Final report

PDS Integrating pasture and timber production

Project code: L.PDS.2010

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Abstract

The implementation of sustainable forest management practices such as thinning can lead to an increase in timber and pasture productivity. Three sites were established in the Gin Gin region of Queensland with the aim of evaluating the performance of native pasture and improved pasture in sustainably managed and un-managed native forest. Plots with randomised block designs were established on each property, incorporating two different treatments for native forests (with and without harvesting or thinning), two treatments for pastures (native pasture and improved pasture), and six replications covering an area of ~11.5 hectares. Tree growth, pasture productivity and financial analysis were evaluated in this project.

Improved grass and legume pastures were sown at two different times: two properties in March 2021, and another in September 2021. Thinning increased the biomass production of native pasture by more than 45% and improved pasture by more than double compared to unthinned forests without pasture improvement. Financially, the best outcomes are anticipated in spotted gum forests with improved pasture, with an estimated NPV of 2,318 $/ha, in comparison to unmanaged native forests with an NPV of 751 $/ha. The least financially attractive scenario was improved pasture with unmanaged forests (695 $/ha), primarily due to the high cost of seeds and poor establishment response due to competition from trees.

The adoption of sustainable forest management practices such as thinning, with the introduction of improved pasture, or even with native pasture, will significantly enhance both timber and beef productivity in spotted gum forests.

Executive summary

Background

In southern Queensland there are ~ 1.5 million ha of potentially harvestable native forest on private land but the productivity of forests varies largely due to environmental conditions and management (Lewis et al. 2020; Pachas et al. 2022). A large proportion of private native forest is grazed by cattle and the pastures growing under forest are considered by property owners as a key resource for their livestock. Most of the forest owners consider themselves as graziers and their beef enterprise is their main source of income. Information available to landholders on the joint benefits of timber and livestock production is scarce. Forage productivity of the native pasture species is inherently low (quantity and quality) especially under unmanaged native forest. There has been little consideration of the potential to improve pasture productivity through the sowing of alternative shade-tolerant species. This could be particularly worthwhile in forests that have been thinned, or recently harvested. Thinning is a sustainable native forest management practice that can improve tree stand productivity by reducing competition between trees. It also provides an opportunity to enhance understory productivity due to reduced competition for resources (light, soil, water and nutrients). This can be viewed as a win-win opportunity to improve both timber and grass productivity. Currently, there is a knowledge gap about grass and legume species suitable to grow under moderate levels of shade.

Very few producers (< 5%) in the southern Queensland region are actively managing their native forest environment to boost livestock grazing and timber production. There is a need for information on the degree of productivity gain in terms of livestock production associated with forest thinning.

Objectives

This project aimed to evaluate the impact of tree density management in private native forest on native and improved pastures for beef productivity. It also aimed to demonstrate the integration of livestock under a sustainable forest management system as an opportunity for increasing beef and timber productivity due to the reduction of competition for light, water and nutrients available for the pasture and trees.

The following aims were achieved in this project:

1. **demonstrate the integration of pastures and forest under sustainable forest management to increase pasture productivity and tree growth.**
    - native pasture productivity increased by 30-50% in thinned forest plots compared to the control plots (unthinned). At two properties, native pasture productivity increased on average 45% (1,075 kg DM/ha) compared to the unthinned stands (716 kg DM/ha), while at Boomerang the native pasture productivity increased 2.6-fold (3,280 kg DM/ha/year) compared to the unthinned stand (1,235 kg DM/ha/year).
    - improved pasture productivity increased by at least 100% in thinned forest compared to the control plots (unthinned). Compared to the control plots, the improved pasture treatment in thinned forest increased in productivity by 316% (3,848 Kg DM/ha), 326% (3,496 Kg DM/ha) and 408 % (1,125 kg DM/ha) at Boomerang, Lundsville and Kantaka Station respectively. timber growth increased by 30% in thinned forest compared to unthinned forest. The diameter at breast height (DBH) and total height growth measured at the end of the project increased by 59% and 36% respectively.
2. **conduct a financial analysis to determine the relative financial performance of establishing pasture in sustainably managed private native forest.** At the conclusion of this project, a financial assessment was conducted to estimate the net present value (NPV) for the four

different treatments. The highest NPV of $2318/ha was calculated for the scenario involving thinning and improved pasture. In comparison, the control treatment involving unthinned forest with native pasture had an NPV of $751/ha.

3. **conduct field days / workshops with the aims of having 100% of core producers and 60% of observer producers with increased knowledge and skills in sustainably thinning their forest areas (e.g. appropriate methods).** A field day in November 2022 with the participation of 18 producers and two webinars were carried out during this project that reached an audience of over 100 listeners. All core producers involved in this project improved their skills and confidence levels by 31% and 17% respectively.
4. **80% of the core group demonstrate an improvement in pasture productivity by managing the forest under sustainable practices.** Most of the core producers have already adopted the integration of timber and livestock and express their intention to extend the area with silvopastoral systems on their property.
5. **20% of observer producers will have adopted or are preparing to adopt new forest management practices.** Unfortunately, we could not confirm this as the survey of the observer producers was unsuccessful.

Methodology

Three Producer Demonstration Sites (PDS) were established at Boomerang (Doughboy, QLD), Kantaka Station (Molangul, QLD) and Lundsville (Gaeta, QLD) in 2020. Each PDS was established using a randomised block design with two native forest treatments (with and without harvesting or thinning), two pasture treatments (native pasture and improved pasture) and six replications. Each PDS contains 24 plots of 50 x 30 m (0.15 ha) covering a total area per property of ~3.9 ha.

In August 2020, 72 permanent plots were established, all trees in the plots were marked with paint, tagged and measured. In the unthinned plots all trees were retained, while in the thinning/harvesting treatments, trees to be retained were selected according to the species and timber potential (bole length, straightness, shape, branching and spacing) and all other trees were removed.

Improved pasture treatments were carried out in 2021 using a selected pasture mix with 50% grass and 50% legume species.

Pasture assessment was carried out in 2021, 2022 and 2023 at the 3 PDS sites. The BOTANAL approach was used to estimate forage production (kg DM ha^{-1}), ground cover (%) and species composition (%).

Results/key findings

Three PDS were successfully established and monitored during this project. These sites served as valuable sources for gathering data on the productivity of both pasture and timber. The information collected from these PDS was presented through field days, reports, and conferences.

Net present value was used to evaluate the financial outcome of four different treatments over 20 years. The best financial performance was achieved with sustainable harvesting/thinning and improved pasture averaging $2,318/ha at the tree properties. Under this scenario, average carrying capacity (CC) was 2.7 ha/AE. The unthinned treatments, either with native or improved pasture, had the lowest NPV with an average of $722/ha, and an average carrying capacity of 16 ha/AE.

Benefits to industry

Sustainable private native forest management has a positive effect on pasture and timber productivity. The research demonstrated that it is possible to combine sustainable thinning practices and pasture development in privately-owned native forests. In south-eastern Queensland there are approximately 1.6 million ha of commercially harvestable native forest on privately-owned land. The productivity of these forests varies due to environmental factors and the way they are managed using silvicultural practices. A significant area of the private native forest is utilised for cattle grazing, and the pastures that grow beneath the forest canopy are considered crucial for the livestock by property owners. The integration of sustainable forest management practices, such as thinning, along with the implementation of improved or native pasture systems, will significantly enhance both timber and beef productivity.

