Exploring perceptions and best practice adoption of silvopastoral systems as a strategy for drought resilience in the Northern Gulf Region of Queensland

Final report

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Disclaimers

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Executive summary

This report, prepared for the North Queensland Regional Forestry Hub and Gulf Savannah NRM. It explores silvopasture as a strategy to enhance drought resilience in grazing areas across the Northern Gulf region. The study highlights both the opportunities and challenges associated with implementing silvopasture and provides key insights for effectively integrating trees and livestock.

Land availability and suitability for silvopasture development:

- The study identified 47,677 ha of X-class land across 35 land types and 12,662,788 ha of pastureland spread across 39 land types as potentially suitable for silvopasture, representing a significant opportunity for implementing silvopasture in diverse land conditions.

Proposed tree species for silvopasture systems

- Seven tree species were selected for their drought resistance and timber value: *Corymbia citriodora subsp. citriodora, Eucalyptus crebra, E. camaldulensis, E. argophloia, E. cambagiana, E. thozetiana*, and *Khaya senegalensis*. Preliminary results indicate that these species show moderate growth, with annual height increments of 0.6 – 1.0 m/year and diameter increments of 0.7 – 1.1 cm/year.
- Further research, including tree improvement, testing species in different soil conditions and environments, along with long-term data collection is necessary to gain a comprehensive understanding of their adaptation and growth rates in silvopasture systems.

Landholder perspectives on silvopasture:

- The project team surveyed 49 individuals across the region to understand local perspectives on silvopasture. Results show that 39.6% of respondents are “somewhat familiar” with silvopasture, while 14.6% are “very familiar” with silvopastoral systems.
- Most respondents (56.5%) see multiple benefits of integrating trees into pastureland, including improved animal welfare, land rehabilitation, ecosystem services, and diversified income streams.
- Key concerns raised included potential competition between trees and grass (31.7%), frequently changing vegetation laws (29.3%), and limited resources and support (24.4%).
- Regulatory and land tenure issues were noted by 30.2% of respondents as the primary challenges to adopting silvopasture practices.
- Interest in transition to silvopasture was high, with 61.7% of respondents considering planting trees in pastureland.
- Respondents requested additional resources, primarily financial support (31.3%), technical advisory assistance (27.1%), market information (22.9%), and flexibility in land use (18.8%).
- Many respondents also believe silvopasture could bring potential economic benefits, with 79.2% perceiving dual-output production (timber and beef).
- Additionally, 77.6% believe silvopasture offers some benefit in mitigating climate change and enhancing drought resilience.

Early-stage knowledge in the adaptation of silvopasture should consider for:

- Current and projected climate characteristics;
- Engagement of landowners in management practices;
- Assistance from state and federal programs for tree planting and managing;
- Federal or state funding support;
- Planning and establishment considerations.

1. Background

Silvopastoral systems (SPSs) are the most common and extended agroforestry systems that integrate livestock, forage production and forestry on the same land management unit in dry areas (FAO, 2021). Broadly, there are two major forms of silvopasture: **grazing and tree fodder systems**. SPSs are deliberately designed and managed to produce a high value timber product in the long term while providing short term annual economic benefit from a livestock component through the management of forage or a yearly crop component.

In grazing systems, cattle graze on pastures under widely spaced or scattered trees, while in the tree fodder systems, the animals are stall-fed with fodder from trees or shrubs grown in blocks on farms. The grazing system of silvopasture has recently gained prominence as an ecologically sustainable and environmentally desirable approach to managing degraded pasture lands in savannah countries. With the recent emphasis on the environmental impact of land use systems, the roles of SPSs in mitigating climate change through building drought resilience in grazing businesses of the Northern Gulf region has been a major area of research focus.

The vast majority of the Northern Gulf region is currently used for **extensive beef cattle grazing**. The regional economy could count on income derived from agriculture (including grazing and horticulture), fishing, mining and tourism. Between 2017-2021, total agriculture production from the Northern Gulf region has varied from $600 to 750M per year, with the majority of livestock income contributing $400- 600M (NRM 2023). **However, the region faces significant pressures due to land management challenges and extreme weather influenced by climate change**. The Northern Gulf region is experiencing the impacts of climate change, with average temperatures across the state increasing by 1^0C over the past century. The region is particularly affected by extreme heat events, increased evapotranspiration rates, water stress and extended drought periods (NRM 2023). More extreme temperatures and changes in rainfall variability could decrease forage production, surface cover and livestock carrying capacity.

The Northern Gulf grazing lands are characterised by a **scarcity of water**, **poor nutrients** and **highly erodible**, which makes both natural and managed ecosystems more vulnerable than elsewhere to climate fluctuations. In addition, land conditions have decreased significantly across the region due to poor management of grazing and vegetation, declining from 72% to 66% between 2002 and 2006. If this trend continues, the region's original grazing capacity could be reduced by 50% by 2046 (NRM 2023). This indicates the necessity of developing and adopting an adaptable management framework for grazing.

Given current and future challenges, emerging evidence demonstrates that silvopasture can contribute substantially to adaptation and mitigation of climate change. However, this needs a shift in perception from grazers to understanding opportunities and identifying benefits of integrating trees and livestock in their land. Grazers' perceptions and well-designed silvopastoral management approaches can support the sustainability of drylands, mitigating climate change, and sustaining livelihoods for local grazing communities in the long term.

Thus, the Gulf Savannah NRM and North Queensland Regional Forestry Hub are exploring silvopasture as a strategic approach that sustainably raises timber and livestock productivity (**production**), increases resilience (**adaptation**), store carbon (**mitigation**) and enhances the achievement of **development goals** the Gulf region. This strategy leverages dual benefits of business diversification and natural synergies that emerge from integrating timber, cattle, and pasture. The outcomes of this project could contribute to the regional priority themes of Tropical North Queensland Drought Resilience Adaptation and Innovation Hub, particularly in areas such as drought and climate change adaptation, as well as land and soil management;

2. Project scope

The project scope is to assess the suitability of various tree species to land conditions in the Northern Gulf Savannah region using technical analysis of existing data and leverage information from North Queensland Forestry and other GIS sources.

The project will explore possible co-benefits of species including drought fodder, the effects of shade on pasture and livestock productivity. In addition, regional establishment methods and strategies are to be considered based on the project's assessment.

The project will also investigate some of the key perceptions held by landholders/graziers across the region around establishing and managing potential silvopastoral systems for drought resilience and timber production.

3. Objectives

This project aims to explore silvopasture as a strategy to increase drought resilience in the Northern Gulf region. This approach is intended to enhance the sustainability and resilience of the ecosystem in response to ongoing climate challenges in the area.

This project addresses the following detailed objectives:

i) Conduct literature to explore species suitability for silvopastoral systems being established silvopasture systems based on land conditions in the Northern Gulf region;

ii) Assess perception of local/producer knowledge and grazing context to integrate trees on the grazing farms in the Northern Gulf Savannah;

iii) Develop early-stage knowledge in the adaptation of silvopasture in extensive grazing in the project region.

4. Methodology

Here are detailed methods to achieve the three methods above:

i) Undertake a literature review to identify soil, landscape types and suitable tree species

- Using spatial mapping, online databases/GIS data sets and existing data from North Queensland Forestry to identify the available land on native forests (X-category) and pasture lands in the Northern Gulf Savanah NRM. Based on spatial data, land types across the Northern Gulf will be identified.
- Use the spatial maps above and explore existing vegetation databases, such as biodiversity status and Norther Gulf Plant Index within the Gulf Savannah NRM region to identify native wood species growing in the region. Then incorporate climate data (temperature and rainfall), consult with local farmers during engagement trip and

consider land types to suggest a list of tree species suitable for growth in drought-prone regions.

- Review and consult with forestry experts to propose tree species that demonstrate strong growth performance and produce high-quality timber, specifically suited for silvopasture systems.

II. Assess perception of local/producer knowledge in a grazing context

- Identify key stakeholders, including local farmers/producers, landowners, business investors, industry bodies and local government.
- Develop structured questionnaires and surveys to gather quantitative and qualitative data using a mixed-methods approach: semi-structured and open-ended sets.
- Individual interviews of at least 50 stakeholders and field observations via engagement trips supported by Gulf Savannah NRM and the Hub.

iii) Develop an early-stage knowledge base specifically for the application of silvopasture in an extensive grazing setting across the project area.

- Review existing research on silvopasture systems, focusing on benefits, challenges, and case studies.
- Gather case studies of successful silvopasture implementations in similar climatic or soil conditions.
- Gather insights from local stakeholders during engagement trips and survey answers above (*method ii*) to develop a comprehensive early-stage knowledge base for silvopasture in an extensive grazing setting.

5. Milestones

The project milestones are shown in **Table 1**.

Table 1. *Project milestone deliverables and due dates*

Milestone	Deliverable	Due date
1	Project commencement: project plan and consultation methodology	6 May 2024
2	Development and delivery of perception survey and literature review	3 June 2024
3	Draft final report	31 Oct 2024
4	Final report	15 Nov 2024

6. Outputs

6.1 Identify soil and landscape types across the Gulf Savannah region

The Northern Gulf is a vast region spanning approximately 196,100 km², nearly 90% of the total area of Victoria. Currently, about 84% of the region is used for extensive beef cattle grazing properties, and roughly 11% is allocated to Conservation and Natural Environments, including National Parks and Private Nature Refuges (NRM, 2023). The region contains four broad bio-regions: Cape York Peninsula, Einsaleigh Uplands, Gulf plains and Wet Tropics (**Figure** 1Figure 1).

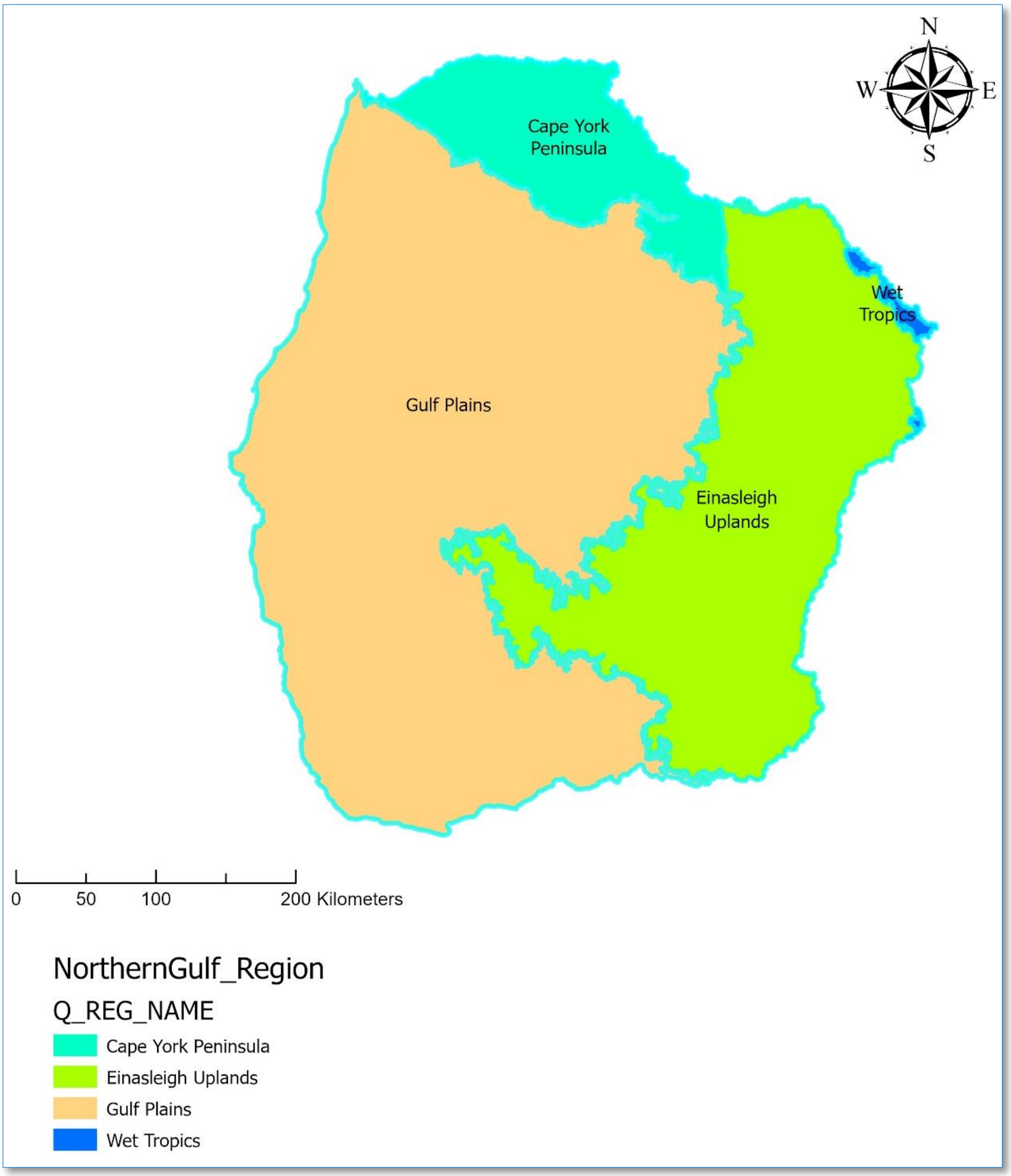


Figure 1. Northern Gulf region (196,100 km²), including four bio-regions: Cape York Peninsula, Einsaleigh Uplands, Gulf plains and Wet Tropics.

The landscape of the Northern Gulf is generally flat, characterised by low-lying tropical savannah. A general assessment has been conducted to identify available land for developing silvopasture. This involved the extraction of spatial data, focusing on regulated vegetation management (RVM) category X-class land and pasture areas in the Gulf region. The assessment used spatial data from Queensland's Grazing Land Management (GLM) regions (GLM Mapping, June 2022). The Northern Gulf region includes 67 distinct land types, as classified under the GLM (Figure 2).

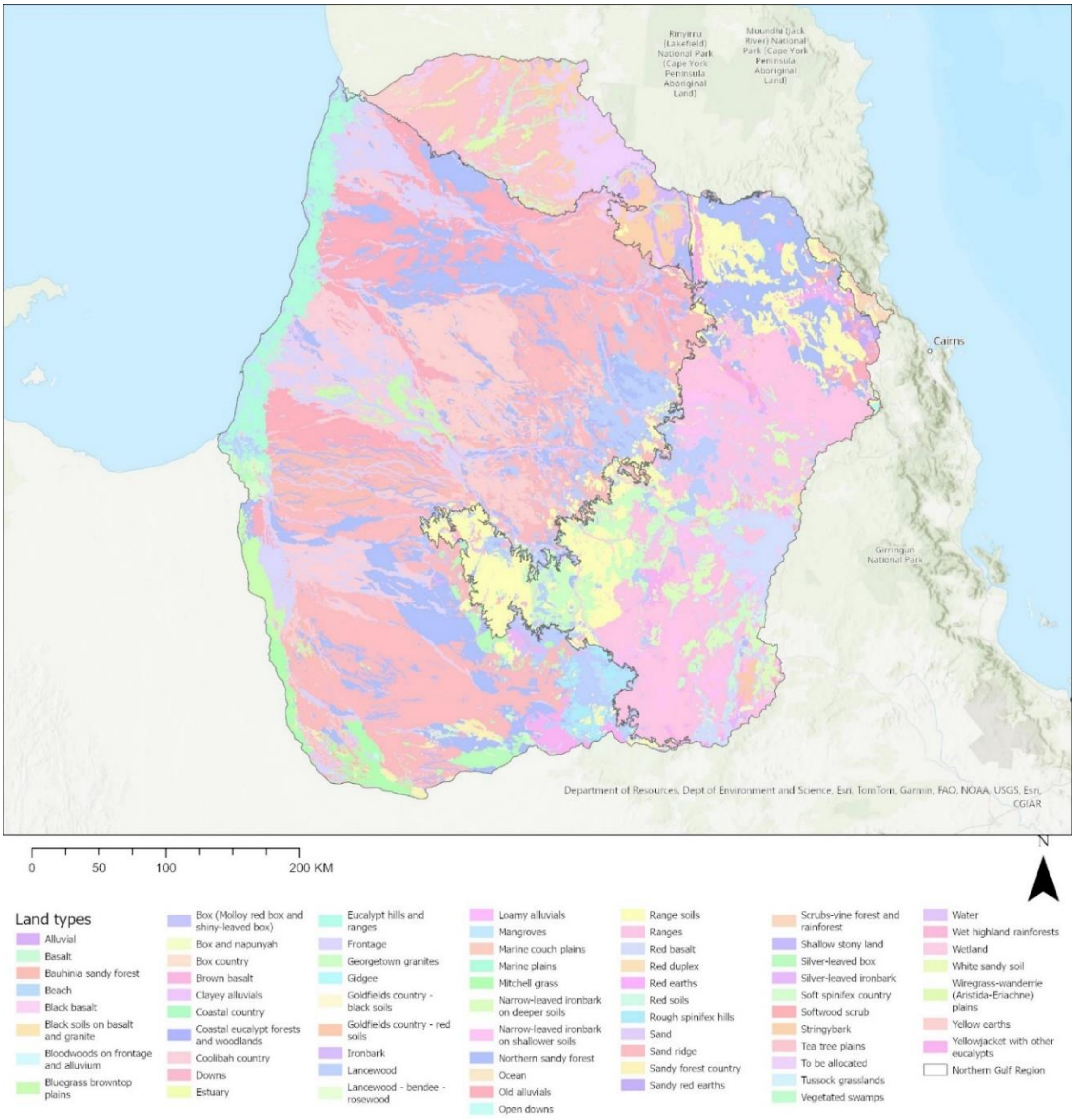


Figure 2. The 67 land types in the Northern Gulf region, with distinct colours representing the different land classifications.

