fragmented control towards coordinated, spatially targeted, landscape-scale and persistently maintained management, especially in high-value cultural, biodiversity, municipal, and tourism landscapes.

These findings also suggest that buffel grass management should not be framed narrowly as a conflict between pastoral production and conservation. A more constructive policy framing is to support pastoral viability while reducing external costs and enabling diversified land-sector income streams. Russell-Smith and Sangha (2018, 2019) identify emerging economic opportunities, many of which depend on maintaining ecological function and reducing the risks posed by high-fuel invasive grasses. In this context, preventing further buffel grass spread can be understood not only as an environmental protection measure, but also as an enabling condition for future diversified land-sector economies in central and northern Australia.

7.6 Limitations and future research directions

Several limitations of the present analysis should be acknowledged. First, the per-hectare standardisation approach necessarily abstracts from spatial heterogeneity in buffel grass impacts across land types, tenure systems, cultural and ecological contexts. The costs of buffel grass invasion in and around Uluṟu-Kata Tjuṯa National Park, where high biodiversity, cultural significance, and tourism value coincide, differ markedly from the costs on pastoral leases. Future work should incorporate spatial mapping and explicit modelling, drawing on the high-resolution mapping data provided by Box et al. (2025), to produce land-type-specific cost-benefit estimates that reflect this heterogeneity.

Second, the absence of published, site-specific cultural valuation data for central Australia is a significant evidence gap, explicitly identified by Alice Springs Town Council during early stakeholder engagement. The annual restoration cost (ARC) proxy used in this study provides a conservative and defensible minimum estimate, but primary stated-preference research, such as community willingness-to-pay studies or participatory valuation with Traditional Owners, would substantially strengthen the cultural cost estimates. Such research should be co-designed with Indigenous communities and guided by AIATSIS (2020) ethics protocols and Indigenous methodological frameworks (Sangha et al., 2024).

Third, the fire cost parameters in this study are transferred from the gamba grass case studies in NT savannas (Beaumont et al., 2018; Setterfield et al., 2013), with contextual adjustments for arid central Australia. Region-specific fire cost data for buffel grass-invaded arid rangelands would improve the precision of these estimates. The qualitative-quantitative integration phase of this study, drawing on interviews and an online survey, provided partial but substantively important ground-truthing of the fire cost assumptions embedded in the economic estimates.

Fourth, this analysis does not explicitly model threshold dynamics or tipping points in ecosystem change, which are known to create non-linear cost trajectories as invasion extent increases (Grechi et al., 2014; Ryan-Colton et al., 2024). Incorporating state-and-transition modelling calibrated to local ecological data would allow future analyses to more accurately represent the escalating marginal social cost of invasion and identify thresholds beyond which remediation costs become prohibitive. This would complement the linear sensitivity analysis presented here and strengthen the economic case for early intervention.

A further limitation revealed through the qualitative–quantitative integration is that some important cost streams remain outside the present economic model despite clear stakeholder evidence of their significance. In particular, Section 6 identified recurrent health effects associated with pollen, smoke, and dust exposure, as well as substantial opportunity costs borne by Aboriginal town camps and homelands when essential-service crews and community resources are diverted to buffel grass control and fire mitigation. Subsequent research should therefore aim to quantify: (i) public-health costs linked to buffel grass exposure and buffel grass-fuelled smoke events; (ii) the opportunity costs of diverted municipal and community services in town camps and homelands; and (iii) the broader social costs of restricted access to Country and disrupted community well-being. Incorporating these domains would improve the completeness of the TEV framework and likely increase the estimated net cost of further buffel grass expansion.

8 Conclusion

The results of this economic impact assessment indicate that further expansion of buffel grass beyond its current distribution would generate large net economic losses for the NT, even under favourable assumptions. Across all discount rates, evaluation horizons, and sensitivity structures, incremental NPV estimates remain substantially negative. This outcome is directly linked to the overwhelming magnitude of social, cultural, ecological, and fire-related externalities relative to the comparatively small pastoral and erosion control benefits that buffel grass provides. The standardised per-hectare values embedded in the analysis clearly highlight this structural imbalance. While additional forage and erosion-control benefits amount to just AU$112.3/ha/year, the corresponding per-hectare external costs total AU$6,328/ha/year, driven predominantly by biodiversity loss, cultural-site degradation, fire-regime intensification, buffel grass management burdens, and scenic amenity decline.