Future research and recommendations

Silvopastoral systems implemented within private native forests have the potential to improve both livestock and timber productivity in the South-East Queensland region. The productivity of pastures can be significantly enhanced especially in commercially harvestable spotted gum forests on private lands (either on freehold land or remnant forests), through the implementation of sustainable thinning operations and pasture improvement strategies.

An extension program/publication could be implemented to bridge the knowledge gap regarding the establishment of pasture species beneath native forests and the management of these forests for timber production.

All the core producers own extensive areas of private native forest on freehold land (Category X) and already have livestock integrated with trees on their properties. In contrast, their adjacent properties have undergone extensive vegetation clearing, resulting in open paddocks with only a few trees per ha. The carbon sequestered by their forests cannot be acknowledged or recognised under any carbon projects operating under the Emissions Reduction Fund (ERF) or Land Restoration Funds (LRF).

Well-managed silvopastoral systems have the potential to enhance timber production, thereby increasing carbon sequestration at the same time as improving pasture productivity. This can contribute to the reduction of greenhouse gas emissions associated with improved beef production efficiency due to an enhancement of pasture productivity. However, at present, there is no suitable methodology available under the ERF specifically designed for silvopastoral systems within private native forests aiming to enhance both timber and beef productivity.

PDS key data summary table

Project Aim:
The implementation of carefully applied forest thinning practices can lead to increased biomass of native pasture and improved timber productivity.

	Comments		Unit
Production efficiency benefit (impact) Pasture productivity – kg DM/ha Stocking rate –AE/ha Tree growth (DBH, total height)	Thinning practice increased pasture and timber productivity.	>50% (native pasture) > 200% (improved pasture) >30% tree growth	%
Reduction in expenditure	N/A	0	
Increase in income **UT NP (unthinned forest + native pasture)** **UN IP (unthinned forest + improved pasture)** **T NP (thinned forest + native pasture)** **T IP ((thinned forest + improved pasture)**	UT NP UN IP T NP T IP	$0 $-56 $498 $1,567	/ha /ha /ha /ha
Additional costs (to achieve benefits)		$0.00	/ha
Net $ benefit (impact)		**$0.00**	**/ha**
Number of core participants engaged in project	9	0	
Number of observer participants engaged in project	N/A	0	
Core group no. ha	25,617	0	
Observer group no. ha	N/A	0	
Core group no. sheep	0	0	head sheep
Observer group no. sheep	0	0	head sheep
Core group no. cattle	6,435		head cattle
Observer group no. cattle	N/A		head cattle
% change in knowledge, skill & confidence – core	Enhance of knowledge and confidence on Silvopastoral systems	24%	
% change in knowledge, skill & confidence – observer	N/A	N/A	
% practice change adoption – core	Core producers have adopted and practice integration of trees and cattle in their property	90%	
% practice change adoption – observers	N/A	N/A	
% of total ha managed that the benefit applies to	E.g. % of total ha, fodder crop is grown on	0%	

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1. Background

1.1 Silvopastoral systems in private native forest Queensland

In southern Queensland there are ~ 1.6 million ha of potentially harvestable native forest on private land but productivity varies due to environmental conditions and management. A large proportion of private native forest (PNF) is grazed by cattle and the pastures growing under forest are considered by property owners as a key resource for their livestock. Most of the forest owners consider themselves as graziers with their beef enterprises as their main source of income. Information available to landholders on the joint benefits of timber and livestock production is scarce. Forage productivity of the native pasture species is inherently low (quantity and quality) especially under unmanaged native forest, and there is little consideration of the potential to improve pasture productivity through the sowing of alternative shade-tolerant species. This could be particularly worthwhile in forests that have been thinned, or recently harvested. Thinning as a sustainable native forest management practice can improve tree stand productivity by reducing competition between trees and provides an opportunity to enhance understory productivity due to reduced competition for resources (light, soil, water and nutrients). This can be viewed as a win-win opportunity to improve both timber and grass productivity. Currently, there is a knowledge gap about grass and legume species suitable under moderate levels of shade.

At the property scale the PNF is usually viewed as a secondary enterprise that competes with the grazing enterprise rather than a complementary enterprise that ensures alternative income, mitigates risk and enhances ecological diversity.

Currently, 340,000 ha of unregulated regrowth PNF in Queensland is directly threatened by broad-scale land clearing. This threat is driven by landholder apathy, poor understanding of PNF economics and harvest security issues surrounding legislative impediments (perceived or real). Landholders that understand the economic value of PNF are unlikely to clear it. Thus, the above-mentioned engagement and education of landholders is critical. PNF can provide a long-term economic, social and environmental resource that increases landholder resilience to climate variability (e.g. income source during times of drought).

Very few producers (< 5%) in the region are actively managing their native forest environment to boost livestock grazing and timber production. There is a need for information on the degree of productivity gain in terms of livestock production associated with forest thinning. Beef production is likely to increase 10-15% in thinned forest compared to unmanaged forest. Native pasture productivity is likely to increase 20-30% in thinned forest and with improved pastures may demonstrate a >50% increase in productivity. With improved management it is also expected that timber productivity would increase by at least 30% (harvesting every 10-15 years rather than every 20-30 years) with combined grazing practices.

2. Objectives

This project aims to evaluate the impact of tree density management in private native forest on native and improved pastures for beef productivity. It also aims to demonstrate the integration of livestock under a sustainable forest management system as an opportunity for increasing beef and timber productivity due to the redistribution of light, water and nutrients available for the pasture and trees when non-commercial trees are removed.

1. demonstrate the integration of pastures and forest under sustainable forest management to increase pasture productivity and tree growth.
2. conduct a financial analysis to determine the relative financial performance of establishing pasture in sustainably managed private native forest.
3. conduct field days / workshops with the aims of having 100% of core producers and 60% of observer producers with increased knowledge and skills in sustainably thinning their forest areas (e.g. appropriate methods).
4. 80% of the core group demonstrate an improvement in pasture productivity by managing the forest under sustainable practices.
5. 20% of observer producers will have adopted or are preparing to adopt new forest management practices.

3. Demonstration Site Design

3.1 Methodology

Site selection and design of the experiment

Three properties were selected for the establishment of the Producer Demonstration Sites (PDS): Boomerang (Doughboy, QLD), Kantaka Station (Molangul, QLD) and Lundsville (Gaeta, QLD) (Figure 1). A randomised block design was utilised on each property to establish the PDS, incorporating two different treatments for native forests (with and without harvesting or thinning), two treatments for pastures (native pasture and improved pasture), and six replications. Consequently, a total of 24 plots of 50 x 30 meters were established on each site, covering a combined area of 3.9 hectares per property.