6.1.1. X-class land

Through spatial analysis using the 2024 RVM mapping, we identified a total of 153,568.7 hectares of X-class land within the Gulf region. The analysis focused on freehold X-class land classified under agricultural land classes C, C2, and C3. Where class C is pasture land, Class C2 is more typically suited to sheep and cattle breeding, while C3 is restricted to grazing with low stocking rates (DSITI & DNRM, 2015). From this, **47,677.0** ha of X-class land with **35 land types** were identified as potentially available for silvopasture development in the region (Figure 3).

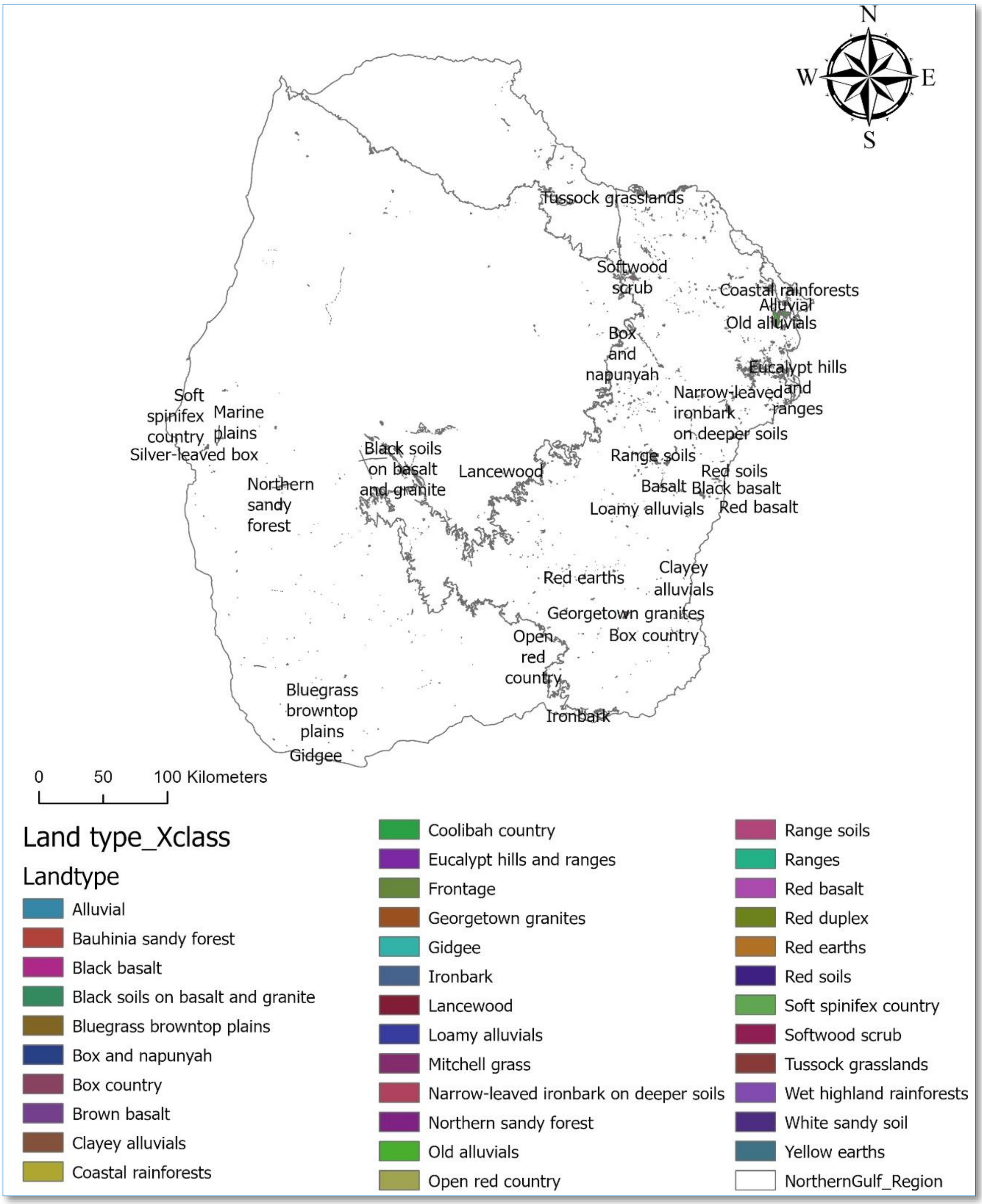


*Figure 3. The distribution of 35 GLM land types based on freehold X-class land, totalling an area of **47,677.0** ha.*

Figure 4 indicates that 17 land types dominate within the X-class land, with detailed descriptions provided in Table 2. Among these, **range soils** and **old alluvial** account for the highest areas, each exceeding 10,050 ha. Range soils are characterised by shallow profiles, variable gravel coverage on the surface, and a surface texture that is sometimes hard-setting or composed of sandy clay. Old alluvial includes alluvial loams and yellow duplex soils, the surface is non-cracking, with a loamy clay texture while the subsoil consists of light to medium clay (Future Beef, 2011).

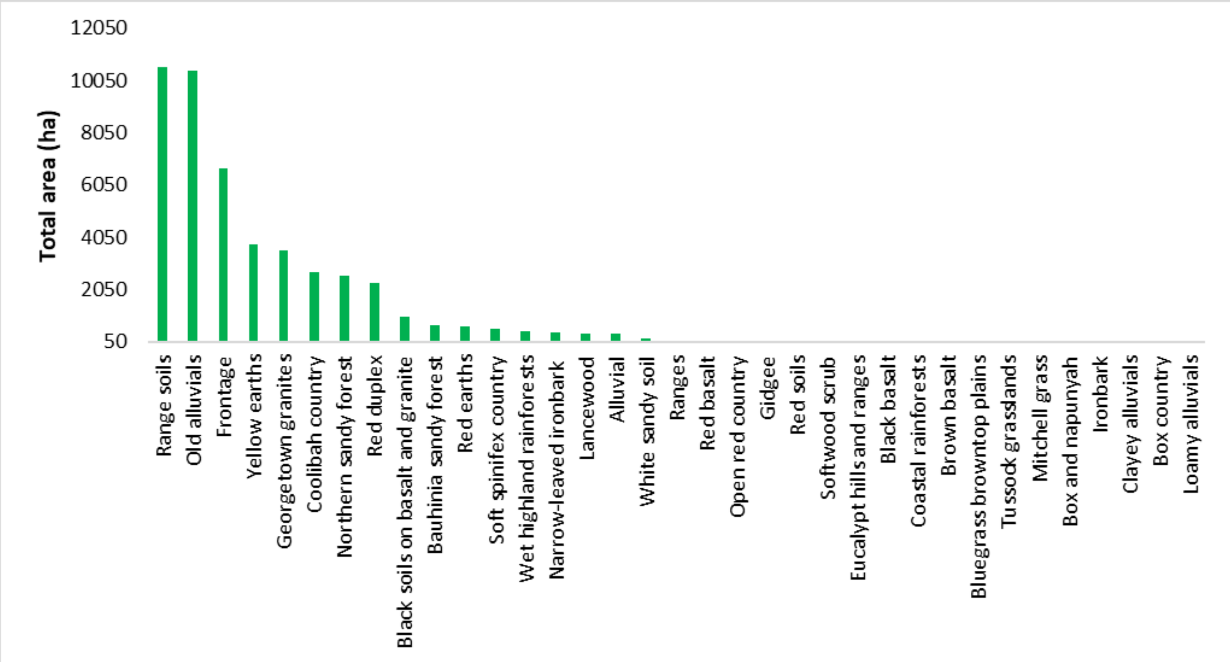


Figure 4. Land type distribution within X-class land

Table 2. The main land types and soils within X-class in the Northern Gulf Savannah. Note that the description is focused on land types > 50 ha.

Land type	Landform	Soil	Native woody vegetation
Range soils	Dissected hilly country	Shallow soils	Silver-leaved ironbark, Narrow-leaved ironbark, Bloodwood
Old alluvial	Level plains including abandoned stream channels, backslopes and adjacent floodplains	Alluvial loams and yellow duplex soils	Ghost gum, Bloodwood, Grey box
Frontage	Level plains	Alluvial loams	Grey box, Moreton Bay ash, Ghost gum
Yellow earths	Mid to lower slopes of level to gently undulating plains	Yellow brown texture contrast soils (solodics)	Grey box and Narrow-leaved ironbark
Georgetown granites	Rolling granite plains	Brown soils of light texture, earthy sands, and texture contrast soils	Gum-topped bloodwood
Coolibah country	Riverine lightly timbered floodplains that are seasonally inundated.	Cracking and calcareous clays. Frequently there is a thin crust of fine soil/sand on the surface. Colours range from dark grey to olive-brown to red-yellow. Commonly interspersed with alluvial soils along stream, river and creek beds	Ghost gum
Northern sandy forest	Outwash plains	Texture contrast soils and sandy grey and yellow earths	Cooktown ironwood, Georgetown box, Bloodwood
Red duplex	Irregular plains and low hills	Texture contrast soils (mostly red podzolics)	Narrow-leaved ironbark, Gum-topped bloodwood
Black soils on basalt and granite	Undulating to gently undulating plains and rises formed on predominantly basalt but also granite and granodiorite	Massive black and brown earths; sometimes cracking	Narrow-leaved ironbark, Bloodwood
Bauhinia sandy forest	Outwash sandy plains.	Red to yellow, light grey uniform or light textured deep sandy soils	Ironwood, Cooktown ironwood, Bloodwood

Land type	Landform	Soil	Native woody vegetation
Red earths	Upper slopes on level to gently undulating plains.	Free draining, grey to red surface grading to red clay soils.	Bloodwood, Narrow-leaved ironbark
Soft spinifex country	Dissected low plateaux and high plains and ridges. Small areas occur on hills and steeper slopes	Skeletal soils and sands and deeper red and yellow earths	Bloodwood
Wet highland rainforests	High hills and steep slopes	Moderately deep to deep, gradational soil with clay loam topsoil over reddish brown subsoil. The main soil type is dermosols.	Mackay cedar, Hoop pine, Red Eungella satinash, Black tulip oak, Silver quandong
Narrow-leaved ironbark on deeper soils	Undulating duplex plains; deep red earth tablelands	Red or yellow earths or duplex	Bloodwood, Silver-leaved ironbark, ghost gum, Lemon-Scented gum
Lancewood	Scarps and remnant plateaus	Skeletal, stony soils	Narrow-leaved ironbark, Darwin woollybutt
Alluvial	Alluvial plains	Deep to very deep cracking clays and gilgaied sandy grey alluvial clays with some seasonal scalding. Deep siliceous texture contrast soils when draining sandy country	Ironwood, False sandalwood
White sandy soil	Low slopes	Sand and impeded drainage cause bogging and low fertility	White cypress

6.2.2 Pasture land

Most of the land across the Northern Gulf region is covered by pasture land and is used for extensive beef cattle grazing properties (Figure 5). Three broad classes of agricultural land (**Class A** = crop land; **Class B** = limited crop land; **Class C** = pasture land) and one non-agricultural land class (**Class D**). The vast majority of the land tenure is Leasehold (approximately 86%), while Freehold accounts for a small proportion (7%).

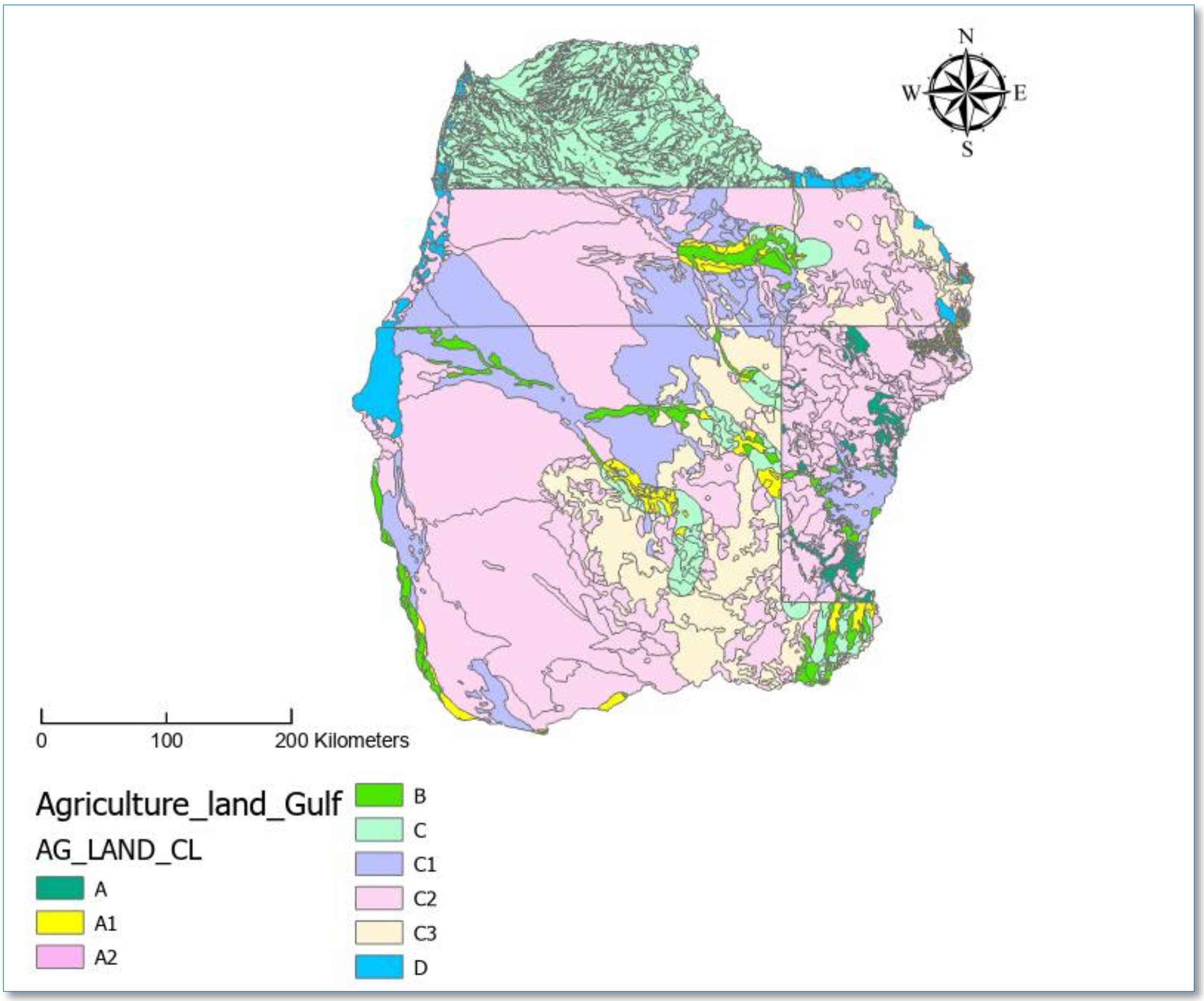


*Figure 5. *Agricultural land classification in the Gulf region*

* ***Class A** = crop land (**A1** = land suitable for a wide range of broadacre crops; **A2** = land suitable for a wide range of horticultural crops only); **class B** = limited crop land, narrow range of crops or crops with specialised requirements e.g. tea, pineapples or plantation forestry); **class C** = pasture land (**C1** = high fertility grazing land typically used for beef cattle fattening; **C2** = suitable land for sheep and cattle breeding; **C3** = restricted grazing with low stocking rates); **class D** = land is not suitable for agricultural use (including grazing), it land alienated from agricultural use (e.g. urban areas) and land with high order conservation tenure (e.g. national parks).*

For this project, we selected agricultural land sub-classes of **C, C2** and **C3** as potentially feasible for silvopasture establishment. Particularly, class C2 is suitable for grazing native pasture, with or without the introduction of pasture species and with lower fertility soils than C1 (**C1** = sown pasture on high fertility soils). Although class C3 is restricted to grazing, it is suitable for light grazing of native pastures in accessible areas and more suited to forestry. Our analysis of the specific land classes C, C2 and C3, shows a total of 15,128,347 ha of grazing native vegetation (Figure 6).