The qualitative analysis strengthens this conclusion by showing that the modelled economic losses are consistent with stakeholders' lived experiences across central Australia. Survey and interview participants consistently identified more frequent and difficult-to-control fires, biodiversity decline, cultural-site degradation, reduced access to Country, and loss of scenic and visitor values as the most significant consequences of buffel grass spread. The qualitative data also revealed additional burdens not fully captured in the current economic framework, including health impacts associated with smoke, pollen and dust, and the diversion of essential community resources in town camps and homelands toward buffel grass control and fire mitigation. These results indicate that the economic case presented in this report is conservative: the broader social, cultural, and environmental costs of further buffel grass expansion are likely greater than those quantified here.

The main results provide a robust economic justification for prevention-focused policy, including the containment of existing infestations, strengthening hygiene protocols, and prioritising control in areas with high cultural or ecological values. Because buffel grass's highest costs accumulate over long timeframes, particularly biodiversity loss, cultural-site damage, and fire-related risk, the negative NPVs associated with marginal spread become even more pronounced at low discount rates or longer horizons. This highlights the importance of early intervention and the high cost of delayed action. The consistency of negative incremental NPVs across all scenarios, horizons, and sensitivity tests confirms that the NT faces a structurally unfavourable cost–benefit trajectory if buffel grass continues to expand. The strongest economic signal, therefore, points toward containment as the only strategy capable of preventing further, irreversible net losses, suggesting the development of collective, holistic, and sustainable landscape-scale solutions involving public and private stakeholders.

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Appendix A. Semi-structured interview guide for non-Indigenous participants

A1. Welcome and consent

Thanks for joining this conversation. This is voluntary, and you can skip questions or stop at any time.
With your permission, we would like to record our conversation so I don't miss anything. Your name won't be used in reports unless you say otherwise.

A2. Experiences with buffel grass

1. How long have you lived or worked in the Alice Springs region, and what has been your experience with buffel grass during that time?
2. What changes have you personally observed in the landscape over the last five years as buffel grass has spread?
3. Where do you see buffel grass most commonly in your region, and where is it starting to move into?
4. Are there places that are still mostly buffel-free that you think are at risk? Why?

A3. Environmental impacts you observe

1. What plants or animals do you see being most affected when buffel grass becomes dominant?
2. Can you describe any changes in fire behaviour (frequency, intensity, spread) since buffel grass became established?
3. Have buffel-related fires affected your operations, community, cultural sites, touristic places, or safety? Approximate number of events, severity, and resource needs.

A4. Management and costs

1. What kinds of buffel-control work do you or your organisation do? (Examples: herbicide, hand removal, mechanical, burning, hygiene, monitoring.)
2. How difficult or resource-intensive is this work in practice: time, people, cost, equipment?
3. Where do you feel management works well, and where does it fail or feel too costly to keep up with?

A5. Public values and landscape change

1. From a public or visitor point of view, what changes caused by buffel are most obvious: scenery, loss of native plants, fire scars, and wildlife declines?
2. Are there places where buffel grass clearly reduces the visitor experience or the 'look and feel' of the landscape?

A6. Policy and priorities

1. What are the biggest barriers to effective buffel grass management in the Alice Springs region: resources, coordination, follow-up, access, policy constraints?
2. After buffel grass was declared a weed in 2024, what practical changes did you expect, and have they happened?
3. Do you agree or disagree that the new buffel grass spread tends to create large net losses for the NT? Why?

A7. Final reflections

1. Is there anything important about buffel grass impacts or management that we haven't covered but you think decision-makers really need to understand?
2. Would you like to receive a plain-English summary of the findings?

Appendix B. Online survey instrument

This appendix reproduces the full online survey instrument used to collect quantitative and qualitative data for the Economic Impact Assessment of Buffel Grass in Central Australia. The survey was distributed via Microsoft Forms between March 2026 and April 2026 and targeted a diverse range of respondents, including residents, Indigenous community members, pastoralists, tourism operators, conservation staff, fire management personnel, and local government representatives.

The survey comprised closed-ended, Likert-scale, ranking, and open-ended questions, designed in accordance with best-practice survey methodology. Consent information, anonymity options, and Indigenous-specific identification preferences were incorporated to ensure ethical compliance with CDU HREC protocol H25132.

B1. Survey introduction and consent

Participants were presented with the following information:

- Purpose of the study
- Voluntary participation and withdrawal conditions
- Confidentiality and data handling
- Indigenous identification and acknowledgment options
- Contact information for the research team

Consent Items:

1. I have read the information above and consent to participate. Options: Yes (continue) / No (exit)

2. Are you comfortable being contacted for a follow-up interview or a results summary? Options: Yes / No

3. If yes, please provide your email and/or phone number. (Optional)

B2. About you

1. Where do you mainly live?

- Alice Springs municipal area
- Nearby community or settlement
- Visitor (non-resident)
- Prefer not to say
- Other

2. Which best describes you?

(e.g., general public, pastoralist, environmental organisation, Indigenous ranger, tourism operator, local government, etc.)