Figure 1. Location of the PDS

Permanent plots

In August 2020, a circular permanent measurement plot of 500 m^2 was established within each plot with the aim of monitoring the tree and pasture growth, totalling 72 permanent plots across all three PDS. In these permanent plots, all trees were identified with tags and measured. In the control plots where thinning or harvesting was not conducted, all trees were left untouched. However, in the plots where thinning or harvesting was applied, trees were selected for retention based on factors such as species and timber potential, considering characteristics such as bole length, straightness, shape, branching, and spacing. The aim was to achieve a spacing of approximately 10 by 10 m (100 stems per hectare) between trees after the thinning process.

Tree measurements

Tree measurements were carried out at the beginning (August 2020) and end of the project (May 2023). Baseline tree variables were evaluated at all sites, including factors such as stand density (number of stems per hectare), diameter at breast height (DBH in centimetres), species composition, total height (HT in m), merchantable height (m), basal area (m^2/ha) and total volume (m^3/ha).

Thinning operation

Thinning was carried out between August-September 2020 at Boomerang, in March 2021 at Lundsville and in September 2021 at Kantaka Station. This was conducted with a chainsaw or brushcutter (for smaller stems) followed by herbicide application (Tordon TM) on the cut stump. Merchantable sawlogs were removed from the plot and sold or retained for the landowner. The number and dimensions of the sawlogs removed from each plot were recorded. At Lundsville and Kantaka Station, a bulldozer was used for the thinning of small diameter trees (<20 cm DBH) and land preparation for the improved pasture treatments. Trees to be retained in the plot were marked with paint and small trees were thinned with the dozer.

Pasture establishment and assessment

Pasture biomass was measured in February 2021, February-March 2022, and May 2023. The BOTANAL methodology (Tothill et al. 1978) was used to estimate forage production (kg DM/ha), ground cover and species composition. Briefly, 16 quadrats (each 0.5 by 0.5 m) were scored in each plot. Additionally, pasture grass samples (12-20 samples) were harvested for calibration purposes at 0.1 m above the soil surface, fresh biomass was recorded, and subsamples were then dried in an oven at 65 degrees Celsius for 72 hours to determine the dry matter (DM) content.

After completing the initial assessments of the baseline pasture conditions in February 2021, site preparation activities were undertaken to facilitate the establishment of pastures. In the case of the Boomerang site, glyphosate herbicide was applied to 12 selected plots that were designated for sowing improved pastures. At the other two sites, soil disturbance was carried out in the thinned plots with machinery (bulldozer) in March 2021 at Lundsville (Fig. 2) and September 2021 at Kantaka Station (Fig. 3).

Figure 2. Overview of a plot at Lundsville with Tom Lewis (DAF), Nahuel Pachas (DAF) and Doug Campbell landholder (left to right). Photo taken in August 2021.

Figure 3. Land preparation for sowing improved pasture at Kantaka Station (treatment with thinned forest).

The sowing of pastures was carried out by hand broadcasting a selected pasture species mix (50% grass and 50% legume species) at a rate of 13.2 kg of seeds per hectare. A germination test was carried out in February 2021 to determine the rate of seed application (kg seeds/ ha) for each selected species with the aim of having the following species composition:

- 25% of Signal grass (*Urochloa decumbens*),
- 25% Rhodes grass (*Chloris gayana*),
- 25% Shrubby stylo (*Stylosanthes scabra*),
- 10% Siratro (*Macroptilium atropurpureum*),
- 10% Caribbean stylo (*Stylosanthes hamata*)
- 5% Fine stem stylo (*Stylosanthes guianensis* var. *intermedia*).

Cattle exclusion cages were installed at Boomerang, and a perimeter fence was established at Lundsville by the landholder (Fig. 4). At Kantaka Station the existing fence network and a rotational grazing system was used to ensure cattle did not have access to the newly established pasture.

Figure 4. Perimeter fence around the trial plots at Lundsville. Photo taken in September 2021.

3.2 Economic analysis

Financial performance analyses of the silvopastoral systems was carried out on each site. This was achieved by simulating the effect of the various silvicultural treatments on tree and pasture growth and cattle productivity under four scenarios:

Scenario 1: Unthinned forest + native pasture

Scenario 2: Unthinned forest + improved pasture

Scenario 3: Thinned forest + native pasture

Scenario 4: Thinned forest + improved pasture

Similar methodology proposed by Francis et al. (2022) was utilised for this analysis. Briefly, the decision support tool (DST), that was developed for spotted gum forest (Lewis et al. 2020b), was used to predict forest growth and their response to silvicultural treatments. The DST uses individual tree data such as DBH, product type and species and runs in RStudio with the Shiny package. This software can simulate the forest growth over time, estimated wood product volume per ha and pasture productivity using the Queensland Government Grass Production (GRASP) model.

Tree data collected in 2020 for each site was used for simulating tree growth and pasture productivity for a 20-year period. In order to evaluate the net present value (NPV), a discounted cash flow analysis of each management scenario was performed. The analysis was conducted in 2023 using Australian dollars (AUD) and a real discount rate of 5%, which accounts for inflation. The financial analysis utilised specific parameter levels, which are presented in Table 1. Up-front investments were assigned to the start of 2020 (year zero) and were not subjected to discounting. All other costs and revenues occurring between 2020 and 2040 (referred to as years 1 to 20) were assumed to be received or paid at the end of each year and were appropriately discounted.

The costs used for the thinning operation were based on expert opinion from Private Forest Service Queensland (Bill Schulke, personal communication, August 2022) and values used by Francis et al. (2022). Expenditure on silvicultural operations involved the selection of the trees to retain and harvest (paint marking the trees to retain); thinning with chainsaw, brush-cutter and machinery (e.g. bulldozer). The estimated timber revenues for each forest management scenario on each property were calculated by multiplying the harvest volume simulated by the DST by the corresponding stumpage price.

Table 1. Parameters adopted for the financial analysis for the PDS

Parameters	Year	$
Grazing costs		
Maintenance cattle (check-up animals, burn, fencing repairing, etc) $/ha	annual	30
Land preparation for sowing pasture ($/ha)	0	250[1] and 500
Seeds (kg/ha)	0	100

[1] At Boomerang the preparation for the establishment of the pasture was done using only herbicide application. The cost was only $250 per ha.

Forestry costs		
Paint marking of retained trees (these trees will not be removed, harvested or treated) (AUD/ha)	0 and 20	100
Thinning (chainsaw, poisoning, brush-cutter)	0	350
Grazing income		
Liveweight farmgate price (AUD/kg)	annual	3.66
Forestry income		
Stumpage price of sawlog (no silvicultural treatment) ($\$/m^3$)	0	80
Stumpage price of sawlog (following silvicultural treatment in year 0) ($\$/m^3$)	20	120
Stumpage of Pole ($\$/m^3$)	0 and 20	150
Stumpage Salvage class log ($\$/m^3$)	0 and 20	20
Stumpage Fencing ($\$/m^3$)	0 and 20	35

The effect of each forest management scenario on cattle carrying capacity was assessed over a 20-year period with GRASP. The cash flows for the 20-year investment period were estimated using the following approach. The pasture production was divided by the annual feed requirement of 3650 kg DM/AE to determine the annual cattle stocking rate, measured in adult equivalents [2] (AE) per ha. Grazing revenue in dollars per hectare was then estimated for each year by multiplying AE/ha per live weight gain (kg/year) and the live weight farm gate price ($/kg). In this analysis, the live weight gain achieved varied depending on whether the animals were grazing native or improved pastures. It was assumed that the beef productivity for native pastures was 100 kg/year, while for improved pastures, it was 120 kg/year. Pasture productivity decline obtained from GRASS per year and the average value of pasture productivity from pasture assessment was used for the calculation of AE/ha for each scenario.