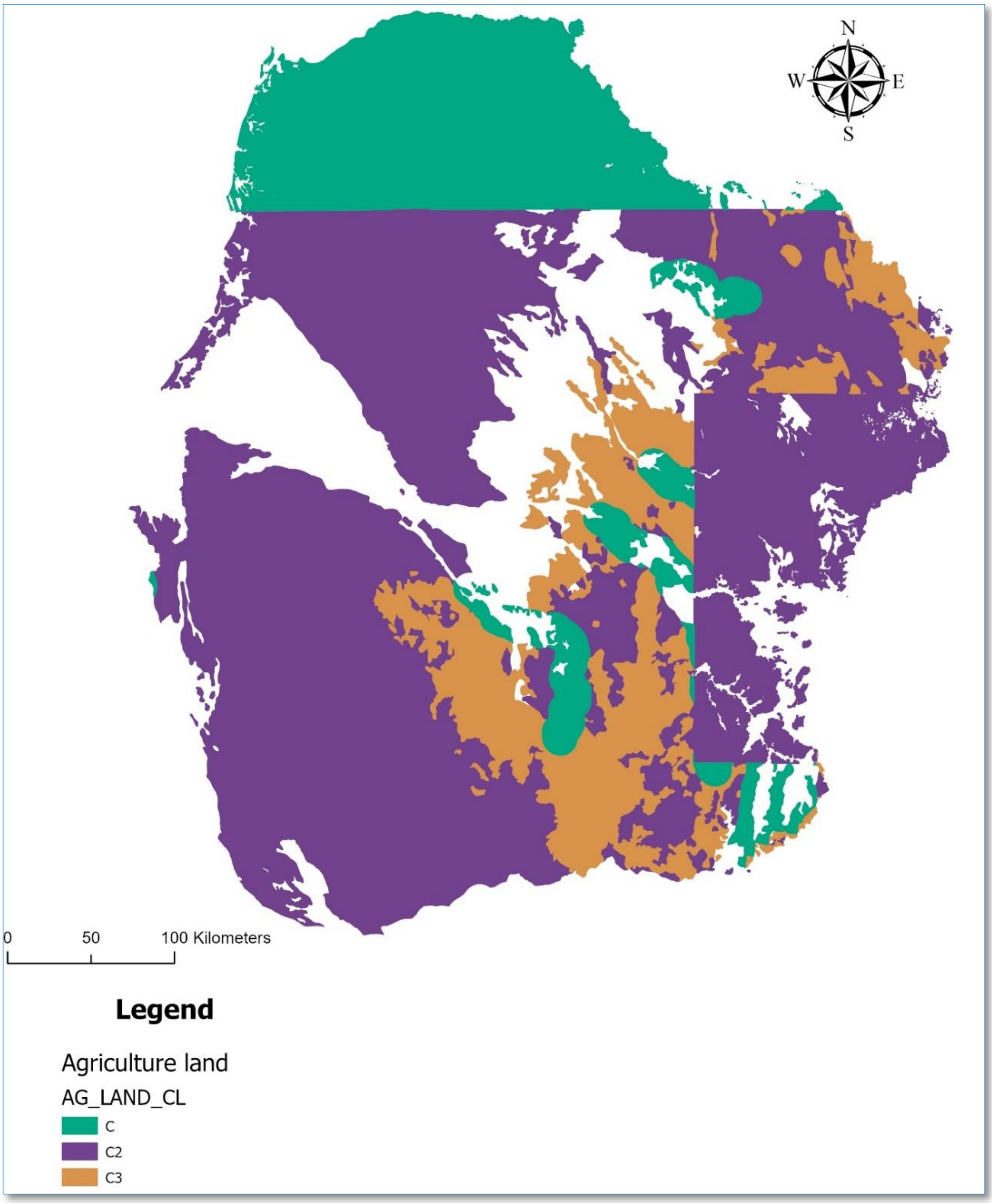


Figure 6. Agricultural land for classes C, C2 and C3 with 15,128,347 ha.

However, of the 67 land types (Figure 2), when overlaid with agricultural land (Figure 6), it was found that approximately half of these land types were unsuitable for silvopasture establishment, for example, beaches, mangroves, sand, sand ridges, vegetated swamps, vine forests on steep hills and ranges, water, marine plans and wetlands. As a result, the remaining available land for silvopasture development within agricultural areas totalled **12,662,788** ha, distributed across **39 land types** (Figure 7).

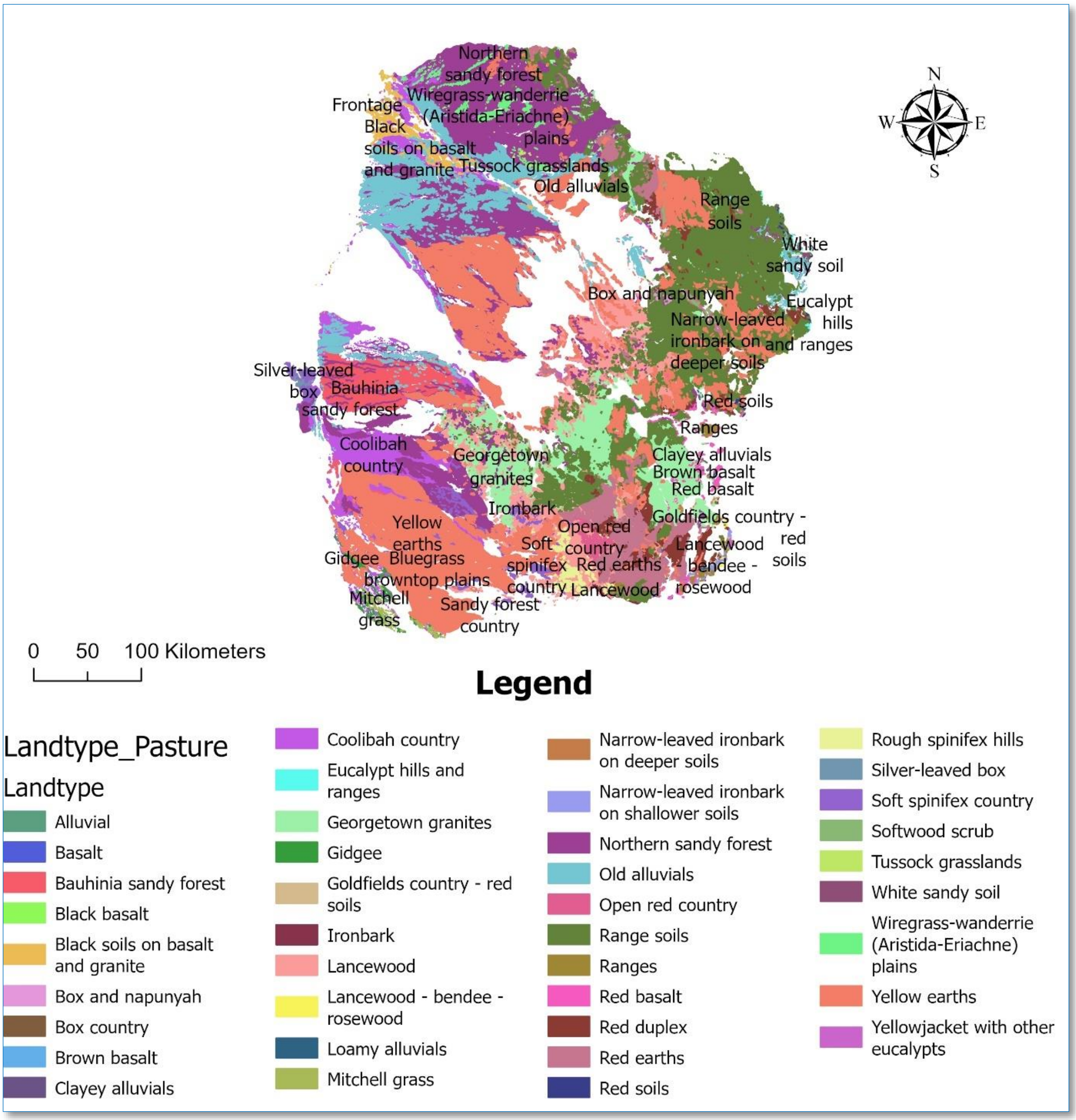


Figure 7. The distribution of GLM land types available for silvopasture development is based on agricultural land classes C, C2 and C3 in the Northern Gulf region. Total agriculture land is estimated at approximately 12,662,788 ha.

Among 39 land types (Figure 7), 12 land types (details of these land types are described in Table 2) exceed over 50,000 ha (Figure 8**a**) and 15 land types accounted for over 10,000 ha (Figure 8**b**). The land types of yellow earths, range soils and Northern sandy forest have the highest areas with over 2,000,000 ha. Details of 15 popular land types are described in Table 3.

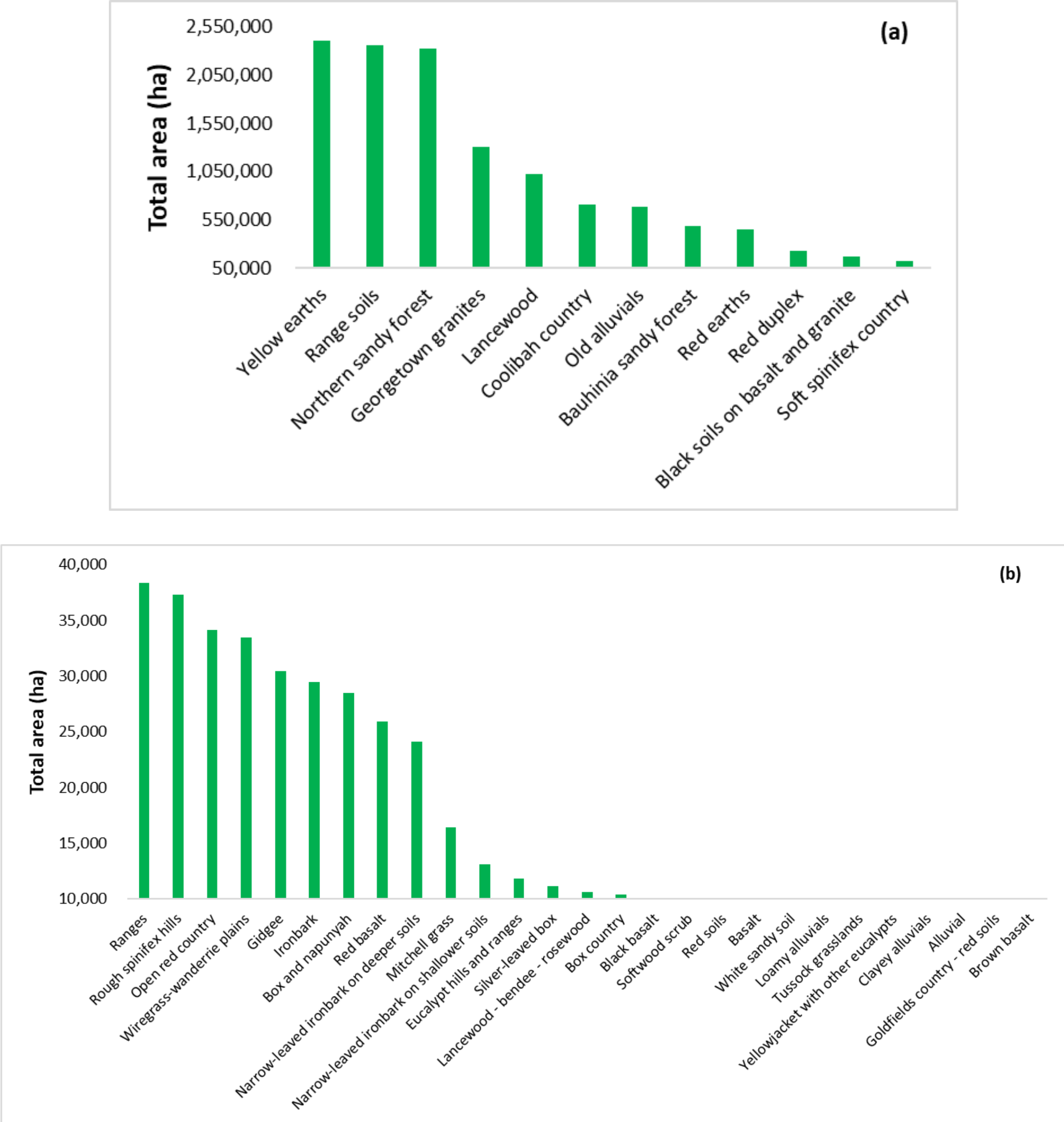


Figure 8. The distribution of GLM land types within native pasture areas: (a) 12 land types exceeding 50,000 ha, and (b) 15 land types exceeding 10,000 ha.