3. Do you identify as Aboriginal and/or Torres Strait Islander?

- Yes
- No
- Prefer not to say

4. Additional consent for Indigenous participants

I consent to being identified in project outputs as a named contributor (optional).

Yes / No

5. Please provide your full name, organisation, and contact details (optional).

B3. Awareness and perception

1. Overall, how concerned are you about buffel grass in Alice Springs?

Likert scale: 1 = Not concerned → 5 = Extremely concerned

2. Where have you personally noticed buffel grass in the Alice Springs region?

(Select all that apply)

3. Where have you noticed buffel grass elsewhere in Central Australia?

(Select all that apply)

4. Perception statements (Likert-scale: Strongly disagree → Strongly agree)

- Buffel grass increases fire risk near town and on Country.
- Buffel reduces native plant and animal diversity.
- Buffel helps reduce dust and erosion in some places.
- Buffel threatens cultural sites and bush foods.
- The NT Government should invest more in buffel management.
- Buffel affects the natural scenic beauty around Alice Springs.
- Buffel improves pasture production.
- Buffel reduces tourist numbers.

5. Provide up to two recent examples (benefits and/or costs) you have experienced, including location and financial/time costs if known.

B4. Local experiences

1. Which situations have you experienced in the last five years that were affected by buffel grass?

(Select all that apply)

2. How many bushfires linked to buffel grass have affected you in the last five years?

3. Describe the impact of these fire(s).

(Location, property damage, travel disruptions, health impacts, etc.)

B5. Management priorities

1. Rank the following buffel grass management outcomes for Alice Springs (drag and drop):

- Protect biodiversity
- Reduce fire risk
- Maintain scenic/visitor values
- Protect cultural sites and water places
- Improve pasture production
- Reduce impacts on infrastructure

B6. Pastoralist sector questions

1. Do you currently graze areas dominated by buffel grass?
- Yes / No

2. Compared with non-buffel pasture, how has buffel affected your enterprise?
Options: Much worse → Much better

3. Approximate buffel pasture area (ha).

4. Agreement statements (Likert scale):

- Buffel improves carrying capacity.
- Buffel contributes to pasture rundown.
- Buffel improves drought resilience.
- Buffel increases fire-management workload/cost.

5. Annual estimate of time, labour, and cost spent managing buffel grass.

6. Estimated contribution (%) of buffel pasture to cattle liveweight gain per year.

7. Number of cattle supported annually by buffel-dominated pasture.

8. Which management options would you consider if incentives were available?
(e.g., rotational grazing, mosaic burning, herbicide control, reseeding natives)

B7. Environment / Conservation / Parks / Landcare questions

1. Which control activities are used in high-value environmental areas?
(Herbicide, manual removal, fire, hygiene measures, mapping, etc.)

2. Perceived effectiveness of these methods.
Scale: Ineffective → Very effective

3. What delivers the best outcomes for buffel control in your area? (Open-ended)

4. Estimate annual buffel-management costs for your organisation.

B8. Tourism Operators / Guides

1. Perception statements (Likert scale):

- Buffel grass affects scenic quality.
- Buffel reduces visitor satisfaction.
- Visitors are unaware of buffel impacts.
- Buffel has affected my tourism business.

2. Describe the nature of these impacts.

3. Estimate additional annual costs imposed by buffel grass.

4. Any other concerns for tourism due to buffel?

B9. Fire management agencies (Bushfires NT, Volunteer Brigades, FES)

1. Relative intensity of buffel-fuelled fires compared to native grass fires.

2. Describe suppression difficulty, standby days, and asset damage.

3. Number of large buffel-linked bushfires in last 5 years.

4. Number of small buffel-linked bushfires in last 5 years.

5. Estimate annual buffel-related bushfire management costs.

B10. Infrastructure (Roads, Rail, Airport, Utilities)

1. Rank increasing risks buffel poses to infrastructure assets.

(Fire exposure, corridor spread, dust/erosion, blockage, etc.)

2. Describe any benefits of buffel grass for infrastructure protection.

3. Estimate annual management costs (buffers, culverts, washouts, repairs).

B11. Cultural dimensions

1. Has buffel grass affected your Country (cultural sites, bush foods, water places)?

Yes / No / Maybe

2. Describe these impacts.

3. What has changed for you?

(e.g., harder access, fewer bush foods, fire impacts)

4. What is the right way to manage buffel on Country? Any protocols?

5. Has buffel affected your health or well-being?

6. Estimate annual management costs for sacred/cultural sites (if possible).

B12. Management preferences and trade-offs

1. Rank preferred buffel-management actions for Alice Springs.

2. How should resources be allocated across land types over the next five years?

Scale: Much less → Much more

3. How satisfied are you with current buffel grass management?

Scale: 1 (Not at all) → 5 (Very)

4. If additional funding were available, how should it be allocated?

(Rank: cultural protection, biodiversity, fire risk, visitor safety, etc.)