3.3 Extension and communication

The following extension and communication activities were carried out for this project:

- Meetings with PDS core producers
- Webinars
- Field days/ Workshop
- Extension material

Periodic meetings with PDS property owners were carried out throughout the entire duration of the project. Communication was also maintained via phone or email.

[2] The AE standard unit is a 450 kg Bos taurus steer at 2.25 years of age.

Webinars were used to reach producers outside of the producers directly involved in the project. Two webinars were conducted during the duration of this project.

Field days were carried out in November 2022 with the aim of presenting preliminary result of the PDS.

For each PDS property, a 2-3 page case study was developed in 2022 containing a summary of the property, activities and learning form the project, based on interviews with the property owners.

3.4 Monitoring and evaluation

A Monitoring and Evaluation plan (MER) was developed at the commencement of the project (2020). The MER was regularly updated and submitted to MLA with each milestone report. Baseline information for each property participating in the PDS was obtained through the core producer survey conducted in 2020. Changes in knowledge, attitude and skills of the core producers were obtained from the surveys carried out at the beginning and end of this project.

The following metrics were obtained from the survey:

- property size (ha),
- private native forest area (ha),
- numbers of livestock (total cattle, beef breeders, number of cattle turned off per year).
- Area with actively managed silvopastoral systems on your property (ha)
- Pasture productivity in native forest areas (average Kg DM/ha)
- Livestock stocking rate in native forest areas (head/ha)
- Area sowed to improved pasture in native forest areas in the last 3 years (ha)
- Area of native forest that has been thinned for timber and/or grazing production (ha)
- Frequency of timber harvesting in native forest areas (years)

The knowledge and skills of participants were evaluated using nine multiple choice question types related to silvopastoral systems. Some of the questions were:

- What is a silvopastoral system?
- What is the most important component to be managed in a silvopastoral system?
- What is the tree basal area (m^2/ha) or tree density suitable for growing pastures in Silvopastoral systems?
- What is the most suitable pasture composition for Silvopastoral systems?
- What is the most important benefit of Silvopastoral systems?
- What would you consider to be the most effective and sustainable method for encouraging or establishing pastures in native forest environments?

Confidence was assessed by a direct question to the core producers rated out of 10:

- How confident are you in managing Silvopastoral systems?

The following questions were used for determining the use/adoption of silvopastoral systems for the core producers:

Do you currently use the following practices? (Mark the following options: normal practice, sometimes, rarely, never or not applicable)

- Silvopastoral systems with native pasture
- Establishment of improved pastures in native forest
- Harvesting native forest for timber products
- Thinning native forest using chopper roller, stem injections or brush-cutter
- Rotational grazing in native pasture

4 Results

4.1Demonstration site results

Three sites were successfully established with the aim of evaluating the effect of sustainable management of private native forest on native and improved pastures. The properties selected for the Producer Demonstration Sites: Boomerang were (Doughboy, QLD), Kantaka Station (Molangul, QLD) and Lundsville (Gaeta, QLD). A summary of the properties involved in the project is shown in Table 2.

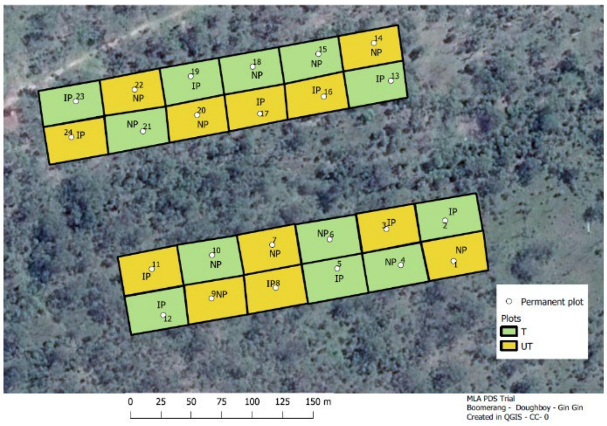
Table 2. Summary of the PDS established at Katanga Station, Lundsville and Boomerang.

Property name	Kantaka Station	Lundsville	Boomerang
Participants	Jamie and Sigrid Peters	Doug and Sue Campbell	Bill Schulke (PFSQ)
Location	Molangul, QLD	Gaeta, QLD	Doughboy, QLD
Average rainfall (mm/year) (2020-2022 period)	1,120	1,120	953
Coordinates	24.764 S, 151.521 E	24.773S, 151.655 E	25.156 S, 151.834 E
Total area	3,394 ha	5,000 ha	3,000 ha
Private native forest area (ha)	1,500 ha		2,000 ha
Total number of cattle	700	1400	250
Area of the demonstration site	3.8 ha	3.8 ha	3.8 ha
Treatments	4	4	4
Blocks	2	2	2
Replications	6	6	6
Category of the PNF according to vegetation Management Act 1999	Category B (block 1) and Category X (block 2)	Category X	Category X

The layout of the experiment established on each property is presented below (Fig. 5).

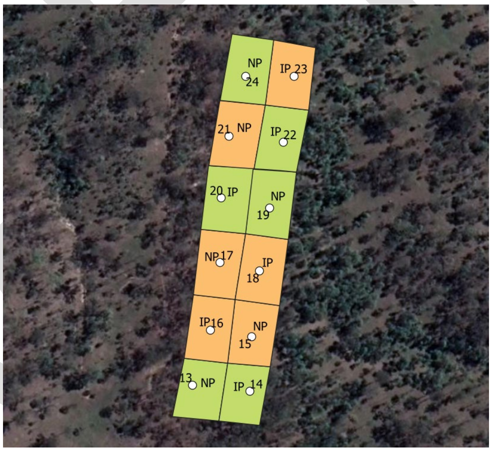
Figure 5. Layout of the PDS experiment: (a) block 1 and 2 at Boomerang; (b) block 1 at Lundsville; (c) block 2 at Lundsville; (d) Block 1 at Kantaka Station; and (e) block 2 at Kantaka Station. Permanent plots are represented with o symbol. Treatments are: thinned (T), unthinned (UT), native pasture (NP) and improved pasture (IP).

a)



b)

c)



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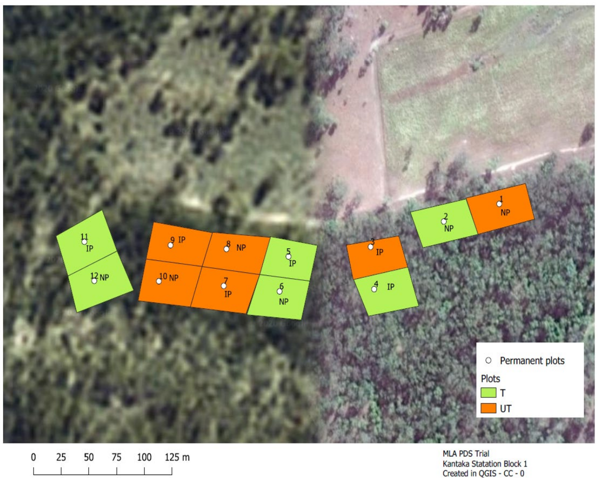