Table 3. Descriptions of 15 land types > 10,000 ha

Land type	Landform	Soil	Native woody vegetation
Ranges	Undulating rises to rolling, steep hills, mountains and mountain ranges	Shallow rocky skeletal soils on steep slopes with shallow texture contrast soils closer to drainage lines	Silver-leaved ironbark, Narrow-leaved ironbark
Rough spinifex hills	Rugged mountains, rocky plateaus, high plains and hilly country	Skeletal and rock outcrops poorly drained deeper soils along drainage lines	Bloodwood
Open red country	Outwash plains, erosional plains. Sometimes on gravelly alluvium or limestone ridges	A variety of soils, the best being deep loamy red earths. Patches of red clays, texture contrast soils and some skeletal soils	Bloodwood, Silverleaf box
Wiregrass-wanderrie plains	Shallow stony land	Not available (N/A)	N/A
Gidgee	Alluvial deposits occurring as plains, floodplains and sediments form undulating plains	Grey-brown cracking clays (vertosols). Minor areas of red/yellow earths (kandosols).	Bloodwood
Ironbark	Hillslopes, plains, fans and sometimes ridges	Deep sandy loam over a sandy clay loam. Texture contrast profile with an ironstone hardpan usually present	Silver-leaved ironbark, Narrow-leaved ironbark, Ghost gum, bloodwood
Box and napunyah	Foot slopes and lower slopes	Skeletal, gravelly texture contrast soils	Napunyah/ Thoezet's Box, Molly box
Red basalt	Irregular stony plains and low hills	Red brown clay loams (euchrozems, krasnozems)	Narrow-leaved ironbark, Gum-topped bloodwood, Ghost gum
Narrow-leaved ironbark on deeper soils	As described in Table 2 above	As described in Table 2 above	As described in Table 2 above
Mitchell grass	Flat to undulating plains. Often adjoins and sometimes mixed with bluegrass browntop plains and/or flooded plains	Grey-brown heavy cracking calcareous clays with uneven, self-mulching and often ashy surfaces, and with some areas of pebbly downs.	Predominantly treeless plains with Whitewood

Land type	Landform	Soil	Native woody vegetation
Narrow-leaved ironbark on shallower soils	Undulating rises to hills and mountains	Shallow rocky soils, texture contrast brown sandy loam over structured yellow brown clay	Narrow-leaved ironbark, Silver-leaved ironbark
Eucalypt hills and ranges	Higher hills and ranges	Shallow to moderately deep soil. The soil types are mostly brown chromosols	Moreton Bay ash, Bloodwood
Silver-leaved box	Timbered to lightly timbered inland plains	Red and yellow earths	Silver-leaved box, Bloodwood
Lancewood - bendee – rosewood	Uplands, ranges and dissected ridges	Shallow rocky soils (rudosols)	Generally pure communities of Lancewood, Bendee or Rosewood, Narrow-leaved ironbark,
Box country	Fans, plains, hillslopes, foot slopes and drainage depressions	Sandy loam topsoils with sodic clayey subsoils.	Ghost gum, River red gum

6.2 Potentially suitable species can be planted in silvopasture the Northern Gulf region

Selecting the appropriate tree species is crucial for maintaining a profitable livestock operation while creating a long-term investment in timber and forest products. Tree species selection should be based on local soil types, site characteristics, climate conditions, and tree value. There is currently limited information on successful tree species used in silvopasture systems within the Northern Gulf region. In this project, we used survey responses, spatial data, and consultations with forestry experts to identify potential tree species suitable for integration into local silvopasture systems.

> We surveyed local people to understand which tree species can thrive well on their land and which species they would prefer to plan using questions 23 and 24 (Appendix 1), as follows:
>
> *Are there any existing species (trees and shrubs) that grow well around your area?*
>
> *Any specific types of trees or shrubs you would prefer to integrate into your pastures for drought resilience?*

According to the survey results, with 37 respondents and 11 non-responses, the majority (60%) expressed a preference for planting species such as **Lancewood**, **Ironbark**, and **Bloodwood** (**Figure 9** [blue writing]). A smaller group (30%) indicated interest in establishing **Leucaena**, **legume trees**, and species of **Eucalyptus** and **Corymbia** (**Figure 9** [green writing]). Only a minority (10%) favoured planting **Hoop Pine**, **Cooktown**, **Ironwood**, **Iron Box**, **Rosewood**, **Silky Oak**, **Mahogany**, **Cedar**, **Moringa**, **Kurrajong**, as well as unspecified native species and native conifers (**Figure 9** [purple writing]).

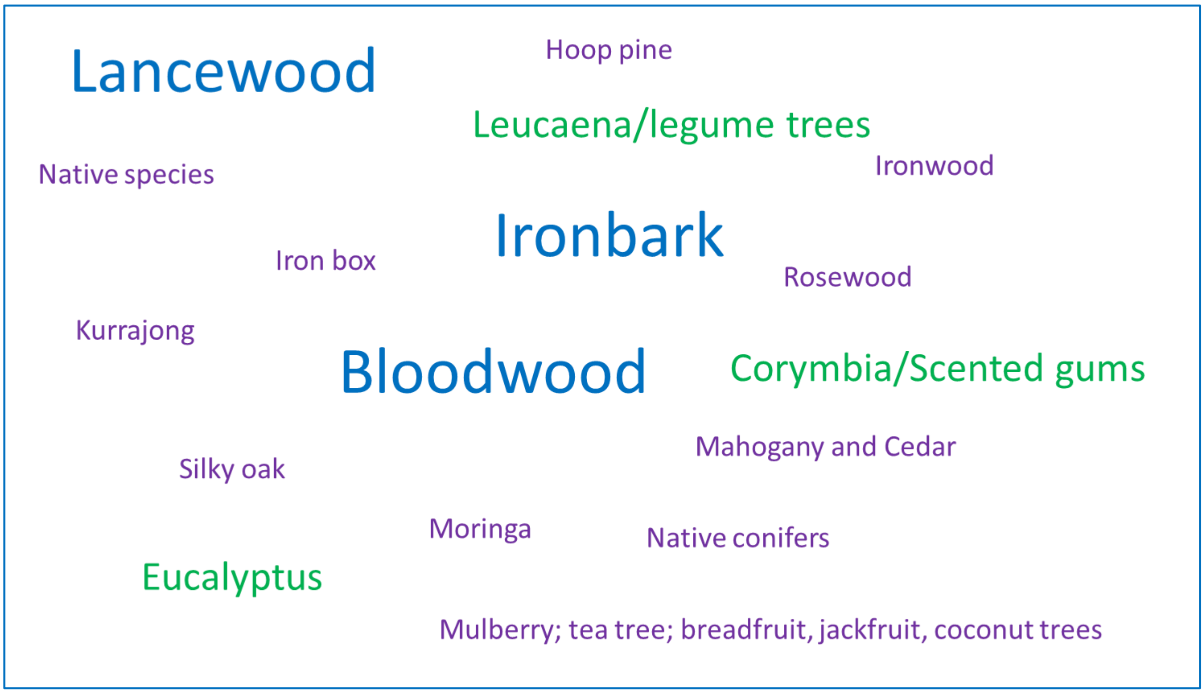


Figure 9. Landholders expressed a preference for species that grow well in local conditions and contribute to improved pasture quality.

The survey responses above (Figure 9) highlighted a few challenges in obtaining a comprehensive understanding of local preferences due to some limitations with online surveys and the inability to engage in direct conversations with all stakeholders (we only engaged with 10 participants during the field tour in May 2024 - **Figure 19**). Here are a few comments from respondents:

- Several landholders (60%) mentioned the preference for planting Lancewood, Ironbark and Bloodwood as these species have **natural growth** in their land and the primary need for trees as **shade for livestock** and **food for cattle** (Lancewood).
- A few respondents indicated a desire for fruit trees (mulberry, tea tree, jackfruit or coconut) which suggests an interest in **agroforestry systems** combining **food production** and **livestock**. **Unfortunately, these sorts of species are not sustainable in this region**.
- A small group of respondents expressed uncertainty or **lack of knowledge about timber species.**

These responses reflect a diverse range of motivations and preferences among landholders, from prioritising livestock needs to exploring agroforestry and timber options.

Based on spatial analysis of woody tree species across the predominant land types (**Table 2** and **Table 3**), a total of 24 woody species (**Appendix 2**) were identified as having natural distribution in the region. However, among the 24 species identified from spatial data (**Appendix 2**) and the list of species provided by respondents (**Figure 9**), the majority are not well-recognised timber species (Australian Hardwood Species Guide, 2018) based on consultations with forestry experts. Based on these assessments, we propose the following **seven species** (**Figure 10**) as the most **suitable for timber production** and **planting within silvopastoral systems** in the Northern Gulf region, including:

Corymbia citriodora subsp. citriodora (Lemon-Scented Gum, Spotted Gum): Grows to 45m high and 1.3m stem diameter on favourable sites otherwise to only half. This species generally has straight, slender trunks with smooth bark. It prefers lighter loamy soils or skeletal soils and drought tolerant (**Appendix 4**).

Eucalyptus crebra (Narrow-Leaved Ironbark): tree to 35m tall, it is widely distributed along the coast and inland slopes and plains of New South Wales and Queensland as far as Cooktown and inland to Einasleigh, Pentland, Alpha, Mitchell and Goondiwindi (**Appendix 4**).

E. camaldulensis (River red gum): medium-sized to tall tree. E. camaldulensis occurs in North Queensland and widespread along rivers of Cape York Peninsula and Gilbert River. This species grows under a wide range of climatic conditions from tropical to temperate, but the main areas are characterised by 5 to 20 frosts in winter and high summer temperatures (**Appendix 4**).

E. argophloia (Chinchilla White gum): Medium to tall tree, growing to 40m high; Naturally occurring trees have good form with stems clear of branches for at least half the tree height. occurs in flat to undulating country at 300-340m above sea level. It prefers deep, dark, heavy clay soils, often with strong gilgai (melon hole) development. It has been recorded growing in brigalow woodland and forest communities associated with belah, poplar box and inland grey box (**Appendix 4**).

E. cambagiana (Dawson gum): Small to medium-sized trees. It occurs on grey clay soils in closed depressions on sandplain or ferricrete. Mainly of central-eastern Queensland, from Charters Towers south almost to Tambo and east to Biloela; also north and west of Charleville, in the Taroom district and south of Rockhampton (**Appendix 4**).

E. thozetiana (Napunyah): Small to medium-sized trees, tree to 17 m tall. Trunks often fluted or shallowly buttressed at base. It is widespread in Queensland from Jundah and Quilpie in the south-west, east to the Darling Downs and north to near Emerald. The species prefers pebbly soils on slight rises (**Appendix 4**).

Khaya senegalensis (African mahogany): This tree from central and west Africa, has a smooth grey-barked trunk. It can grow 15 - 30 metres tall. The species has been identified as a potentially valuable plantation species suitable for commercial planting in the dry tropics of Australia (Reilly and

Robertson, 2006). The species was probably first introduced into Australia as a street tree and in parkland plantings. CSIRO established the first plantation trials at sites near Darwin during the late 1950s. It was later included in mine rehabilitation programs established in Cape York during the early 1970s. More recently large-scale plantations have been planted in the Northern Territory (Reilly and Robertson, 2006) (**Appendix 4)**.

We also undertook a preliminary assessment of the growth and survival of **seven species** based on data collected from **15 research trials** established from **1989 to 2003** (**Appendix 3**). The data (see **Table 4**) presents survival, average height and diameter increments for the seven tree species, highlighting their growth performance over a specific period. This analysis provides insights into the potential growth dynamics of these species, which can be critical for establishing silvopasture systems in the region. Preliminarily results indicate that most species show moderate growth with **height increments** ranging from **0.6 – 1.0 m/year** and **diameter increments** between **0.7 – 1.1 cm/year in this region**. However, it is important to note that some trials lack diameter data and measurements varied across ages of 2.1 to 21.7 years. Additionally, survival rates varied from 6.2% to 100%, influenced by the availability of a good growing environment (e.g soil nutrients, suitably drained soils and planting year). Thus, **further research that includes tree improvement, testing species in different soil conditions and environments, along with long-term data collection** is necessary to gain a comprehensive understanding of their adaptation and growth rates in silvopasture systems.

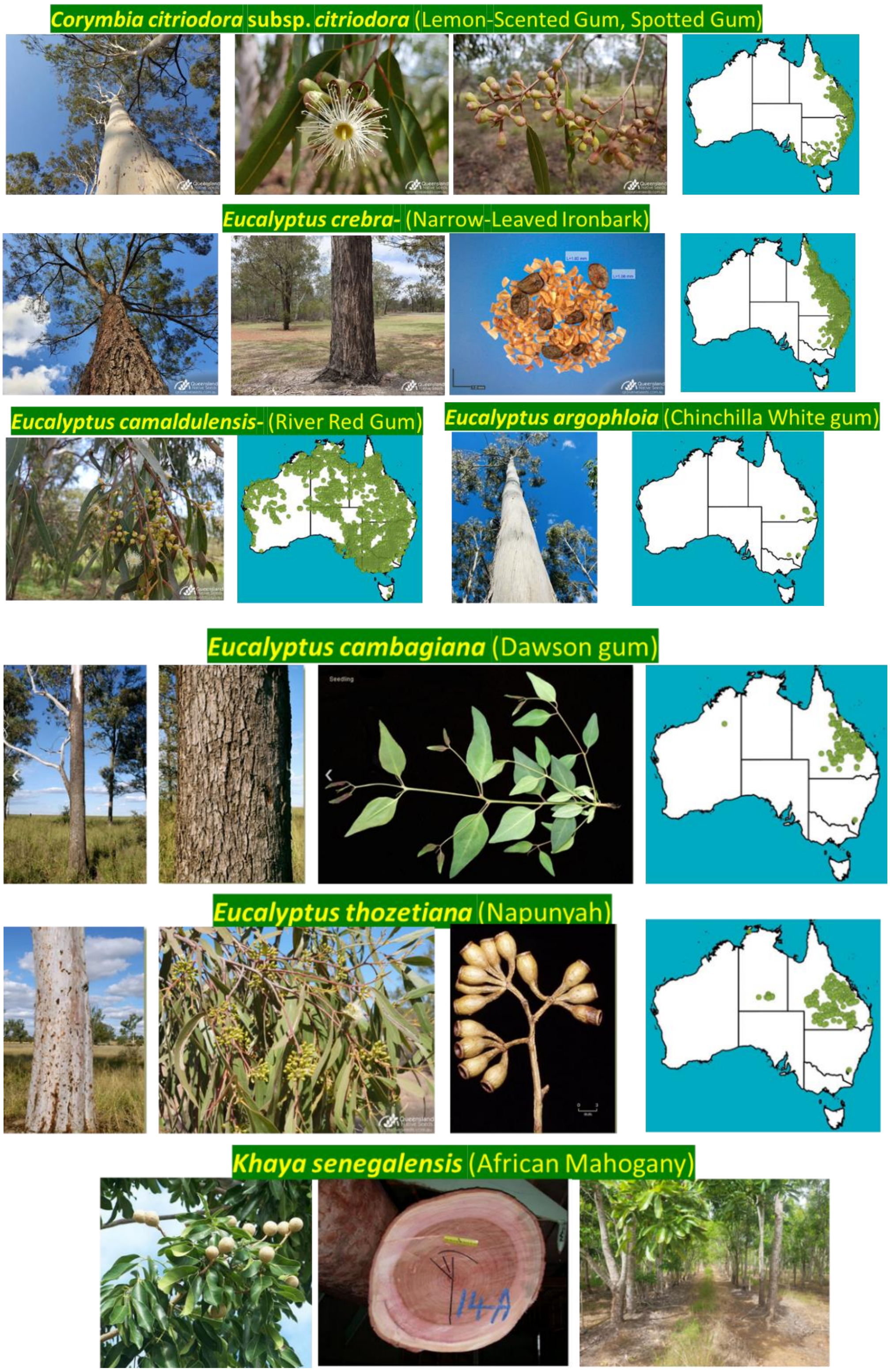


Figure 10. Photos of seven potential tree species can be planted in silvopasture models in the Northern Gulf region (Photo sources: EUCLID and Queensland Native Seeds).