5. Any other ideas or trade-offs we should consider?

B13. Closing

Participants were thanked and invited to submit supporting documents (optional) to: samy.leytonflor@cdu.edu.au

Appendix C. Indigenous consultation: semi-structured interview guide

C1. Welcome and consent

Thanks for joining this conversation. This is voluntary, and you can skip questions or stop at any time.

With your permission, we would like to record our conversation so I don't miss anything.

Your name won't be used in reports unless you say otherwise.

C2. About you and Country

1. Could you tell us a bit about yourself and the Country/place you care for or work in? (e.g., role, how long you've been there.)
2. What cultural sites, plants, animals, stories, or practices are found in this area that are particularly significant or important?

C3. Cultural impacts of buffel grass

1. How has buffel grass affected cultural sites, sacred places, or water places (e.g., rockholes, springs)?
2. Has buffel grass affected cultural plants or bush foods that are important for health, ceremony, or teaching?
3. Has buffel grass changed how often or easily you can travel on Country? How so?

C4. Intergenerational knowledge and well-being

1. Has buffel grass affected your ability to teach young people about Country, plants, animals, or cultural practices?
2. Does buffel grass affect the well-being of your community in any way (physical, spiritual, emotional)?

C5. Cultural fire and land management

1. Has buffel grass changed the way fire behaves on Country?
2. Has buffel grass affected cultural burning practices or your ability to care for Country?
3. Can you estimate the annual time, labour, and financial costs involved?

C6. Sharing knowledge with the government

1. What would you like government agencies and researchers to understand about cultural values and buffel grass?
2. How can Indigenous Rangers, Elders, and Traditional Owners be better included in buffel management planning?

C7. Policy and priorities

1. What are the biggest barriers to effective buffel grass management in the Alice Springs region: resources, coordination, follow-up, access, policy constraints?
2. After buffel grass was declared a weed in 2024, what practical changes did you expect, and have they happened?
3. Do you agree or disagree that the new buffel grass spread tends to create large net losses for the NT? Why?

C8. Final reflections

1. Is there anything important about buffel grass impacts or management that we haven't covered but you think decision-makers really need to understand?
2. Would you like to receive a plain-English summary of the findings?

Appendix D. Detailed calculation notes: Economic impact assessment

D1. Overview of the calculation framework

This appendix documents in full detail all input parameters, formulae, unit conversions, and data sources used to derive the economic estimates reported in the main body of this report. The purpose is to provide a transparent, reproducible record that allows independent reviewers, land managers, and policymakers to audit the calculations, test alternative assumptions, and understand how individual parameter choices affect the aggregate findings.

The economic impact assessment applies a Total Economic Value (TEV) framework, integrating market values with non-market values to derive social net benefits across management scenarios. All monetary values are expressed in Australian dollars (AU$) at 2025 base-year prices unless otherwise stated. Historical values from cited literature have been adjusted for inflation using the Consumer Price Index (CPI) approach described in Section D7.

The incremental analysis evaluates the net economic effect of an additional 1,000 hectares of buffel grass expansion beyond the current distribution. Annual per-hectare flows are projected over time horizons of 5, 20, 30, and 50 years at discount rates of 5%, 7%, and 9%, following best-practice guidance for Australian agricultural and environmental cost-benefit appraisal.

D2. Market benefits

D2.1. Forage benefit: Livestock production

Buffel grass provides high-quality forage in arid and semi-arid regions, increasing carrying capacity and liveweight gain for cattle enterprises. The benefit was estimated using a partial discounted cash flow (DCF) model built on enterprise-level bioeconomic parameters.

D2.1.1. Worked calculation

Beef output = 300 steers × 170 kg/head = 51,000 kg/year
Gross revenue = 51,000 kg × AU$4.10/kg = AU$209,100/year
Annual net benefit = AU$209,100 – AU$91,500 – AU$37,500 = AU$80,100/year
This figure represents a gross margin before interest, depreciation, and tax. Standardised to the 1,000 ha modelling area, this equates to AU$80/ha/year.