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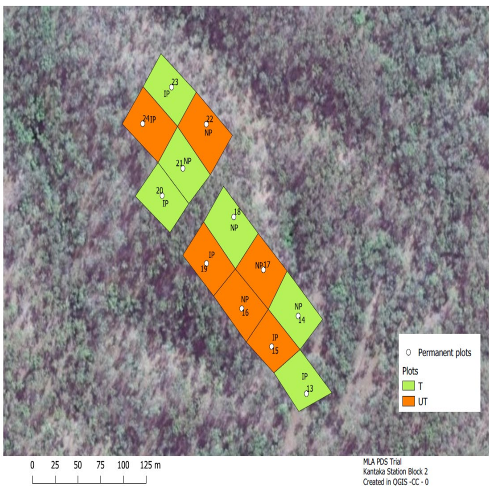


A summary of the tree measurements carried out at the beginning of the experiment is presented in Table 3. Each PDS has slightly different forest characteristics with respect to species composition, soil and land category (e.g. Category X or Category B remnant), covering a broad range of situations. The average initial stand density prior to the thinning was 350 stems/ha, with some plots with over 600 stems/ha. After the thinning, average stand density was 98 stems/ha. Overall, basal area (m^2/ha) was reduced by 50% in the thinned treatments. On these plots, high value species were retained (e.g. spotted gum, forest red gum) and the average diameter at breast height (DBH) and total height increased by 16% and 19% respectively after the selective thinning. In the remnant vegetation (Category B) (e.g. block 1 at Kantaka Station), habitat trees were marked and left according to current legislation (e.g. 4 habitat stems/ha and 1 recruitment habitat stem/ha).

The measurement carried out at the end of the experiment shows a 59% growth increment in the diameter at breast height (DBH) and a 36% increase in the total height when selective thinning was implemented. The annual increases in DBH and total height observed in the three properties are shown in Fig 6 and 7.

Figure 6. Average annual DBH increments registered at Boomerang, Lundsville and Kantaka Station. Standard error is shown in bars.

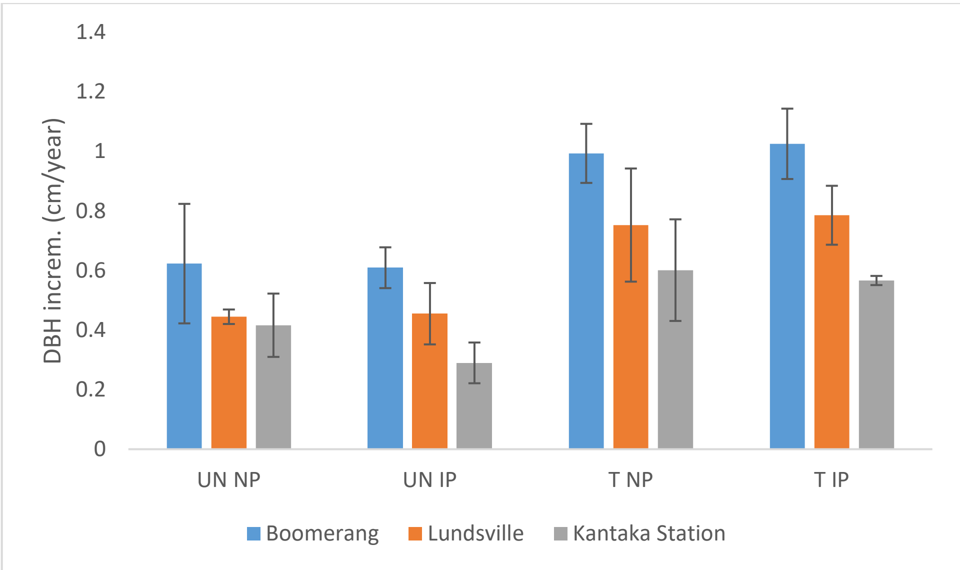
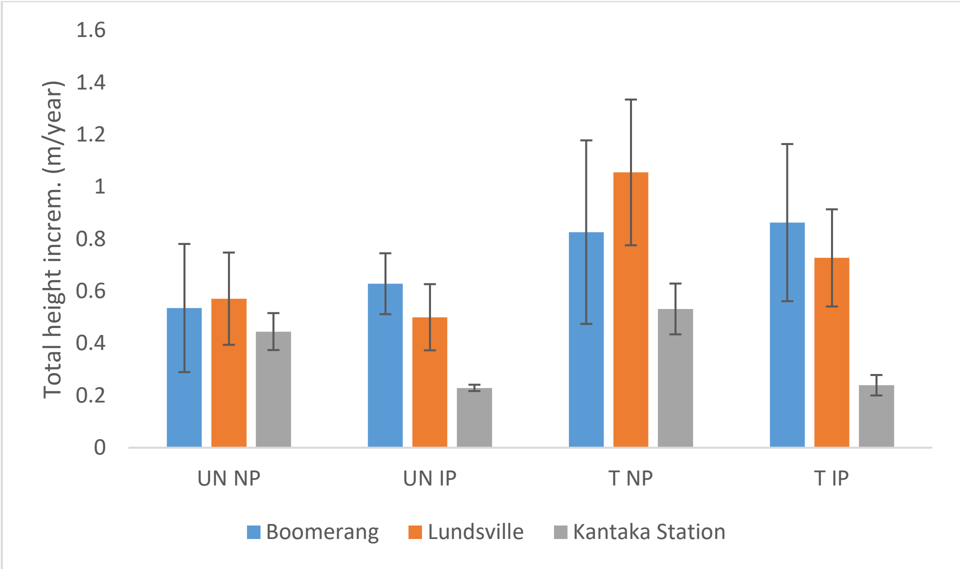
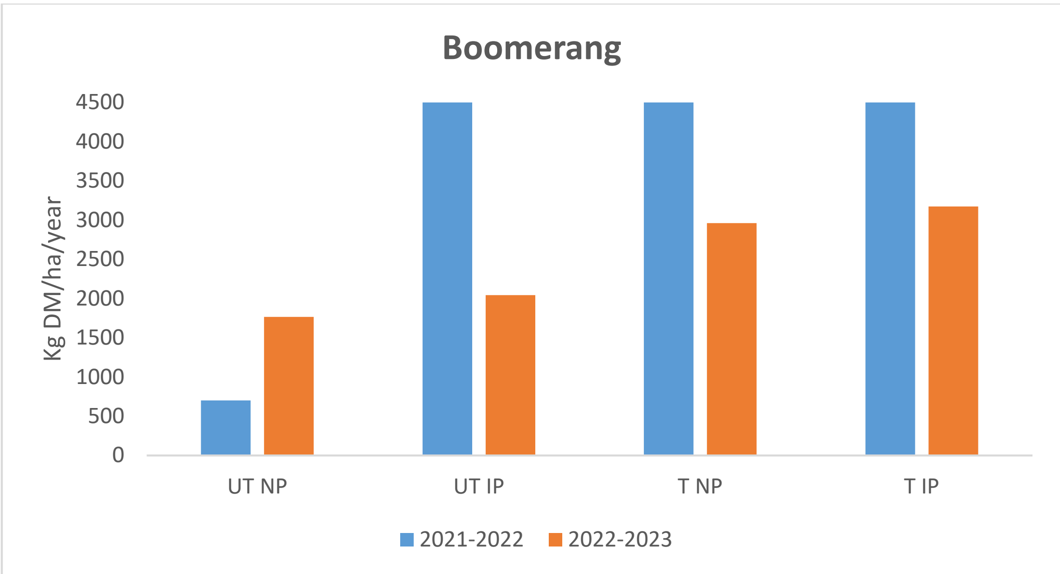


Figure 7. Average annual total height increments observed at Boomerang, Lundsville and Kantaka Station. Standard error is shown in bars.