Table 4. Preliminarily assessment of the growth and survival of seven potential tree species in the region of interest (N/A means data not available)

Species	Trial ID	Rainfall	Measured age	Survival (%)	Height increment (m/year)	Diameter increment (cm/year)
Corymbia citriodora* subsp. *citridora Average height increment = 1.0 Average diameter increment = 0.9	395 HWD[#]	859	**11.9**	29.8	1.4	1.4
	503 AHWD	1014	**10.8**	70.3	1.1	1.0
	503 CHWD	800	**21.7**	64.6	0.8	0.6
	508 AHWD	411	6.0	21.9	0.7	N/A
	508 FHWD	755	5.4	77.5	1.0	0.7
	806 AATH	633	5.0	62.5	0.9	1.0
E. crebra Average height increment = 0.7 Average diameter increment = 1.0	806 AATH	633	5.0	6.2	0.8	1.0
	508 AHWD	411	6.0	41.7	0.7	N/A
	508 FHWD	755	5.4	95.0	0.7	0.9
E. camaldulensis Average height increment = 1.0 Average diameter increment = 0.9	738 ATH	N/A	2.1	92.9	1.3	N/A
	806 AATH	633	5.0	72.9	0.7	0.9
	332 HWD	371	3.0	100.0	**1.6**	N/A
	333 HWD	443	3.0	57.1	1.2	N/A
	334 HWD	443	3.1	7.1	0.7	N/A
	341 HWD	371	2.1	71.4	**1.6**	N/A
	343 HWD	443	2.1	14.3	0.5	N/A
	503 AHWD	1014	**10.8**	73.3	0.9	1.0
	503 CHWD	800	**21.7**	70.0	0.7	0.7
	508 AHWD	411	6.0	43.1	0.7	N/A
	508 FHWD	755	5.4	100.0	0.8	0.8
E. argophloia Average height increment = 0.9 Average diameter increment = 0.8	332 HWD	371	3.0	85.7	1.4	N/A
	333 HWD	443	3.0	85.7	1.5	N/A
	341 HWD	371	2.1	64.3	1.0	N/A
	343 HWD	443	2.1	28.6	0.8	N/A
	395 HDW[#]	859	**11.9**	30.1*	1.2	1.4
	503 AHWD[#]		**21.7**	43.3*	0.7	0.6

Species	Trial ID	Rainfall	Measured age	Survival (%)	Height increment (m/year)	Diameter increment (cm/year)
	508 AHWD		6.0	54.2	0.6	0
	508 FHWD		5.4	86.4	0.7	0.9
	738 ATH		2.1	78.6	0.7	N/A
	806 AATH		5.0	45.8	0.6	1.2
E. cambagiana Average height increment = 0.8 Average diameter increment = 0.8	738 ATH		2.1	57.1	0.6	N/A
	332 HWD		3.0	100	1.3	N/A
	333 HWD		3.0	71.4	1.1	N/A
	334 HWD		3.1	100	0.8	N/A
	341 HWD		2.1	71.4	0.4	N/A
	343 HWD		2.1	85.7	0.6	N/A
	503 AHWD#		**21.7**	30.0	0.6	0.5
	508 FHWD		5.4	95.0	0.9	1.1
E. thozetiana Average height increment = 0.7 Average diameter increment = 1.1	738 ATH		2.1	35.7	0.3	N/A
	332 HWD		3.0	78.6	0.7	N/A
	333 HWD		3.0	50.0	0.7	N/A
	341 HWD		2.1	64.3	0.6	N/A
	508 FHWD		5.4	90.0	1.0	1.2
K. senegalensis Average height increment = 0.6 Average diameter increment = 0.9	806 AATH		5.0	60.4	0.7	0.9
	810 AATH		13.4	96.7	0.9	1.8
	856 ATH		10.2	35.4	0.8	1.5
	508 FHWD		5.4	100	0.3	0.4
	503 AHWD		**10.8**	67.2	0.3	0.6

#: Survival was calculated for post thinning. Trial data accessed from the DAF Forest Technologies Database

6.3 Local/producer knowledge in a grazing context

The Tropical North Queensland Drought Resilience Adoption and Innovation Hub (TNQ Hub), led by James Cook University, aims to support land managers and communities in preparing for future drought and climate resilience. The primary agricultural industries within the TNQ Hub include extensive livestock grazing with 88% of land use, including beef cattle and wool. Grazing of livestock, especially beef cattle on native pasture is the most widespread land use in Gulf Savannah. The TNQ Hub hoped that grazers would shift intensive grazing into silvopastoral systems.

To support this transition, the project team (including UniSC, Forestry Hub and Gulf Savannah NRM) developed a survey form (**Appendix 1**) comprising 27 questions. These questions aim to cover key perceptions regarding the establishment and management of potential silvopastoral systems for drought resilience and timber production. The survey addresses topics such as livestock management, awareness of the benefits of integrating trees into grazing areas, main challenges to adopting silvopasture practices, and key resources needed to build confidence in establishing silvopasture systems.

6.3.1 Demographic characteristics and number of responses

The population distribution across the Northern Gulf is approximately **9,392 people** by 2023 (**Figure 11**), with the highest proportion being Mareeba Shire (56%) while Cook Shire has the smallest number (0.5%). Due to limited time and funds, we surveyed 49 individuals across the region and the dominant participants were living in Mareeba Local Government Area and the rest included Carpentaria Shine, Cook Shire, Etheridge Shire, Tablelands Regional and Cairns Regional Council.

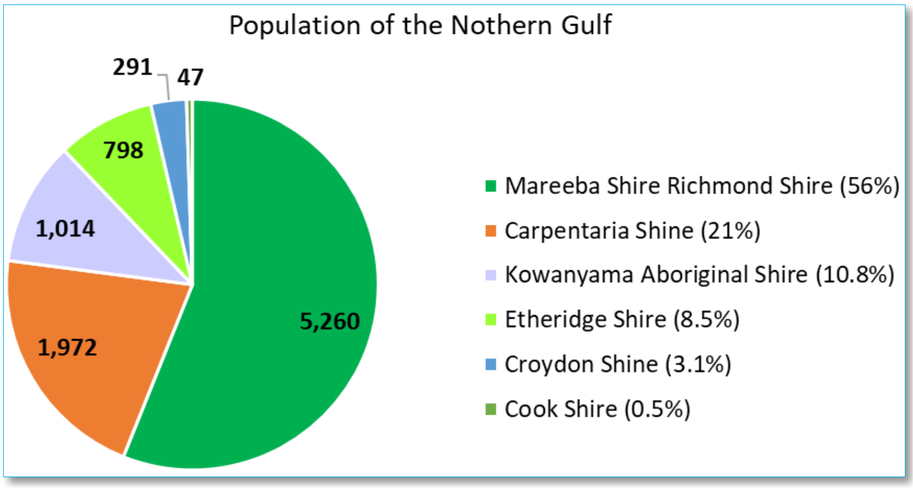


Figure 11. The population distribution across the Northern Gulf is approximately 9,392 people by 2023.

Table 5 shows the number of survey respondents with a balanced gender distribution, with 50% male and 50% female, and a majority (43.8%) aged 55 or older. Other age groups included 45 to 54 (20.8%), 35 to 44 (16.7%), 25 to 34 (14.6%), and 18 to 24 (4.2%). In terms of education, nearly half (48.9%) held a high school diploma or equivalent, while 20% had some college or an associate's degree, 13.3% had a bachelor's degree, and 17.8% had a master's degree or higher. The majority of respondent types identified as farmers or producers (51%), followed by landowners (40.8%), and a smaller proportion represented local government (8.2%).

Regarding land tenure, most respondents owned their land (69.7% freehold), while 27.3% operated on leasehold land, and a small number (3%) were part of a forest consent area. In terms of cattle scale, 22.9% of respondents managed less than 100 cattle, 10.4% had between 0 and 500 cattle, 6.3% managed 500 to 1,000 cattle, and 25% managed between 1,000 and 5,000 cattle. A small group (6.3%) has more than 5,000 cattle, while 29.2% of respondents did not have cattle operations.

Table 5. Summary respondent characteristics, n is the number of respondents.

Characteristics	Categories	n	Percentage (%)	Comment
Age	18 to 24	2	4.2	Skipped: 1
	25 to 34	7	14.6	
	35 to 44	8	16.7	
	45 to 54	10	20.8	
	55 or over	21	43.8	
Gender	Male	24	50	
	Female	24	50	
Education level	High school diploma or equivalent	22	48.9	Skipped: 4
	Associate's degree or some college	9	20	
	Bachelor's degree	6	13.3	
	Master's degree or higher	8	17.8	
Respondent type	Farmer/ Producer	25	51.0	Skipped: 1
	Landowner	20	40.8	
	Local government	4	8.2	
Land tenure	Freehold	23	69.7	Skipped: 16
	Leasehold	9	27.3	
	Forest consent area	1	3.0	
Cattle scale	Less than 100	11	22.9	Skipped: 1
	0-500	5	10.4	
	500-1000	3	6.3	
	1000-5000	12	25.0	
	Over 5000	3	6.3	
	Not applicable	14	29.2	

This demographic and land use profile highlights the diversity of backgrounds among survey participants, with a substantial proportion being experienced farmers or landowners managing a range of cattle scales, education levels, and land tenure types. Despite limitation of participant numbers, the responses to other questions give an overall indication of priorities and problems of transferring from intensive grazing to silvopasture.

6.3.2 Current level of familiarity with silvopastoral systems and neighbour or community perceptions

Figure 12a highlights a current level of familiarity with silvopastoral systems among respondents, with 54.2% indicating they were either somewhat familiar (39.6%) or very familiar (14.6%). However, nearly half (45.9%) of respondents had little to no familiarity, either having heard of it but not familiar with details (29.2%) or being not familiar at all (16.7%). This suggests that while some awareness exists, there is still significant room for education and outreach to increase understanding of silvopastoral systems.

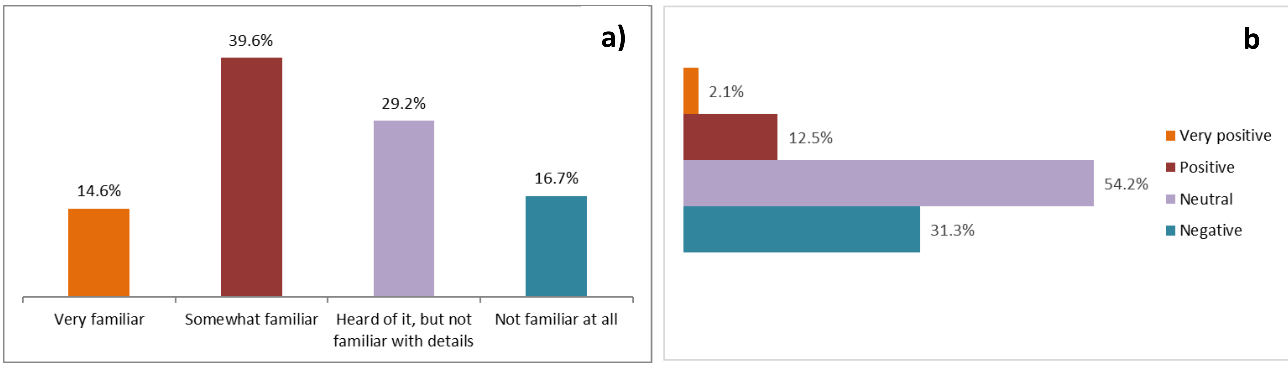


Figure 12. Current level of familiarity with silvopastoral systems and perceptions within neighbours or communities.

When asked about the perceptions of their neighbour's or community's views (Question 24, **Appendix 1**), the majority of respondents (54.2%) believed their communities held a neutral stance, with 31.3% of perceptions being negative (**Figure 12b**), while only 14.6% thought the views were positive (12.5%) or very positive (2.1%). This indicates a potential barrier in public acceptance or understanding of the benefits of silvopastoral systems, with relatively few respondents perceiving strong support for them in their communities. Thus, **addressing these negative or neutral perceptions through targeted communication and demonstration of the system's benefits could be key to fostering wider acceptance and engagement**.

6.3.3 Benefits of integrating trees or shrubs into grazing areas and positivity impact on livestock's well-being and productivity

Figure 13 shows that a majority of respondents (56.5%) recognise the comprehensive benefits of integrating trees or shrubs into grazing areas. This suggests that most respondents see **multiple benefits from planting trees in pastureland** such as **enhanced animal welfare, land rehabilitation, improved ecosystem services,** and **diversified income streams**. Of the individual benefits, diversified income streams (21.7%) were identified as the most important, indicating the financial potential of silvopastoral systems, particularly through timber production and carbon credits (**Figure 13**). Enhanced animal welfare (13.0%) also stood out, emphasizing the role of trees in providing shelter and reducing heat stress for livestock (**Figure 13**).

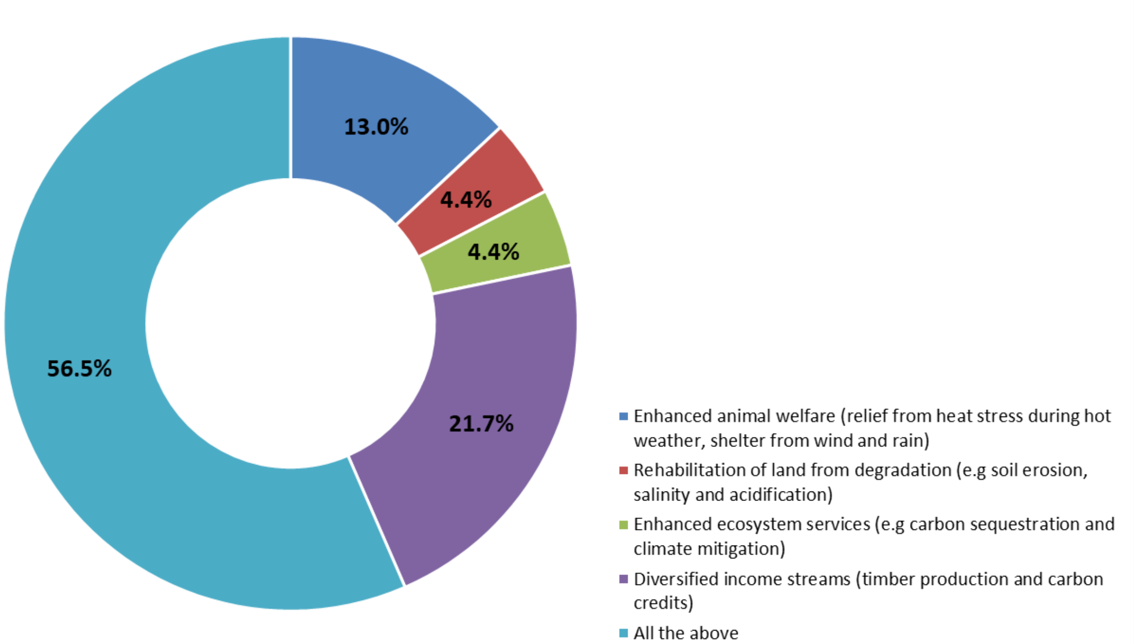


Figure 13. Primary benefits of integrating trees or shrubs into grazing areas

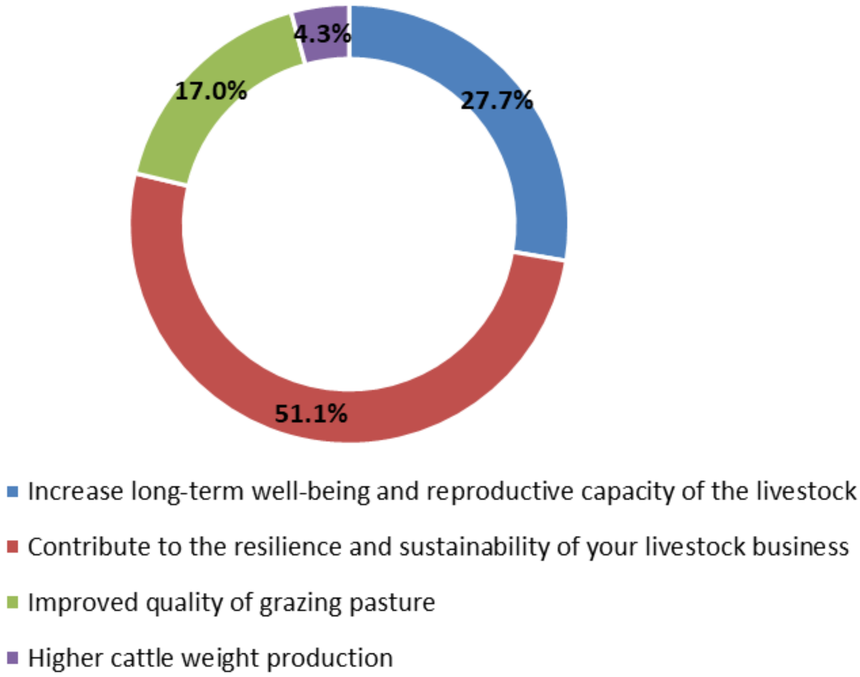


Figure 14. Positively impact livestock well-being and productivity

Along with the primary benefits of silvopasture, respondents largely believe that silvopastoral systems could positively impact livestock well-being and business sustainability. Over half (51.1%) indicated that silvopastoral systems contribute to the **resilience and sustainability** of their livestock businesses, while 27.7% noted the potential to **increase long-term well-being and reproductive capacity** (**Figure 14**). The focus on resilience and sustainability reflects a broader recognition of silvopastoral systems as a long-term strategy to enhance both environmental and economic outcomes. **Improved quality of grazing pasture** (17.0%) and **higher cattle weight production** (4.3%) were seen as less significant but still notable impacts on livestock productivity (**Figure 14**). This suggests that respondents are more focused on the overall resilience and welfare benefits than immediate productivity gains.