D2.1.2. Scope note on carrying capacity and feed-security values

The calculation above yields the annual incremental net benefit of new buffel grass establishment on an additional 1,000 ha and does not represent the total economic contribution of buffel grass across existing NT pastoral holdings. The carrying-capacity uplift delivered by the historical establishment of buffel pastures, supporting stocking rates of 161–384 steers per 1,000 ha across NT production systems (Bowen & Chudleigh, 2019; Cameron, 2013; Dixon et al., 2020), constitutes a substantially larger total value that is embedded in existing enterprises and is outside the scope of the marginal analysis. Similarly, the feed-security value of standing dry-season buffel grass biomass as a drought buffer (Bowen et al., 2021; Watt et al., 2023) operates at the wholeenterprise scale and cannot be meaningfully expressed as a per-hectare marginal increment without primary longitudinal enterprise data. Both values are acknowledged as real and material pastoral benefits; their exclusion from the worked calculation reflects the constraints of the incremental TEV framework and the data limitations documented in the Scope of Requirements (DLPE, 2025), not a judgment that they are zero.

D2.2. Erosion control: Transport corridors

Buffel grass reduces surface runoff velocity and sediment transport along unsealed roads, rail alignments, and drainage lines, lowering road washout frequency and culvert maintenance costs. The avoided-cost method was applied.

D2.2.1. Worked calculation

Avoided washout events = 6 × 0.35 = 2.1/year
Avoided washout cost = 2.1 × AU$8,000 = AU$16,800/year
Avoided culvert cleaning = 8 × 0.35 = 2.8/year
Avoided culvert cost = 2.8 × AU$2,500 = AU$7,000/year
Total avoided maintenance cost = AU$16,800 + AU$7,000 = AU$23,800/year
Additional avoided costs (dust suppression, grading) = AU$8,400/year
Total erosion control benefit = AU$32,200/year (AU$32/ha/year on 1,000 ha base)

D3. Market costs

D3.1. Buffel grass management costs

Comprehensive management costs were estimated across three components: (1) roadside buffer maintenance; (2) hygiene and washdown protocols; and (3) an annualised control programme.

D3.1.1. Worked calculation

Buffer maintenance = 720 km × AU$100/km = AU$72,000/year
Hygiene cost = AU$35,000/year
Annualised control cost = (1,500 ha × AU$5,500/ha) ÷ 10 years = AU$825,000/year
Total annual management cost = AU$72,000 + AU$35,000 + AU$825,000 = AU$932,000/year
Standardised value (1,500 ha base) = AU$621/ha/year

D3.2. Fire regime intensification

Buffel grass drives a grass-fire feedback loop: increased fine-fuel loads → continuous fuel beds → hotter, faster, more frequent fires → further buffel grass expansion. Fire cost estimates draw on gamba grass studies (the best-documented analogue) as a conservative proxy for buffel-driven arid-zone fire impacts, adjusted for lower fuel loads in central Australian conditions.

D3.2.1. Worked calculation

Pre-invasion annual fire cost = 4 events × AU$1,000 = AU$4,000/year
Post-invasion wildfire cost = 7 events × AU$27,000 = AU$189,000/year
Standby cost = 25 days × AU$16,000 = AU$400,000/year

Asset repair = AU$386,484/year
Gross post-invasion fire cost = AU$189,000 + AU$400,000 + AU$386,484 = AU$975,484/year
Net incremental fire cost = AU$975,484 − AU$4,000 = AU$971,484/year
After further rounding and adjustment for partial attribution of standby to buffel grass:
Reported incremental fire cost = AU$890,484/year
Standardised value (10,000 ha base) = AU$89/ha/year

D4. Non-market costs

D4.1. Restoration of land for biodiversity conservation

Biodiversity conservation was valued using an ecological restoration cost method: the minimum expenditure required to restore the ecological functions of degraded sites to their pre-invasion state.

D4.1.2. Buffel grass cover estimate for Tjoritja / West MacDonnell National Park

Zone	Approx. Share of Park	Buffel Likelihood	Reason
Alluvial plains & drainage lines	~25–30%	High	Buffel prefers run-on zones, creeklines, and disturbed sediment.
Foothills, slopes, mid-range benches	~40–50%	Moderate–high	Buffel expands upslope once established; aerial burns confirm spread through range country.
High rocky ridges and cliffs	~20–30%	Low–moderate	Buffel occurs in pockets, especially below cliffs and in talus slopes.

D4.1.3. Conservative buffel-cover coefficients

Zone	Area (ha)	Conservative Cover %	Buffel Area (ha)
Alluvial & drainage zones	~60,000 ha	50%	30,000 ha
Foothills & slopes	~80,000 ha	30%	24,000 ha
High ranges	~60,000 ha	10%	6,000 ha

Based on the 94,000 ha burned in early 2023 and given that NT Parks & Wildlife reported buffel grass as a major and underestimated fuel source in the West MacDonnell ranges, a conservative estimate indicates that approximately 60,000–95,000 ha of Tjoritja / West MacDonnell National Park supports sufficient buffel grass cover to influence fire behaviour. For modelling purposes, a central conservative estimate of ~70,000 ha (≈35% of the park) is appropriate.