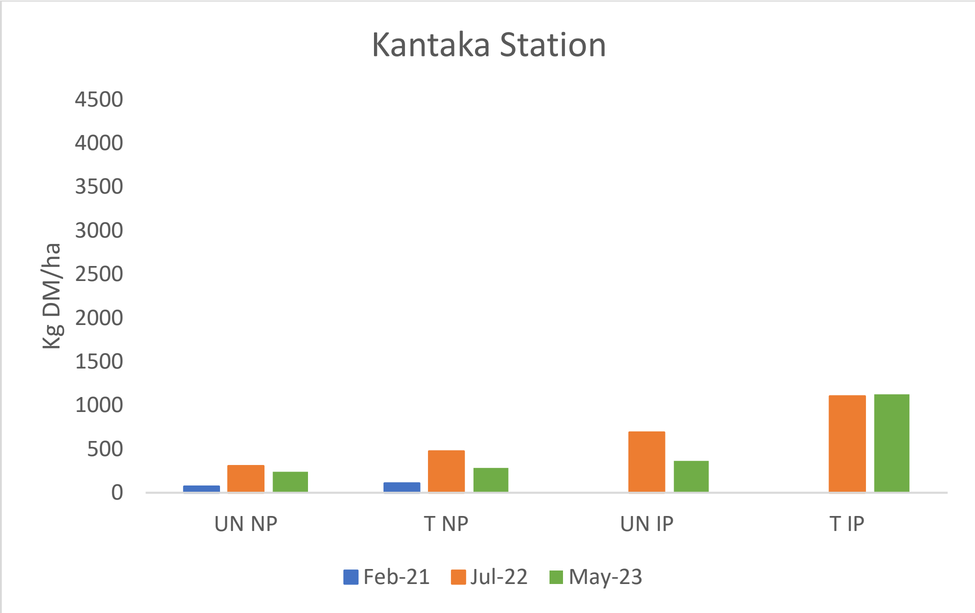
Pasture productivity expressed as Kg DM/ha/yr was obtained from the exclusion cages at Boomerang. The initial pasture assessment carried out in February 2020 registered a baseline of pasture availability of 818 and 1,050 kg DM/ha in the unthinned and thinned treatments. This assessment was carried out before the establishment of the improved pasture treatments. Averages over two years indicated that the lowest pasture productivity was obtained in the control treatment (1235 kg DM/ha/yr). The unthinned treatment with improved pasture, thinned forest with native pasture and thinned forest with improved pasture registered increases in productivity of 266%, 306% and 312% respectively.

Figure 8. Pasture productivity expressed as Kg DM/ha/ha observed at Boomerang for the period 2021-2022 and 2022-2023.



Botanical assessments were conducted at Kantaka and Lundsville in February 2021, June 2022, and May 2023 (Fig.9 & 10). Kantaka Station had the lowest pasture productivity, which can be attributed to its location on a rocky ridge. The thinned forest plots with improved pasture displayed four times greater biomass (1,115 kg DM/ha) compared to the control (273 kg DM/ha). It is worth noting that the paddocks were subjected to rotational grazing, and the measurements were taken 10-15 days after the animals were removed from the paddock. Therefore, the obtained values do not fully reflect the overall productivity of the pasture per hectare but provide a snapshot of the pasture condition at that particular time.

Figure 9. Pasture biomass (kg DM/ha) measured at Kantaka Station in February 2021, July 2022 and May 2023.



At Lundsville, the measurement of pasture biomass indicated a three-fold increase (3,808 kg DM/ha) in thinned forests with improved pasture treatments compared to unthinned forests and native pasture treatments (1,116 kg DM/ha). It is worth noting that the assessment conducted in February 2021 marked the end of a three-year drought period. In 2022, all treatments were left ungrazed for a minimum of nine months after establishing a perimeter fence around the experiment. Grazing by the animals began at the end of July 2022, following a rotational grazing schedule set by the property owner. In December 2022, a prescribed fire was carried out, and from that point on, beef cattle were not allowed access to the experiment until the pasture assessment date (May 2023).

Overall, establishment of improved pasture was much easier in the plots that were thinned and where thinning residues were removed, compared to the unthinned treatments. Sowing improved pasture in an unthinned forest is not recommended.

Figure 10. Pasture biomass (kg DM/ha) measured at Lundsville in February 2021, July 2022 and May 2023.

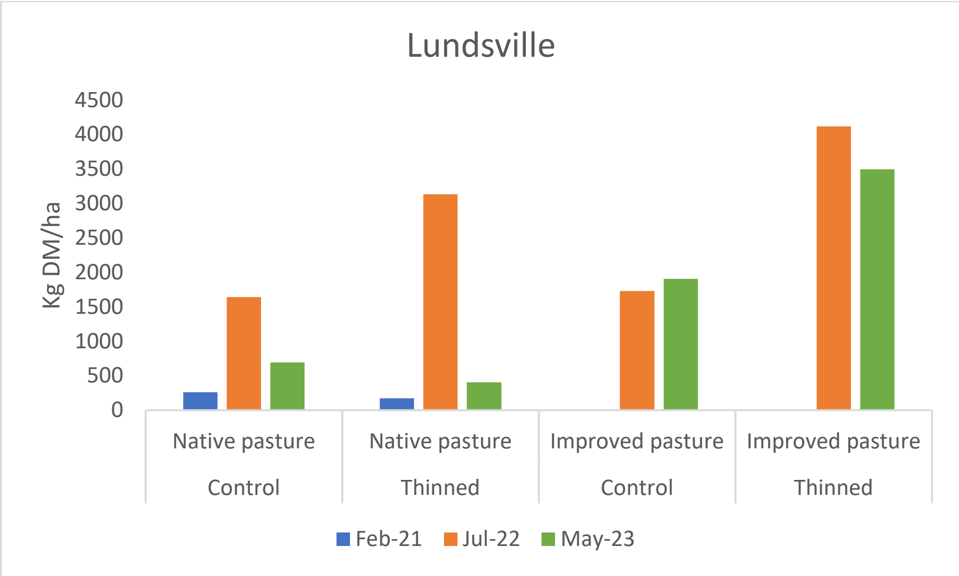


Table 3. Summary of the preliminary results at Kantaka Station, Lundsville and Boomerang after the establishment of the four treatments: unthinned with native pasture (UT NP), unthinned with improved pasture (UT IP), thinned with native pasture (T NP) and thinned with improved pasture (T IP).