6.3.4 Main challenges or barriers to adopting silvopasture practices

Survey results indicate that the primary concern for respondents regarding the implementation of silvopastoral systems is *competition between grass and trees*, with 31.7% identifying this as a significant issue (**Figure 15**). This reflects **a common worry that trees might compete with pasture for water, nutrients, and sunlight, potentially affecting livestock productivity**. In addition, 29.3% of respondents were concerned about **vegetation laws changing frequently**, highlighting the regulatory uncertainty that may hurdle landowners from adopting silvopastoral practices (**Figure 15**). A significant proportion (24.4%) of respondents expressed concerns about whether sufficient *resources and support* would be available to help landowners implement and manage these systems (**Figure 15**), pointing to the need for more accessible guidance and financial or technical assistance. Concerns about *tree damage by livestock* (7.3%) and the *long time for timber returns* (7.3%) were less prominent (**Figure 15**).

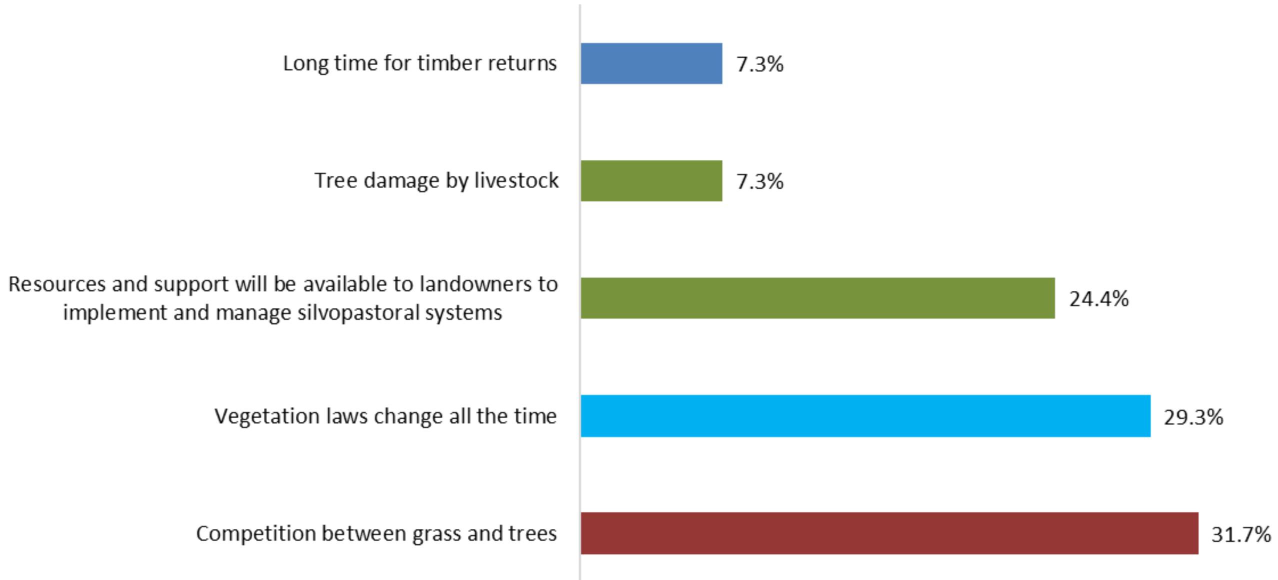


Figure 15. Respondents are concerned about implanting silvopastoral systems in grazing areas.

Following a factor of vegetation laws change all the time (**Figure 15**), the main challenges or barriers to adopting silvopasture practices are **primarily regulatory constraints or land tenure issues**, which were indicated by 30.2% of respondents (**Figure 16**). Frequent changes in vegetation laws create significant challenges for land management, particularly when it comes to land clearing. Even if mapping shows that land is available for clearing under a Category X classification, farmers may still be unable to clear it due to complex regulations. For example, if a landowner wants to amend the regulated vegetation management map to reclassify an area as Category X, they must apply to the chief executive. However, the chief executive can only approve this reclassification if specific conditions outlined in sections 20AH or 20AI of the Vegetation Management Act are not met (**Vegetation Management Act 1999**). In addition, an area is not considered Category X if the chief executive, under section 20CA, determines it does not qualify. These legal complexities create uncertainty for landowners.

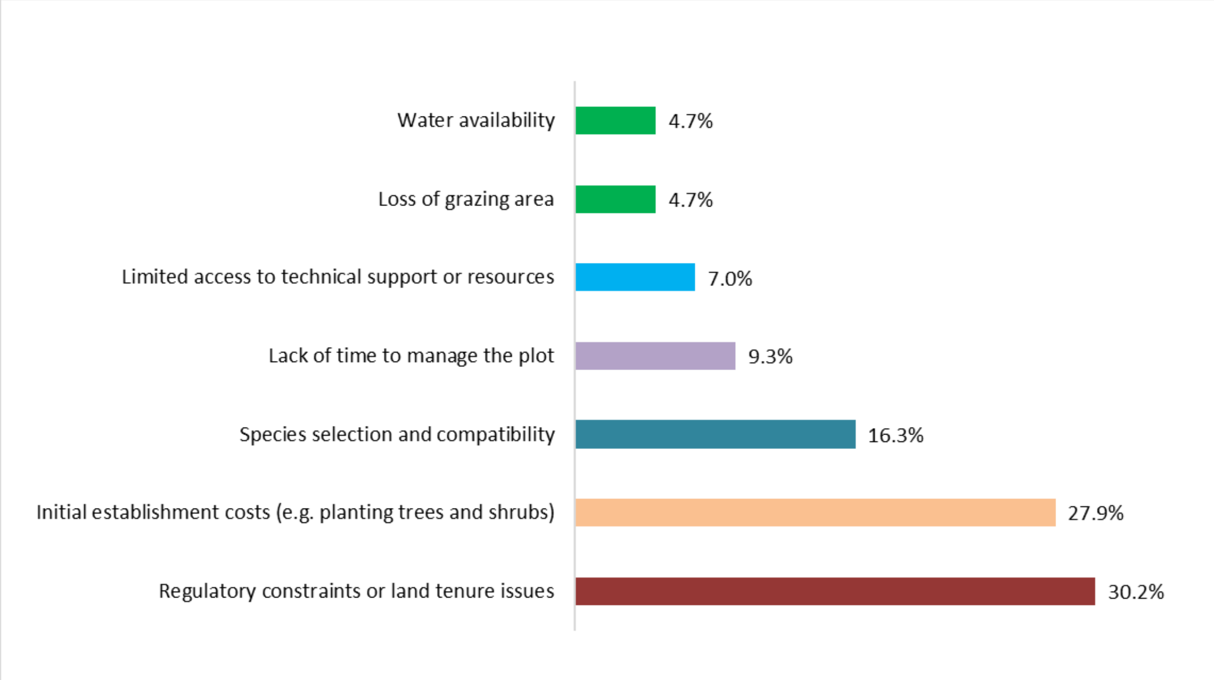


Figure 16. Main challenges or barriers to adopting silvopasture practices

The 27.9% of participants identified the high **initial establishment costs**, such as tree and shrub planting, as a significant challenge (**Figure 16**). **Species selection and compatibility** also pose challenges for 16.3% of respondents (**Figure 16**). Other barriers include a **lack of time to manage silvopasture plots** (9.3%), limited access to technical support or resources (7.0%), and concerns over **loss of grazing area** and **water availability**, each cited by 4.7% of respondents (**Figure 16**).

6.3.5 Integrating trees into pastureland: willingness, confidence levels and resource needs

When looking at the willingness to plant trees on grazing land, the majority (61.7%) have considered integrating trees into their pastureland, which reflects a significant interest in silvopasture and its potential benefits (**Figure 17a**). However, a notable minority (38.3%) have not considered this option (**Figure 17a**) which could be due to uncertainty or lack of confidence in managing silvopasture systems. This is evident in the responses related to confidence levels: the largest group expressed a neutral level, nearly one-third were somewhat confident, 16.7% were not confident, and only 12.5% felt very confident (**Figure 17b**).

When asked about what additional information or resources are needed for implementing silvopasture into their farms. Most respondents indicated **financial resources** (31.3%) as the most requested support, indicating that cost may be a major barrier to adopting silvopasture **Figure 17c**. Grants and subsidies could make silvopasture more accessible, especially for those who are hesitant due to potential establishment costs. **Technical advisory assistance** (27.1%) was the second most requested resource, reflecting a need for expert guidance from sources such as government agencies or Forestry Hubs. This support would aid in effectively integrating trees into pasturelands, managing tree growth alongside livestock, and addressing the technical complexities of silvopasture. In addition, **market information** (22.9%) was also in demand, with nearly a quarter of respondents interested in understanding market opportunities for wood products, which could positively impact their willingness to invest in silvopasture if they see potential economic returns.

The remaining respondents (18.8%) expressed a need for assurance from the government to ensure they **will not face restrictions on land use in the future** (e.g. clearing or harvesting on freehold land). These respondents emphasised the importance of resource security, underscoring the need for guaranteed access to their land for management activities without fear of regulatory constraints. Concerns were also raised about the risk of land being "**locked up**," which could limit its integration into broader food systems. Additionally, they highlighted the need for clear guidance on carbon opportunities and market potential for thinning products, both of which are crucial for making informed decisions on adopting silvopasture practices.

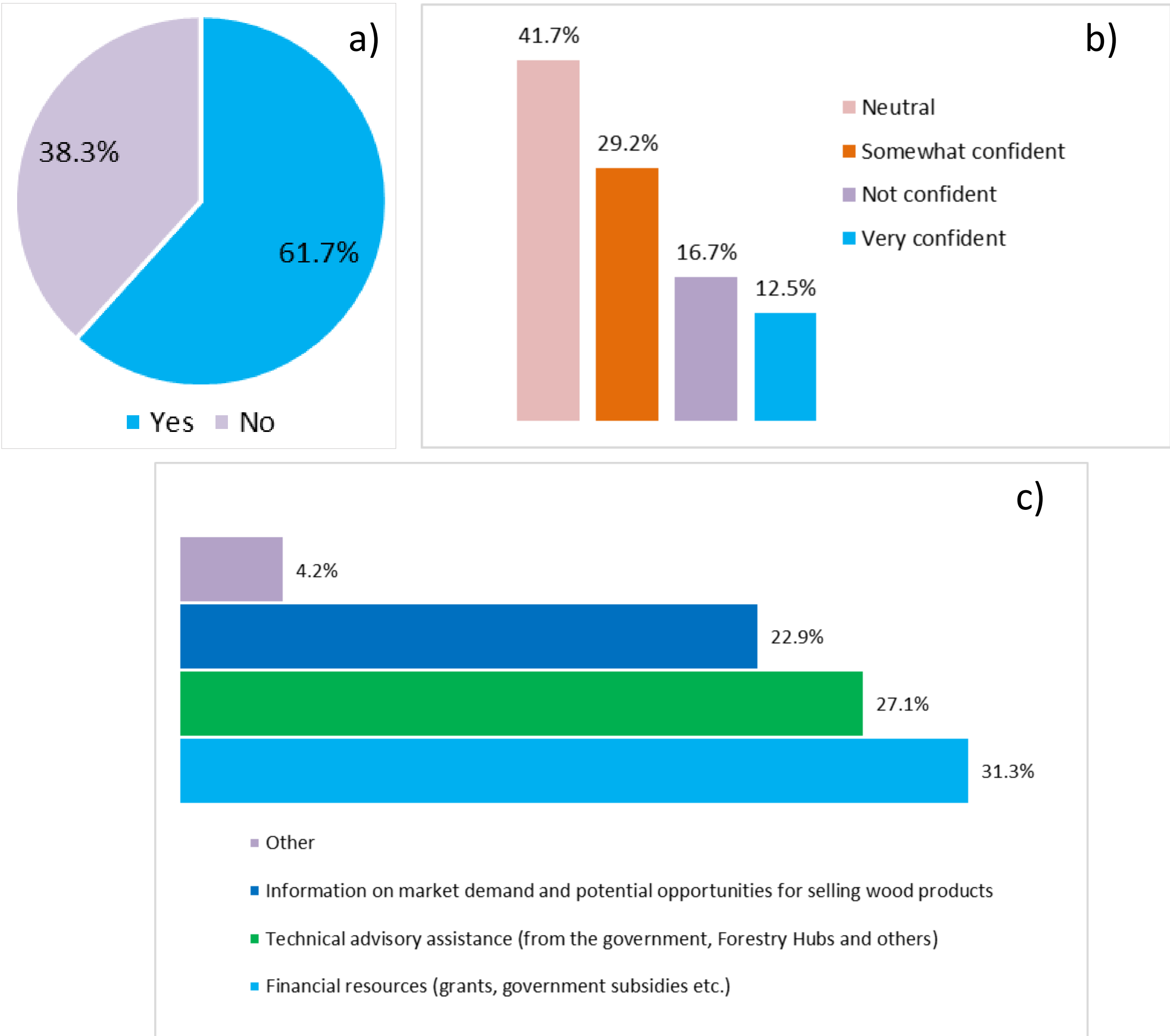
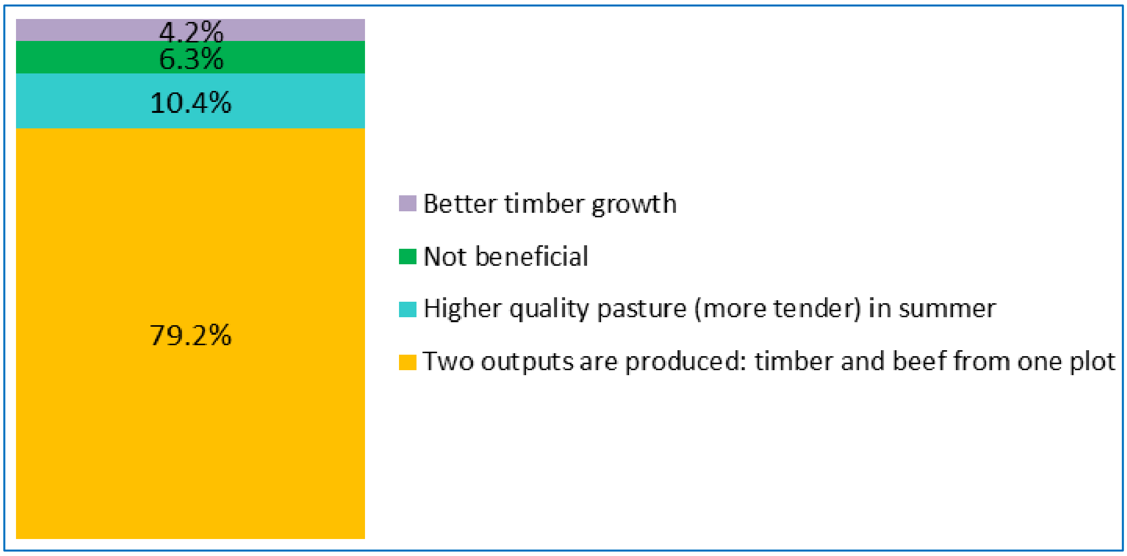


Figure 17. Consideration for integrating trees into pastureland (a), confidence levels for implementing and managing a silvopasture system (b) and additional information or resources needed to facilitate the transition to silvopasture practice (c).