D4.1.4. Worked calculation

Annual biodiversity cost = AU$2,250/ha × 1,000 ha = AU$2,250,000/year
Standardised value = AU$2,250,000/year ÷ 1,000 ha = AU$2,250/ha/year

D4.2. Cultural site degradation

The annual restoration cost of a representative 100-hectare sacred site in the Alice Springs municipality was used as a proxy for the cultural value of country affected by buffel grass.

D4.2.1. Worked calculation

Annual restoration cost = (AU$2,250/ha/year + AU$2.75/ha/year + AU$2.57/ha/year +AU$4.91/ha/year) x 100 ha = AU$226,023/ha/year
Standardised value = AU$226,023 ÷ 100 ha = AU$2,260.23/ha/year

D4.3. Scenic amenity reduction

This appendix outlines the methodology used to estimate annual scenic-amenity losses attributed to buffel grass invasion within Uluṟu–Kata Tjuta National Park (UKTNP). The method integrates (i) visitation numbers, (ii) an adjusted per-visitor willingness-to-pay (WTP) value reflecting reduced scenic quality, and (iii) the spatial extent of buffel grass influence within the park. The estimate is specifically adjusted for an affected area of approximately 3,000 ha, derived from mapped sandplain and sandstone range areas where buffel grass is known to occur. UKTNP receives an estimated 250,000 visitors per year (Australian Government, 2026), underscoring the importance of accurately quantifying visitor-experience impacts associated with landscape transformation.

A Basic Value Transfer (BVT) approach was used to estimate the aggregated non-market cost of buffel grass invasion to the scenic amenity of protected areas. In the absence of NT-specific stated-preference studies, values were transferred from peer-reviewed Australian studies, with contextual adjustment.

D4.3.1. Habitat composition inside Uluru–Kata Tjuta National Park

Habitat Type	**% of Park**	**Area (km^2)**	**Area (ha)**
Sandplains & dunefields	93%	1,410 × 0.93 = 1,311.3 km^2	131,130 ha
Sandstone ranges	6%	1,410 × 0.06 = 84.6 km^2	8,460 ha
Other / minor types	1%	14.1 km^2	1,410 ha

Buffel estimates were only applied to the first two.

D4.3.2. Affected area and exposure proportion

Buffel grass has been modelled to affect approximately 3,000 ha of UKTNP, representing the combined contributions of invaded sandplains and sandstone range habitats (Box et al., 2025). Relative to the park's estimated 141,000 ha, this corresponds to 2.1% of the park being directly affected. Although this proportion reflects the spatial extent of buffel grass, it likely understates visual exposure, because buffel grass is concentrated in highly visible locations at the base of Uluru and in creeklines, run-on zones, and foothills at Kata Tjuta, sites that correspond closely with primary to visitor nodes. Therefore, this 2.1% figure is treated as a conservative baseline exposure proportion.

D4.3.3. Adjusted Willingness-to-Pay (WTP) Per Visitor

Standard non-market valuation studies often use a fixed per-visitor WTP to protect scenic or environmental quality. However, applying the full WTP to all visitors would overstate impacts because:

1. Visitors exhibit heterogeneous preferences; not all place equal value on scenic quality.

2. Not all visitors will perceive or attribute scenic degradation specifically to buffel grass.
3. The affected area constitutes a small but visually significant portion of the overall landscape.

To address this, a behaviourally adjusted WTP of AU$7.00 per visitor was used. This adjustment is grounded in protected-area valuation literature (e.g., Tisdell, 2012) and is constructed to represent a realistic lower-bound estimate of per-visitor welfare loss associated with buffel-driven scenic degradation.

D4.3.4. Worked calculation

Annual scenic amenity cost = 125,000 visitors × AU$7.00/visitor (3,000 ÷ 141,000) = AU$93,085.11/ha/year

Standardised value (1,000 ha of buffel grass) = AU$93,085/ha/year ÷ 1,000 ha = AU$93.09/ha/year[6]

D9. Key limitations and conservative assumptions

- Non-pastoral industry impacts (tourism, infrastructure, mining services) are identified as potentially high but are not fully quantified due to the absence of NT-specific primary data.
- Long-term fire cost data specific to buffel-affected arid regions are not yet available; gamba grass proxies were applied conservatively.
- Cultural site valuation covers only one representative site type (sacred river). The full range of cultural landscapes affected, songlines, ceremony sites, and resource areas, is not individually valued.
- Scenic amenity estimates capture only per-visitor WTP for landscape quality; indirect economic losses from reduced visitation volumes and shortened stays are not included.
- All parameter estimates are conservative by design; the true net cost of buffel grass expansion is likely to be higher than modelled.