	UT NP	UT IP	T NP	T IP
Kantaka Station				
Main species	Spotted gum, narrow-leaved red ironbark, red bloodwood, swamp-box			
Initial stand density (trees/ha)	317	310	330	266
Stand density after thinning (trees/ha)	317	310	73	76
Diameter at breast height (cm)	21.1	20.8	27.5	24.2
Total height (m)	17.9	18.1	23.5	19.2
Basal area after thinning (m^2/ha)	11	11	4.7	3.5
Lundsville				
Main species	Forest red gum, red bloodwood, spotted gum, narrow-leaved red ironbark, swamp box, wattle			
Initial stand density (trees/ha)	392	346	296	306
Stand density after thinning (trees/ha)	392*	346*	80	110
Diameter at breast height (cm)	16.3	17	23.1	18.2
Total height (m)	12.6	13.4	17.1	16.1
Basal area (m^2/ha)	9.9	8.9	4.3	4.1
Boomerang				
Main species	Spotted gum, narrow-leaved red ironbark, forest red gum, red and brown bloodwood, turpentine, white mahogany			
Initial stand density (trees/ha)	340	400	303	370
Stand density after thinning (trees/ha)	340	400	136	116
Diameter at breast height (cm)	14.8	15.9	15.4	13.9
Total height (m)	12.8	14.1	15.2	15.2
Basal area (m^2/ha)	6.6	9.5	4.1	2.1

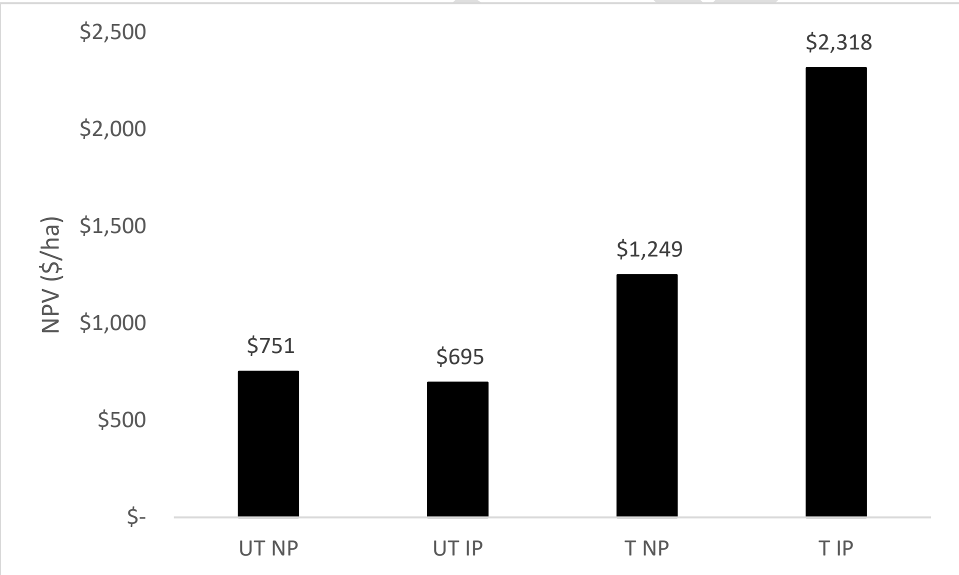
4.2 Economic analysis

Overall, silvicultural thinning together with pasture improvement produced the highest NPV, followed by thinning with native pasture. Averaging figures for the 3 properties, the NPV of unthinned forest with native pasture (control) was $751/ha and the lowest performance was obtained in the unthinned with improved pasture scenario with $695/ha (Fig 11).

The present values of cost, revenues and NPV's per ha for each PDS and scenario are presented in Table 4. The maximum NPV values were observed at Lundsville ($3,008/ha) and Kantaka Station ($1,523/ha), both under the thinned and improved pasture scenario. The lowest NPV was registered in the scenario with unthinned forest and improved pasture at Lundsville (-105 $/ha) followed by the unthinned forest with improved pasture at Kantaka Station ($244/ha).

The financial result obtained in this project is aligned with the NPV found by Francis et al. (2022), who reported $2,396/ha for the property at Boomerang. The lower value could be attributed to the lowest cattle price used in their analysis ($2.54/kg). A positive financial outcome for silvopastoral systems within spotted gum forest was also reported by Venn et al. (2022).

Figure 11. Average NPV (n=3) according to four management scenarios evaluated in this project. Unthinned with native pasture (UT NP), unthinned with improved pasture (UT IP), thinned with native pasture (T NP) and thinned with improved pasture (T IP).



Grazing income estimates were based on the average pasture production per treatment observed throughout the experiment, as well as the decrease in pasture productivity determined by GRASS and basal area of trees. For the scenario involving sustainable thinning and improved pasture over a 20-year period, the average cattle stocking rate was calculated to be 0.38 AE/ha, which is equivalent to 2.7 ha per animal. On the other hand, in the unthinned forest scenario with either native pasture or improved pasture, the average stocking rate was 0.1 AE/ha (or 12 ha/AE).

Table 4. Present value of costs and revenues and Net Present Values (NPV) per ha at each PDS property by management scenario: unthinned with native pasture (UT NP), unthinned with improved pasture (UT IP), thinned with native pasture (T NP) and thinned with improved pasture (T IP).

	Boomerang				Lundsville				Kantaka Station			
	UT NP	UT IP	T NP	T IP	UT NP	UT IP	T NP	T IP	UT NP	UT IP	T NP	T IP
Pasture establishment cost ($/ha)	0	250	0	250	0	600	600	600	0	0	600	600
Silviculture treatment cost ($/ha)	0	0	450	450	0	0	450	450	0	0	450	450
2020 Timber revenue ($/ha)	0	0	37	638	0	0	430	740	0	0	0	183
2040 timber revenue ($/ha)	753	868	847	608	2670	735	818	796	1041	1124	1016	741
Grazing revenue ($/ha)	220	269	816	914	317	309	904	3066	208	274	788	2199
Stocking rate (AE/ha)	0.12	0.15	0.33	0.35	0.04	0.06	0.14	0.45	0.04	0.05	0.12	0.33
Carrying capacity (ha/AE)	8	7	3	3	23	17	7	2	23	19	8	3
NPV ($/ha)	853	1945	2159	2422	683	-105	413	3008	716	244	1175	1523

4.3 Extension and communication

Two webinars were conducted during the project:

- "Wood n steaks: timber and grazing for income diversification and carbon neutrality" was carried out on 7 September 2020 by Tom Lewis and Nahuel Pachas (DAF). Information about the opportunities for silvopastoral systems in Queensland's private native forest was presented to an audience of 61 participants.
- "Cattle, grass and trees: Combinations, pitfalls and opportunities" was carried out on 21 June 2021 by Bill Schulke (PFSQ). Bill presented an overview of the opportunities of integrating beef and timber enterprises in Queensland. A recording of the webinar can be found online at: https://futurebeef.com.au/knowledge-centre/cattle-grass-and-trees-combinations-pitfalls-and-opportunities

A field day was organised on 17 November 2022 at Kantaka Station and Lundsville. Preliminary information on timber and pasture productivity was presented by Nahuel Pachas (DAF) and Bill Schulke (PFSQ) to an audience of 20 people. Information presented during the field day is attached in Appendix 1.