6.3.6 Potential long-term economic benefits, mitigate climate change and improve drought resilience

Figure 18 highlights a significant awareness and appreciation for the long-term economic advantages and climate benefits of silvopastoral systems. Notably, 79.2% of respondents perceive the ability to produce two outputs (timber and beef) from one plot as a significant economic benefit. This suggests a strong preference for integrated production systems that enhance overall productivity and potentially increase profitability. Only 10.4% of respondents believe that silvopastoral systems contribute to higher-quality pasture during summer. This may indicate a less recognised advantage or a perception that quality improvements are secondary to the dual output benefit. A small percentage of respondents (only 6.3%) view silvopastoral systems as not beneficial, reflecting a growing awareness of the advantages of integrated systems or possibly a lack of understanding of the potential benefits.



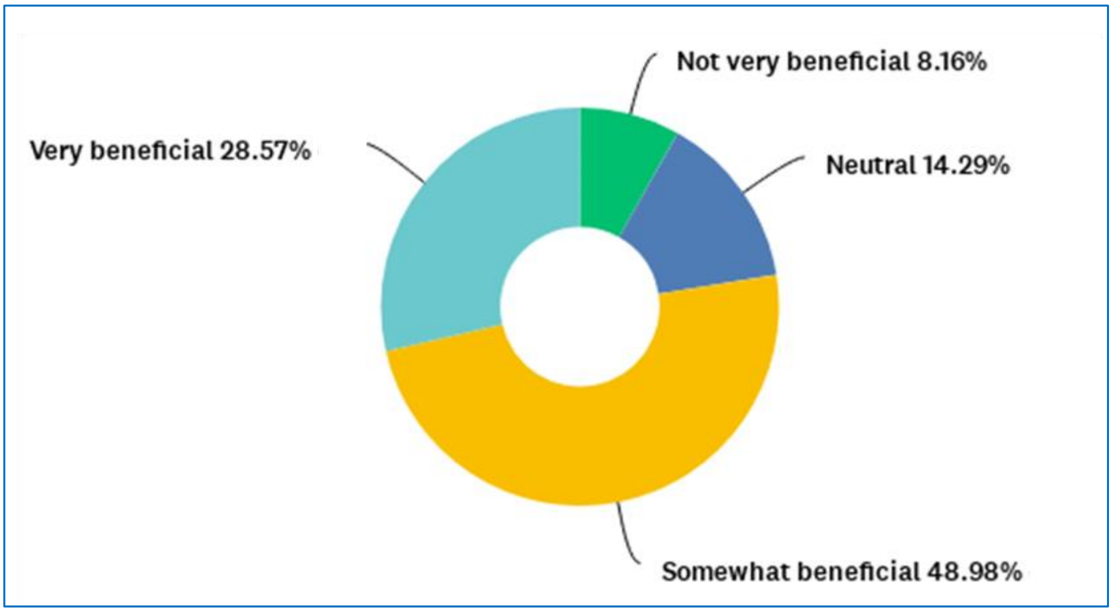


Figure 18. Potential long term economic benefits (top), along with the mitigation of climate change and improvements in drought resilience (bottom).

A combined total of 77.6% of respondents see silvopastoral systems to be at least somewhat beneficial in mitigating climate change and improving drought resilience (49.0% somewhat beneficial and 28.6% very beneficial). This indicates a strong belief in the positive environmental impact of integrating trees and livestock. However, the neutral (14.3%) and not very beneficial (8.2%) responses show that while many see potential benefits, there remain some uncertainties or mixed perceptions regarding the effectiveness of these systems in addressing climate change and drought challenges (**Figure 18)**.

Figure 19. A field tour and on-ground assessment between 20 -24 May 2024.

6.4. Early-stage knowledge in the adaptation of silvopasture: from traditional pasture to tree -integrated systems.

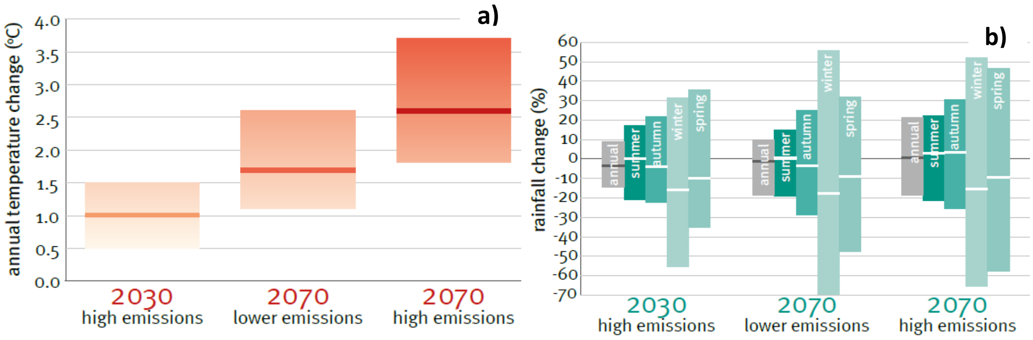
Silvopasture presents significant climate adaptation benefits that address challenges such as drought, heat and heavy rainfall. Integrating trees into pastures creates shade for livestock and provides protection in harsh weather conditions. In addition, silvopasture systems contribute to carbon sequestration and improve soil health by increasing organic matter, enhancing water retention, and promoting efficient water filtration. When both elements – livestock and trees are combined, it can improve the local ecosystem, which is a powerful strategy for building drought resilience in grazing operations and adapting to climate change. However, the adaptation of silvopasture in extensive grazing systems in Northern Gulf Savannah is still in its early development stages, particularly focusing on enhancing ecosystem resilience and livestock productivity. This project emphasises key considerations around establishment and management principles for tree species in silvopastoral systems.

6.4.1 Climate change considerations

According to the 2019 report on *Climate change in the Gulf region* (State of Queensland, 2019), the Gulf region is generally hot to very hot throughout the year:

- The annual average temperature is **26 degrees** (°C). The December to February average temperature is **30°C**; for July to August, the average is 22°C.
- Annual and seasonal average rainfall are variables affected by local factors such as topography and vegetation, and broader-scale weather patterns. Annual average rainfall is **751 mm** and rainfall is generated by heavy thunderstorms or tropical cyclones between **November** and **March**.
- The region's **annual average potential evaporation** is more than **twice the annual average rainfall**, leading to rapid **soil moisture depletion**.
- The region is also known for **low-nutrient soils**, and susceptibility to erosion, which necessitates native species that can be adapted to the region's nutrient-deficient soils.

- By 2030, annual average temperatures are predicted to rise between 0.5°C and 1.5°C (**Figure 20a**) compared to the 1986–2005 climate. By 2070, the projected increase ranges from 1.1°C to 3.7°C (**Figure 20**Error! Reference source not found.**a**), depending on future emissions levels. The r egion's current summer average temperature is 30°C. This could rise to over 31°C by 2030 and to over 33°C by 2070. **Figure 20b** shows rainfall patterns for 2070 are expected to remain, with possible slight declines in winter and spring rainfall.



Projected annual average temperature changes for the Gulf region. The horizontal line on each bar is the middle (median) projected temperature change. The extent of each bar indicates the range of projected changes.

Projected annual and seasonal rainfall changes for the Gulf region. The horizontal line on each bar is the middle (median) projected rainfall change. The extent of the bar indicates the range of projected changes.

Figure 20. Climate projections for the Gulf region (Source: Climate change in the Gulf region, 2019, version 1).

The current and projected climate characteristics emphasise the **importance of establishing silvopasture trials in the Northern Gulf region to enhance future climate resilience and drought resistance.** Converting intensive grazing to silvopasture systems can also generate ecological and financial benefits. Shelter provided by trees **decreases livestock stress**, **improves animal health** and **increases feeding efficiency**. Forage growing in a shady, low wind environment near trees is protein rich, lower in fiber and more digestible for livestock compared to forage growing in open pasture (Smith et al., 2022). Recent findings from dryland regions that have integrated trees into their silvopasture systems demonstrate impressive results, for example:

Kenya: In the highlands of Kenya, areas with tree cover and perennial grasses experience surface temperatures as low as 25°C on sunny days, compared to about 56°C in deforested and bare soil regions.

Latin America: Pasture-based cattle farms in Latin America have reported remarkable increases in productivity after incorporating trees into their systems. Forage production rose by over 175%, and milk production per hectare increased by more than 75%.

India: In the dryland regions of Jhansi, India, a 10-year rotational silvopastoral plan has led to a tenfold increase in production. This case illustrates the effectiveness of strategic planning and management in maximising the benefits of tree integration in grazing land.

Senegal: Over the past 30 years, hundreds of villages in Senegal have actively protected their common grazing lands, transforming degraded shrublands into thriving savannah landscapes. This initiative has resulted in an increase in woody cover of up to 65%, demonstrating the successful restoration of ecosystems and the enhancement of local grazing resources.

Source: FAO, 2021, Building climate-resilient dryland forests and agrosilvopastoral production systems.

6.4.2 The importance of engaged landowner management and technical assistance for tree and forage systems

Silvopasture is a management option requiring a high level of management. Unlike traditional single-product systems (intensive grazing), managing trees, cattle, and forage within silvopasture systems demands technical expertise and a deep understanding of each component's role and interaction. Survey results (**sections 6.3.5 and 6.3.6**) above highlighted that most respondents see value in integrating trees into pasturelands, they lack confidence and feel constrained by financial and technical barriers. Thus, assistance from state and federal programs can often provide essential support, offering technical resources for tree planting, pruning, thinning, and pasture establishment during the transition to silvopasture.

Successful implementation of silvopasture requires more than just land availability. It requires a high level of willingness from landowners to accept and actively participate in managing the complex interactions between trees and forage over time as silvopasture is not simply a **"plant it and leave it" approach**. This management includes ongoing care of tree species, ensuring proper growth and productivity while simultaneously overseeing forage components to optimize both pasture health and livestock productivity. Landowners need to be prepared to engage in adaptive management practices that may involve from initial planting to pruning and thinning to achieve long-term success in silvopasture.

6.4.3 Initial establishment and long-term management costs

Converting intensive grazing to silvopasture requires a significant investment related to establishment and ongoing management (**Table 6**). Establishing silvopasture requires investment in tree planting, site preparation, and fencing to protect young trees. There are also maintenance costs for managing tree growth, soil quality, and ensuring optimal spacing to balance forage and shade, as well as costs for managing potential pests and diseases.

Federal or state-level investments are essential in supporting producers and landowners transitioning to silvopasture. With appropriate funding, producers can enhance economic returns, improve resilience to drought, and contribute to environmental sustainability through practices that increase carbon sequestration and boost livestock productivity.

Table 6. Costs involved in silvopasture.

Initial establishment costs	*Long-term management costs*
Site preparation ○ Land clearing: This can be done using either machinery or herbicides. Costs include equipment rental or purchase, labour and cost of herbicides ○ Row preparation: Titling or ploughing rows for tree plantings requires machinery and labour ***Soil testing and amendments (if necessary)*** ○ Soil sampling: testing the soil to determine nutrient levels is crucial for tree growth	***Tax classification and eligibility:*** *does the system qualify for tax incentives or exemptions?* ***Annual forage establishment*** ○ Seeds ○ Herbicide to control weeds ○ Labour ○ Equipment usage and maintenance ***Fence maintenance*** ○ Regular upkeep and repairs for effective livestock management ***Fertiliser amendments (if necessary)***

○ Fertiliser for tree planting and forage ***Seedling procurement*** ○ Seedling cost: this includes the cost of seed collection, seedling production and any logistics involved in transporting seedlings to the site ***Labour for planting*** ○ The labour associated with tree planting might include number of workers required and the duration of planting activities ***Fencing*** ○ Fence type: Options include permanent or temporary fencing, such as high-tensile electric fencing or portable polywire. Additional costs depend on whether solar-powered or traditional fencing systems are used	○ Nutrient supplementation for soil health and forage productivity ***Labour costs for pruning and thinning*** ***Forest management activities:*** ○ Management effort for pests and diseases control to sustain tree health and productivity

6.4.4 Planning and establishment considerations

Livestock

Livestock must be intensively managed in silvopasture systems to ensure the sustainability of both the trees and the pasture. Key factors such as timing and duration of grazing, stocking rates, and carrying capacity of the pasture must be carefully monitored to maintain site quality and tree seedling survival by minimising damage to seedlings (especially during the first to second year after planting trees). Depending on the density and growth rate of both trees and forage, livestock should be rotated between "pastures" to support growth and productivity of trees and forages.

Trees

Trees in silvopasture systems can be established in one or two ways by: thinning existing trees in native forests (e.g X class land), or planting new trees on existing pastureland. Silvopasture trees can be arranged in uniform block plantings, clusters or in single or multiple rows, with the primary goal of optimising space and light availability for both trees and forage. There are common tree planting configurations such as single-row plantings, double-row plantings and multiple-row plantings (**Figure 21**).

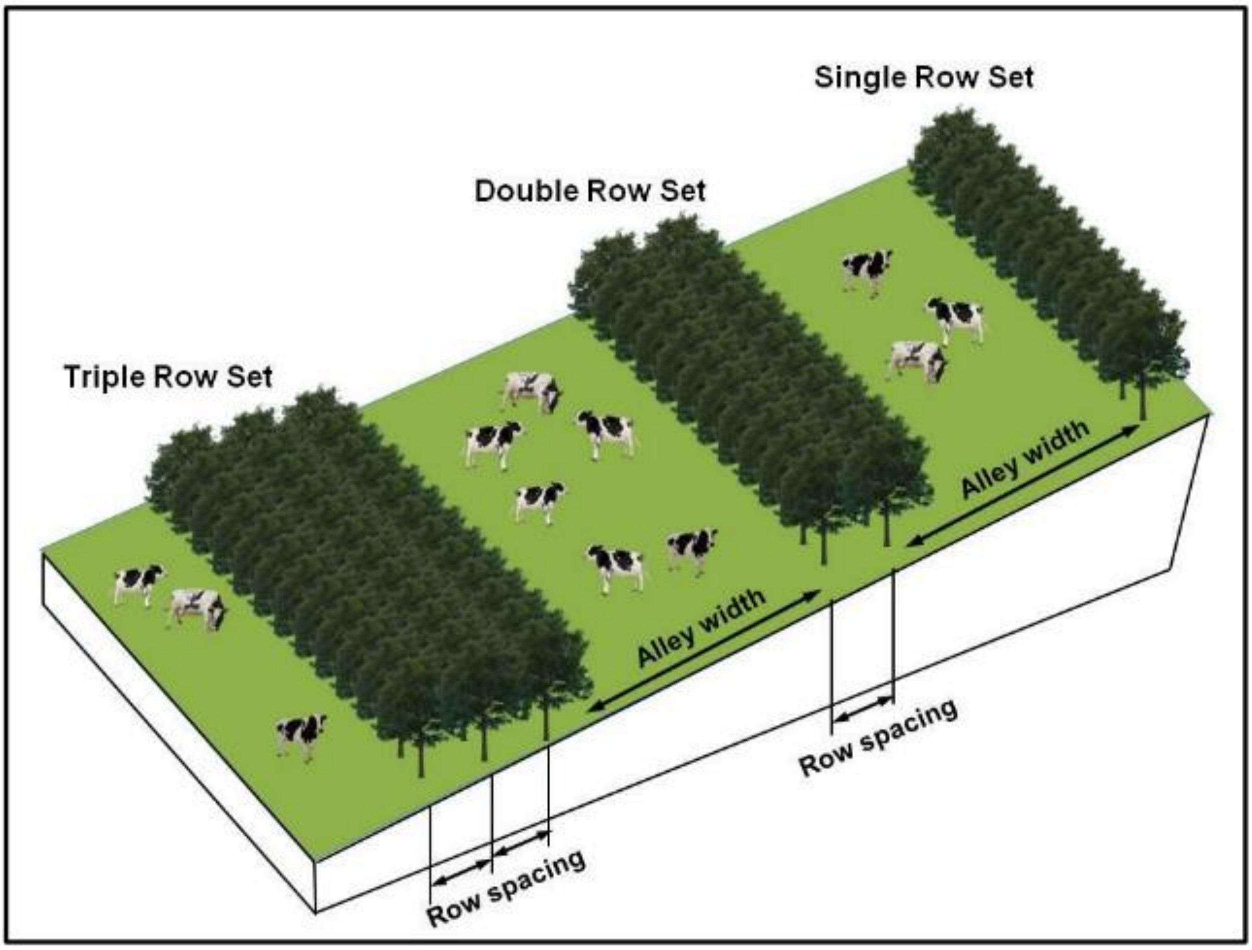


Figure 21. An example design of silvopastoral systems with single, double or triple rows (source: USDA National Agroforestry Center 2000).