[6] Note: This estimate captures only the per-visitor scenic amenity premium. It does not include broader tourism losses from fire closures, cultural landscape degradation, wildlife loss, or safety risks. The total non-market tourism cost is likely substantially higher.

Appendix E. Key quantitative survey metrics

Appendix E1. Management satisfaction rating distribution

Rating	Count	Percentage
1 – Very dissatisfied	51	50.5%
2	27	26.7%
3 – Neutral	17	16.8%
4	2	2.0%
5 – Very satisfied	4	4.0%
Total valid responses	101	—

Note. 77.2% of respondents rated satisfaction at 1 or 2 out of 5. Only 4.0% rated satisfaction at the maximum level. Mean = 1.82, median = 1.0.

The critically low satisfaction score is not merely a reflection of the sample's conservation orientation. It persists across government respondents (n=13, mean concern 4.0/5), who, as institutional actors, have operational knowledge of management limitations, and whose dissatisfaction is less likely to reflect ideological positioning than genuine assessment of program adequacy. This finding independently reinforces Report 2's characterisation of the Weed Management Branch's annual budget allocation as structurally inadequate relative to the identified problem scale, and the compounding cost of continued reactive management.

Appendix E2. Likert-scale perceived impact ratings across eight statements

Statement	Agree/strongly agree	Neutral	Disagree/strongly disagree
Increases fire risk near town & Country (n=102)	84.3%	8.8%	6.9%
Reduces native plant & animal diversity (n=101)	83.2%	5.9%	10.9%
Threatens cultural sites & bush foods (n=100)	81%	8%	11%
NT govt should invest more in management (n=102)	79.4%	4.9%	15.7%
Affects natural scenic beauty (n=102)	79.4%	5.9%	14.7%
Helps reduce dust & erosion (verges/airfields) (n=102)	38.2%	32.4%	29.4%
Improves pasture production in the region (n=102)	40.2%	34.3%	25.5%
Reduces the number of tourists (n=101)	35.6%	31.7%	32.7%

Note: Agree = Strongly agree + Agree; Disagree = Disagree + Strongly disagree. Items above the dividing line are harm-oriented (mean agree 79.4–84.3%); items below are contested or benefit-oriented (mean agree 35.6–40.2%).

Agreement levels for the five harm-oriented items were consistently high, ranging narrowly between 79.4% and 84.3%, a spread of only 4.9 percentage points. This uniformity suggests that concern about buffel grass operates across multiple impact dimensions simultaneously rather than being concentrated in any single domain, a pattern consistent with the multi-pathway harm model underpinning Reports 1 and 2.

The three contested or benefit-oriented items present a markedly different profile. Agreement with the dust and erosion reduction benefit was split almost evenly (38.2% agree, 29.4% disagree, 32.4% neutral), suggesting that respondents with experience of verge stabilisation or airfield management recognise this function, while others either observe negative post-fire erosion outcomes or have no direct experience. One survey respondent specifically noted: *"The above 'dust and erosion' option is ambiguous. I have observed less dust and less erosion because of buffel grass".* Agreement with pastoral production benefit was similarly contested (40.2% agree, 25.5% disagree), with the pastoral sub-sample of grazers (n=10) unanimously agreeing on improved carrying capacity and drought resilience. The tourist reduction item showed the widest disagreement and highest neutral rate, consistent with difficulty in attributing visitor behaviour change specifically to buffel grass.

Appendix E3. Self-reported experienced impacts: Counts and percentages (n=101)

Experienced Impact (past 5 years)	Count	% of Respondents
Impacts on other plants and animals	77	76.2%
More frequent fires	69	68.3%
Damage to trees	58	57.4%
Restricted access to places	55	54.5%
Pollen allergies	54	53.5%
Loss of culturally important sites	45	44.6%
Damage to fences, signs or utilities	33	32.7%
Better feed for stock (benefit)	17	16.8%
More dust and erosion reduction around a site (benefit)	17	16.8%
None of these	3	3.0%

Note. Multi-select item; percentages do not sum to 100. Additional write-in responses included landscape identity loss, trail inaccessibility, mountain-biking and 4WD hazards, snake risk, and reduced wildflower displays.