Case study extension material was developed for Lundsville, Kantaka Station and Boomerang, containing summary information about their beef enterprise and preliminary results of the PDS. See Appendices 2, 3 and 4 respectively.

4.4 Monitoring and evaluation

Surveys were conducted with the core producers at the beginning and towards the end of the project. Based on the answers received, their skill levels showed an average improvement of 31%, and their confidence in the silvopastoral system increased by 17%. Prior to this project, all of them were already aware of the concept of integrating trees and livestock, and the majority had implemented silvopastoral systems on their properties. However, they were not familiar with the combination of sustainable thinning and pasture improvement. By the end of the project, all the core producers expressed their willingness to expand the area dedicated to silvopastoral systems, except for one producer who was selling their property.

There were noticeable changes in practices and adoption within the properties directly engaged in this project. As an example, the producers began implementing thinning operations in nearby areas after witnessing the thinning activities conducted as part of the project. While no improved pasture seed was sown under the thinned forest, the producers noted that rotational grazing facilitated the spread of legumes and desired pasture species into recently thinned areas. They acknowledged that this process is gradual and can take 3-5 years but emphasised that this low cost approach is feasible.

Although this project did not specifically focus on evaluating the limitations of adopting silvopastoral systems, some information and feedback were gathered during fieldwork in November 2022 and conversations with PDS producers. It appears that the main limitations identified are the high cost of thinning operations, difficulty in finding reliable professionals to mark and harvest trees while prioritising retention of the best ones (rather than high-grading), a lack of understanding regarding suitable thinning activities in remaining forest areas, and a need for more information on establishing pastures within silvopastoral systems within native forests. Most of these limitations and barriers were also identified and described by Lewis et al. (2022).

During our visit to the PDS properties, the producers frequently raised questions about the carbon market, carbon sequestration by trees, and the process of becoming carbon neutral. Given the extensive areas of private native forest in remnant (Category B) and freehold land (Category X) that they own, many companies approached them with offers for carbon projects under the “Avoided clearing of native regrowth” method in the ERF. However, agreeing to participate in such projects would require them to commit to locking up the area for a minimum of 25 years (up to 100 years), thereby preventing them from harvesting trees for timber or stand quality improvement and potentially resulting in reduced income and pasture productivity.

4.5 Outcomes in achieving objectives

The following aims were achieved in this project:

1. **demonstrate the integration of pastures and forest under sustainable forest management to increase pasture productivity and tree growth.**
    - native pasture productivity increased by 30-50% in thinned forest plots compared to control plots (unthinned). At two properties, native pasture productivity increased on average 45% (1,075 kg DM/ha) compared to the unthinned stands (716 kg DM/ha), while at Boomerang the native pasture productivity increased 2.6-fold (3,280 kg DM/ha/year) compared to the unthinned stand (1,235 kg DM/ha/yr);
    - improved pasture productivity increased by at least 100% in thinned forest compared to the control plots (unthinned). Compared to the control plots, the improved pasture treatment in thinned forest increased in productivity by 316% (3,848 Kg DM/ha), 326% (3,496 Kg DM/ha) and 408 % (1,125 kg DM/ha) at Boomerang, Lundsville and Kantaka Station respectively.
    - timber growth increased by 30% in thinned forest compared to unthinned forest. The DBH and total height growth measured at the end of the project increased by 59% and 36% respectively.
2. **conduct a financial analysis to determine the relative financial performance of establishing pasture in sustainably managed private native forest.**
    - At the conclusion of this project, a financial assessment was conducted to estimate the net present value (NPV) for the four different treatments. The highest NPV of $2318/ha was calculated for the scenario involving thinning and improved pasture. In comparison, the control treatment involving unthinned forest with native pasture had an NPV of $751/ha.
3. **conduct field days / workshops with the aims of having 100% of core producers and 60% of observer producers with increased knowledge and skills in sustainably thinning their forest areas (e.g. appropriate methods).**
    - A field day carried out in November 2022 with the participation of 18 producers and two webinars were carried out during this project that reached an audience of over 100 listeners. All core producers involved in this project improved their skills and confidence levels by 31% and 17% respectively.
4. **80% of the core group demonstrate an improvement in pasture productivity by managing the forest under sustainable practices.**
    - Most of the core producers have already adopted the integration of timber and livestock and express their intention to extend the area with silvopastoral systems on their property.
5. **20% of observer producers will have adopted or are preparing to adopt new forest management practices.**
    - Unfortunately, we could not confirm this as the survey of the observer producers was unsuccessful.

5 Conclusion

The three Producer Demonstration Sites established in this project provided valuable information about the benefits of forest management and improving pastures in private native spotted gum forest. Thinning practices carried out to increase the productivity of the forest had a positive effect on pasture productivity (both with native and improved pasture) due to the reduction of competition for light, water and nutrients. The implementation of forest management practices led to substantial growth in the retained trees, with a notable increase of over 35% in diameter at breast height (DBH). In terms of pasture, forest management significantly improved native pasture productivity, resulting in a remarkable enhancement of over 45% and a more than two-fold increase with the introduction of improved pasture compared to an unmanaged forest.

To ensure the successful establishment of pasture within a private native forest, it is crucial to prioritise certain key aspects. Achieving a thriving pasture requires careful planning, considering the following factors:

a) Selecting a suitable mixture of grasses and legumes that are well adapted to the specific environmental conditions, such as soil type, temperature, and rainfall patterns.
b) Using high-quality seeds and determining the appropriate sowing rate based on pre-germination tests.
c) Carrying out slight to moderate soil disturbance on the site to facilitate optimal seed-to-soil contact.
d) Choosing the right moment for sowing the pasture, taking into account factors like adequate soil moisture levels. Timing the sowing process appropriately enhances the chances of successful establishment.
e) Allowing sufficient time for the pasture species to flower and spread their seeds before initiating grazing activities.

By taking these considerations into account and implementing thoughtful planning, improved pasture can establish and propagate effectively, leading to improved overall productivity and sustainability. The preliminary results obtained are promising and continued long-term monitoring of these PDS would be desirable.

6 Benefits to industry

In much of the approximately 1.6 million hectares of commercially harvestable native forest on private land in south-eastern Queensland, cattle grazing is the predominant land use. Although the quality and volume of the pasture below these forests is crucial to livestock productivity, most of these areas are at present unmanaged and limited in productivity. The results of this research demonstrate the potential to improve productivity in native spotted gum forests used for grazing through the implementation of sustainable forest thinning and pasture improvements. Adoption of these practices could significantly enhance farm profitability and benefit the cattle and timber industries in the region. An extension program to bridge the knowledge gap on pasture species selection and tree management for timber production would assist in achieving this aim.

7 Acknowledgment

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9 Appendix

9.1 Case Study Lundsville

9.2 Case Study Kantaka Station

9.3 Case Study Boomerang