Examples from silvopastoral trials in Cardwell (CRCNA), where trees were planted in two- and three-row configurations with 10m and 20m alleys. The Steak 'n Wood project features several configurations: trees planted in double rows with a 20m Leucaena alley, trees in double rows with 15m pasture alleys, and additional two-row alley configurations with 8m, 12m, and 16m alleys. This project (Steak 'n Wood) also includes thinned systems with native pasture and thinned systems with improved pasture in native forests.

The spacing between trees or tree rows should be wide enough gaps to provide open spaces for pasture production. Most forage species require a minimum of 50% light for optimal growth and careful management of canopy density to ensure adequate light availability. Specifically, the tree canopy should be managed to allow for 40% to 60% light penetration. As canopy cover exceeds 50-60%, the amount of light reaching the ground will decrease and the quality of the forage will deteriorate. Therefore, timely thinning and proper pruning are important practices to enhance log value while ensuring sufficient sunlight for forage growth.

Early stage silvopasture trials have been successfully implemented in Cardwell (Figure 22), North Queensland with Caribbean pine (*Pinus caribaea* var. *hondurensis*). This species demonstrates compatibility with grass production (Megathyrsus maximus var. maximus) and legumes (*Stylosanthes guianensis*, *Calopo mucunoides*, *Mimosa pudica* and *Sena obtusifolia*) and supporting livestock grazing in a silvopastoral system. Three planting densities were established for the pine plantation: 833 trees/ha; 556 trees/ha and 333 trees/ha. However, in this project, we have proposed seven hardwood species (detailed **in Section 6.2**) as potential species for establishing silvopasture systems in the Gulf region. On average, hardwood species typically need more room to grow and take a longer time to reach maturity than softwood. **Further research is necessary to test and evaluate appropriate planting density as well as the adaptability and performance of these hardwood species under diverse regional conditions**.

*Figure 22. Caribbean pine (*Pinus *caribaea* var. *hondurensis) integrated with cattle in a silvopastoral system in Cardwell, North Queensland.*

Integrating tree Legumes and herbaceous legumes

Adequate soil fertility, proper pH, and well-developed structure provide the foundation for a productive silvopasture system. However, the soil in the Northern Gulf region is a variety of types (**Table 2** and **Table 3**) which is almost characteristic of low nutrient status, low nitrogen, light textures, high pH, low moisture, and cracking. In many soils, nitrogen levels are insufficient for optimal plant growth, limiting pasture productivity. Integrating tree legumes or herbaceous legumes plays a significant role in enhancing both animal nutrition and soil fertility.

Tree Legumes and herbaceous legumes could address soil issues by fixing atmospheric nitrogen through symbiotic bacteria (rhizobia) on their roots. This process converts nitrogen into a form that can be utilised by plants, enriching soil fertility and enhancing the growth of both forage species and surrounding grasses. The amount of nitrogen fixed by legumes depends on their growth conditions, with fixed nitrogen levels varying widely—from under 50 kg/ha/year (equivalent to 100 kg of urea/ha) to over 200 kg/ha/year (exceeding 400 kg of urea/ha) (Mayberry et al., 2021). This natural nitrogen input significantly benefits the entire silvopastoral system, improving soil health (soil organic carbon and total nitrogen), reducing the need for synthetic fertilisers and indirectly supporting tree growth.

Figure 23. From top to bottom in the photos: Leucaena (Leucaena leucocephala) has been established at Whitewater Station (top) and Pinnarendi Station (bottom).

Tree legumes such as *Leucaena leucocephala* have been established in Queensland and research shows that Leucaena improves animal performance due to its high nitrogen content. This species offers an economic benefit to the Queensland cattle industry. Live weight gains of 0.7–1.70 kg/head/day have been recorded in Leucaena/grass pastures. This growth is comparable to, or higher than, grazing on buffel grass alone (0.47–1.30kg/head/day) and to grain-fed lot feeding (1.41 kg/day). The annual economic benefits to Queensland from Leucaena production systems is estimated at $14 million (DNRM, 2003). A case study at Whitewater Station (**Figure 23**) in North Queensland indicates that cows grazing in Leucaena combined with native pasture achieved an average daily weight gain of 0.48 kg/day, compared to cows grazing on native pasture alone.

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Steak 'n Wood project: https://www.mla.com.au/research-and-development/reports/2023/steak-n-wood-demonstrating-livestock-productivity-and-environmental-service-benefits-of-trees-on-farm-in-northern-systems/

Appendix

Appendix 1. Survey form used to interview

Landholder Perceptions of Silvopastoral Systems in North Queensland

Exploring perceptions and best practice adoption of silvopastoral systems as a strategy for drought

Gulf Savannah NRM and the North Queensland Regional Forestry Hub are exploring silvopasture as a strategy for building drought resilience in the Northern Gulf region through the dual benefits of business diversification and the natural synergies and co- benefits that arise in combining timber, cattle and pasture.

This survey is designed to collect required information from the key stakeholders on different aspects of silvopastoral systems being established in the region. Information will be completely confidential and individuals will not be identified in the analysis of data.

Please note this survey relates to intentionally planting trees to establish silvopasture systems within existing cattle businesses. It does not address the management of pre-existing trees within pastures.

1. Please provide your full name (for future correspondence)

2. Your postal address (optional)

3. What is your Local Government Area or closest Suburb/Regional town?

4. What is your email address for further communication?

5. Could you share your telephone number for any follow-up discussions?

6. What is your age group

18 to 24
25 to 34
35 to 44
45 to 54
55 or over

7. Gender

Male
Female
Other

8. What is your current level of education?

High school diploma or equivalent
Associate's degree or some college
Bachelor's degree
Master's degree or higher

9. What is your role in agriculture and forest industry? (Please choose the most relevant options. If you are not a Farmer/Producer or Landowner, please select "non applicable" in questions 10-13 below)

Farmer / Producer
Landowner
Business investor
Industry bodies
Local government
Other (please specify)

10. What type of land do you currently own/manage?

Natural vegetation (remnant native forests)
Improved pastures / developed crops (X category)
Both
Not Applicable
Other (please specify)

11. What land tenure applies?

12. What is the total land area in hectares?

13. How many cattle do you manage?

Fewer than 100
0-500
500-1000
1000 - 5000
Over 5000
Not applicable

14. Section B — Perceptions of silvopasture systems.

What is your current level of familiarity with silvopastoral systems?
Very familiar
Somewhat familiar
Heard of it, but not familiar with details
Not familiar at all

15. In your opinion, what do you perceive as the primary benefits of integrating trees or shrubs into grazing areas?

Enhanced animal welfare (relief from heat stress during hot weather, shelter from wind and rain)
Rehabilitation of land from degradation (e.g soil erosion, salinity and acidification)
Enhanced ecosystem services (e.g carbon sequestration and climate mitigation)
Diversified income streams (timber production and carbon credits)
All the above
Other (please specify)

16. What concerns do you have about implementing silvopastoral systems in grazing areas?

Tree damage by livestock
Competition between grass and trees
Resources and support will be available to landowners to implement and manage silvopastoral systems
Vegetation laws change all the time
Long time for timber returns
Other Concerns? (please specify)

17. What do you consider to be the main challenges or barriers to adopting silvopasture practices?

Initial establishment costs (e.g. planting trees and shrubs)
Lack of time to manage the plot
Species selection and compatibility
Regulatory constraints or land tenure issues
Limited access to technical support or resources Loss of grazing area
Water availability?
Other (please specify)

18. How confident are you in your ability to implement and manage a silvopasture system effectively?

Very confident
Somewhat confident
Neutral
Not confident

19. How do you think silvopastoral systems might positively impact livestock's well- being and productivity? (Slider)

Increase long-term well-being and reproductivity capacity of the livestock
Contribute to the resilience and sustainability of your livestock business
Improved quality of grazing pasture
Higher cattle weight production

20. What do you perceive as potential long-term economic benefits of silvopastoral systems that combine various productions (e.g. animal production and timber products) compared to traditional grazing practices limited to single animal production?

Two outputs are produced: timber and beef from one plot
Better timber growth
Better cattle performance
Higher quality pasture (more tender) in summer
Not beneficial

21. Would you see silvopastoral systems as a management option to mitigate climate change and to improve drought resilience?

Not very beneficial
Neutral
Somewhat beneficial
Very beneficial

22. Have you ever considered integrating the planting of trees or shrubs into your pastureland?

Yes
No

23. Are there any existing species (trees and shrubs) that grow well around your area? Any specific types of trees or shrubs you would prefer to integrate into your pastures for drought resilience?

Trees and shrubs that grow well around your area?

Which species would you currently prefer to integrate into your pastures for drought resilience?

24. What do you assume your neighbours' or community's perceptions of silvopastoral systems?

Very negative
Negative
Neutral
Positive
Very positive

25. What additional information or resources would you need to feel confident about implementing silvopastoral systems on your farm?

Financial resources (grants, government subsidies etc.)
Technical advisory assistance (from the government, Forestry Hubs and others)
Information on market demand and potential opportunities for selling wood products
Any other please specify

26. Would you like to be updated about the Regional Forestry Hub's project on silvopastoral systems?

Yes
No

27. Would you be interested in participating in a field visit to observe established silvopasture systems?

Yes
No

Appendix 2. List of 24 tree species with natural distribution across the Gulf region.

No.	Common name	Scientific name
1	Black tulip oak	*Argyrodendron actinophyllum*
2	Bloodwood	*Corymbia terminalis/gummifera*
3	Cooktown ironwood	*Erythrophleum chlorostachys*
4	Darwin woollybutt	*Eucalyptus miniate*
5	False sandalwood	*Eremophila mitchellii*
6	Georgetown box	*Eucalyptus microneura*
7	Ghost gum	*Corymbia dallachiana*
8	Grey box	*Eucalyptus leptophleba*
9	Gum-topped bloodwood	*Corymbia erythrophloia*
10	Hoop pine	*Araucaria cunninghamii*
11	**Lemon-Scented gum**	***Corymbia citriodora* subsp. *citriodora* – CCC**
12	Mackay cedar	*Paraserianthes toona*
13	Molly box	*Eucalyptus leptophleba*
14	Moreton Bay ash	*Corymbia tessellari*
15	**Napunyah/ Thoezet's Box**	***Eucalyptus thozetiana***
16	**Narrow-leaved ironbark**	***Eucalyptus crebra***
17	Pink bloodwood	*Corymbia intermedia*
18	Red Eungella satinash	*Acmena resa*
19	**River red gum**	***Eucalyptus camaldulensis***
20	Silver quandong	*Elaeocarpus grandis*
21	Silverleaf box	*Eucalyptus pruinosa* subsp. *pruinose*
22	Silver-leaved ironbark	*Eucalyptus shirleyi*
23	White cypress	*Callitris glaucophylla*
24	Whitewood	*Atalaya hemiglauca*

Appendix 3. Information on 15 trials that planted seven tree species

Trial ID	Address	Planted date	Measured date	Lat/long	Rainfall
395 HWD	Aldoga - approx. 20 km west Gladstone	26/03/2003	04/03/2015	23.834º south 151.052º east	859
503 AHWD	Mr Bruce Watkins property, Hansen Road, 5 km west of Walkamin on the Atherton Tablelands	17/02/2000	16/11/2010	17.121º south 145.396º east	1014
503 CHWD	Henry property, Sugarbag Station, via Mt Garnet, 40km west of Mt Garnet on the Atherton Tablelands	15/02/2001	03/11/2022	17.926º south 144.993º east	800
508 AHWD	'Pasha', via Mt Coolon - John and Lindy Heelan	01/04/2000	10/04/2006	21.679º south 147.481º east	411
508 FHWD	Nebo Shire Council	16/06/2001	05/11/2006	21.694º south 148.699º east	755
806 AATH	Elliott Main Channel - Site 1 (Burdekin)	14/08/1996	01/08/1991	19.863º south 147.266º east	633
738 ATH	N/A	01/06/1990	23/06/1992	N/A	
332 HWD	Noonbah property, Longreach	01/06/1989	21/05/1992	24.109º south 143.188º east	371
333 HWD	Leander property, Longreach	01/06/1989	22/05/1992	23.286º south 144.059º east	443
334 HWD	Arid Zone Research Institute, Longreach	01/05/1989	20/05/1992	23.444º south 144.281º east	443
341 HWD	Noonbah property, Longreach	01/05/1990	21/05/1992	24.109º south 143.188º east	371
343 HWD	Arid Zone Research Institute, Longreach	01/05/1990	20/05/1992	23.444º south 144.281º east	443
810 AATH	Elliott Main Channel - Site 1 (Burdekin)	01/08/1991	14/08/1996	19.863º south 147.266º east	633
854 ATH	Normanton Carpentaria Shire	01/02/2002	07/08/2002	17.680º south 141.083º east	920
856 ATH	Charters Towers City Council, Nth Qld	01/04/2002	15/06/2012	20.062º south 146.295º east	546

Appendix 4. Online resources of seven tree species

Species name	Source
Corymbia citriodora subsp. citriodora – CCC	https://apps.lucidcentral.org/euclid/text/entities/corymbia_citriodora.htm https://apps.des.qld.gov.au/species-search/details/?id=26383 https://profiles.ala.org.au/opus/foa/profile/Corymbia%20citriodora
E. argophloia	https://www.woodsolutions.com.au/wood-species/hardwood/gum-spotted https://apps.des.qld.gov.au/species-search/details/?id=12508
E. crebra	https://qldnativeseeds.com.au/plant-profiles/eucalyptus-crebra
E. camaldulensis	https://en.wikipedia.org/wiki/Eucalyptus_camaldulensis https://www.woodsolutions.com.au/wood-species/hardwood/gum-river-red Field Guide to Eucalypts, Volume 3. M. Ian H. Brooker, D. A. Kleinig (Page 266)
E. cambageana	https://apps.lucidcentral.org/euclid/pdf/entities/eucalyptus_cambageana.pdf Field Guide to Eucalypts, Volume 3. M. Ian H. Brooker, D. A. Kleinig (Page 316) https://apps.des.qld.gov.au/regional-ecosystems/details/?re=10.3.15
E. thozetiana	https://apps.lucidcentral.org/euclid/text/entities/eucalyptus_thozetiana.htm
Khaya senegalensis	Evaluation of the Wood Quality and Utilisation Potential of Plantation grown Khaya senegalensis (African Mahogany). RIRDC Project DNT32A, by D.F. Reilly and R.M. Robertson African mahogany (Khaya senegalensis) plantations in Australia – status, needs and progress. Nikles, D G; Reilly, D F; Dickinson, Geoffrey R; et.al.