Impacts on other plants and animals were the most frequently reported category (76.2%), closely followed by more frequent fires (68.3%). This ordering is analytically significant: it grounds perceived biodiversity impacts in direct personal observation rather than abstract ecological concern, and establishes fire frequency as a lived experience for more than two-thirds of responding stakeholders. The convergence of fire experience data with the modelled fire cost parameters in Section 4.2.2 (AU$793,380/yr incremental fire cost; frequency assumption of one to five events per year) provides independent qualitative support for the plausibility of the frequency assumption, without constituting a causal attribution of specific fire events to buffel grass fuel loads.

Pollen allergies (53.5%) ranked fifth, above loss of culturally important sites, confirming that health impacts from buffel grass are a widespread and frequently experienced phenomenon across the survey population, rather than a marginal concern limited to specific subgroups. This finding is discussed further in Theme 4. The near-equal reporting of better feed for stock and dust/erosion reduction (both 17/101, 16.8%) is consistent with a respondent pool in which pastoral and infrastructure respondents, who are most likely to have experienced these benefits directly, constitute a modest but measurable fraction of the sample.

Appendix E4. Management preferences and ranked priorities. Lower mean rank = higher priority

Rank	Management Priority	Mean Rank	Analysis
#1	Reduce fire risk	2.06	Consistent with 84.3% Likert agreement and #1 in experienced impacts; pastoral sector concern rating mean = 1.27/5 reflects divergence from the broader sample
#2	Protect biodiversity	2.26	Aligns with AU$2,250/ha/yr biodiversity restoration cost in Part 1; 83.2% Likert agreement
#3	Protect cultural sites & water places	3.30	81.0% agreement; Indigenous respondents report access loss and sacred site damage; broader scope than 100 ha riparian proxy in Part 1
#4	Reduce impacts on infrastructure	3.69	Fire exposure to public areas ranked #1 infrastructure risk by 83% of infrastructure respondents
#5	Maintain scenic/visitor values	4.55	79.4% Likert agreement; tourism respondents (n=2) reported 100% Strongly agree on all four tourism items
#6	Pasture production	5.14	Lowest priority; likely reflects under-representation of pastoral sector in sample (n=11 grazers; mean concern 1.27/5)

Note. Mean rank scores derived from respondent drag-and-drop ordinal rankings. Pastoral productivity ranked lowest; its mean rank of 5.14 reflects both the sample's conservation orientation and the structural finding in this report that incremental pastoral benefits (AU$80/ha/yr) are outweighed by external costs (AU$6,328/ha/yr).

The dominance of fire risk reduction (mean rank 2.06) is analytically consistent with the pattern of perceived impacts documented in Section 5, where 68.3% of respondents reported direct experience of more frequent fires. Respondents with direct fire experience predictably prioritise reducing fire risk over longer-term ecological outcomes. Biodiversity protection (rank 2, mean 2.26) and cultural site protection (rank 3, mean 3.30) are positioned consistently with the economic cost structure of this report, where these two categories constitute the two largest per-hectare annual external cost items. The funding allocation ranking (fire: mean 2.13; biodiversity restoration: mean 2.46; cultural site protection: mean 3.17) mirrors the outcome priority ranking with near-identical ordinal structure, indicating robust internal consistency in respondent preferences.

Appendix E5. Municipal management action priorities. Lower mean rank = higher priority

Rank	Municipal Management Action (Alice Springs area)	Mean Rank Score
#1	Active control at high-value cultural/biodiversity sites	2.89
#2	Fuel-load reduction: herbicide after burning/mowing	3.15
#3	Fuel-load reduction by slashing/mowing	4.06
#4	Expand community Landcare efforts	4.19
#5	Road/rail hygiene + herbicide buffer zones	4.47
#6	Fuel-load reduction by burning (where appropriate)	4.68
#7	Targeted pastoral support (integrated grazing + fire)	5.34
#8	Do nothing	7.21

Note. Active control (herbicides/hand pulling) at high-value sites ranked highest (mean rank 2.89). Slashing/mowing without follow-up herbicide ranked third (mean 4.06). 'Do nothing' ranked last (mean 7.21).

The ranking of active control at high-value sites above fuel-load reduction by herbicide after burning/mowing is noteworthy: respondents prioritise weed suppression at priority locations over landscape-wide fuel management, a preference that aligns directly with the strategic rationale for Scenarios 2 and 3 in Report 2 and the targeted site management approach recommended by Participant 1. The strong preference against fuel-load reduction by slashing/mowing alone (mean rank 4.06) is consistent with empirical evidence that slashing without herbicide follow-up can stimulate vigorous buffel grass regrowth and increase rather than reduce long-term fuel loads. Survey comments further elaborated: *"Burning just excites it, unless there can be consolidated effort to burn, then spray"*; *"slash then spray. Must follow up forever otherwise a waste of time"*.