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A CASE STUDY

Composting Mootels on the West Coast

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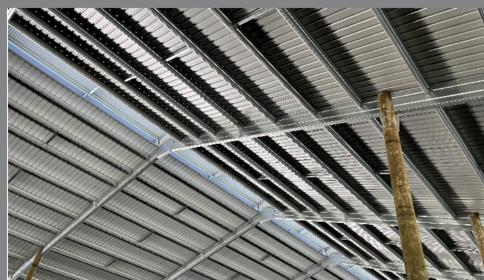


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2 ACKNOWLEDGEMENTS

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3 Executive Summary

Dairy farming in New Zealand faces challenges. The industry's social license to operate is being questioned as environmental and animal welfare standards tighten. Amid these pressures, maintaining profitability is paramount. Composting shelters, known as "composting mootels[1]", have emerged as tools to address these challenges. Yet, New Zealand-specific knowledge on integrating composting mootels into pastoral farm systems is limited.

This project investigated the experiences of three dairy farms on the South Island's West Coast that recently adopted composting mootels. By conducting farmer interviews, Overseer modelling, biophysical sampling, financial analyses, and examining the practical learnings of these farmers, the study aimed to enhance understanding of composting mootels. The emphasis lies on the real-world, trial and error learning that these farmers have undertaken.

The farms in focus, Prospect Farm (Haupiri), Mangawaro Farm (Inangahua Landing), and Turkey Creek Farm (Mawheraiti), are situated in one of New Zealand's most remote and wettest regions. The 2022/2023 season marked the first full season of composting mootel use for these farms. All these farmers diligently learned from the handful of New Zealand farms already using composting mootels. Comprehensive farmer interviews were conducted at Prospect and Mangawaro Farms, while Turkey Creek Farm, which joined the study later, underwent biophysical sampling, Overseer modelling, and financial analysis.

Key findings include:

- For Prospect and Mangawaro Farms, Overseer modelling indicated a 47% average reduction in nitrogen root zone loss post-mootel adoption. This aligns with the results by Durie and Woodford (2022). However, Turkey Creek reported a lower reduction of 18.2%.
- Though the phosphorus loss modelling remained inconclusive, it is hypothesized that using mootels in winter would lessen soil compaction and reduce contaminant runoff. This would also mean less need for winter crops, leading to reduced fertiliser use and its associated risks.
- Anecdotal benefits noted include better cow and staff well-being, attributed to shelter from harsh winter conditions and dry, comfortable bedding.
- Methane emissions for all farms were estimated to have increased post mootel, however, Overseer is limited in its ability to model mootel effluent management and therefore we have limited confidence in this result. OverseerFM (v6.5.2) currently is also unable to model aerobic composting processes and therefore the impact on methane and nitrous oxide emissions. It is imperative further research is done to quantify the impact of a mootel system on a farms Green House Gas emissions to ensure any investment is a sound business decision for farmer's long term.
- Interestingly, the main motivation for these farms was not financial gain, but enhancing business resilience against the declining social acceptance of intensive winter grazing and stricter environmental regulations.

[1] The term "composting mootel" was coined by Keith Woodford in his AGMARDT 2021 report to differentiate these systems from other housed systems such as free stall barns or herd-homes.

In designing their composting mootels, the farmers focused on optimizing feeding, loafing, and floor areas. The mootels' design ranged from $6.5m^2$ to $9.3m^2$ per cow. While definitive conclusions on ideal stocking rates were elusive, initial indications suggested higher areas per cow enhanced composting effectiveness. The design also prioritized internal concrete feed lanes to keep feed dry and careful consideration of the pitch of the mootel roof to ensure sufficient airflow to dissipate moisture from the compost stack.

Generally, cows would be transitioned into the mootels early June, with time in the barn increasing after dry-off. As calving proceeded, cows would be transitioned back onto pasture. Barns were also seen as a viable option for use at the height of summer to alleviate heat stress.

Significantly, when cows used mootels they were more efficient at feed conversion, while utilisation also increased. As a result, the need for intensive winter grazing was reduced. This lowered the risk of soil compaction, as well as discharges of sediment, phosphorous, and *E.coli*. Furthermore, this led to financial benefits. Costs typically associated with winter forage crops (such as cultivation, purchase of seeds, planting, and maintaining the crop) were reduced. From an animal health perspective, it is believed efficient feed conversion and utilisation will assist in body condition score improvements, particularly over winter.

Mootel construction costs ranged from $1,200,000 - $2,909,920. These costs covered mootel construction, siteworks and concrete, woodchip for bedding material, and plant and equipment. On a per cow basis the costs were between $3,250 and $4,000. We note that inflation in recent years means that any prospective mootel investing farmer should consider a range of $3,500 to $6,000 per cow. The woodchip bedding material is an ongoing expense estimated at $3m^3$/per cow annually with each cubic metre costing from $25 to $35. This translates to approximately 0.17c/kgMS.

All case study farmers expected to see milk solid production increases through the adoption of mootels. Due to the limited timeframe of our project, we had insufficient data to confirm or reject this assumption. In their first season using mootels one farm saw a 14.9% increase on their five-year average, while another saw a 20.4% increase. However, it should be noted these farms experienced a favourable spring and there were changes in feed inputs, cow numbers, and (on one of the farms) there was a change in management. The third farm only saw a modest increase of 0.5%. This was partially attributed to the effects of drought, and a facial eczema outbreak.

The case study farms demonstrate there is significant environmental, social, and animal welfare gains to be made by integrating a composting mootel into a dairy farm system. Yet, there is a clear need for additional research on design, usage, and bedding compost management. Aspiring mootel adopters should heed the insights from pioneering New Zealand farmers and conduct thorough due diligence.

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5 INTRODUCTION

Animal housing structures, known as composting shelters, hold the potential to address environmental, profitability, and social license challenges within New Zealand's dairy industry. What sets these shelters apart from traditional dairy housing facilities is the natural composting process within the animals' resting areas. To prevent confusion with other dairy housing systems, such as freestall barns or herd-homes, we will refer to these structures as "Composting Mootels."

While Composting Mootels are common in the Northern Hemisphere, they introduce a novel approach in New Zealand. Here, they've been adapted to align with the nation's dominant pasture-based grazing systems. In essence, cows spend part of their time beneath a roofed structure, resting on a thick layer of plant-based materials, including sawdust or wood shavings. The aerobic composting process, enhanced by daily stirring and proper ventilation, integrates the bedding with animal waste to produce compost. This process generates heat, maintaining the bedding's warmth and dryness, allowing its utility for up to a year or more before needing replacement. Once the compost is ready for removal, it serves as a natural fertilizer for paddocks, enriched by the nutrients from the animal waste. Significantly, unlike other dairy housing structures, Composting Mootels eliminate the need for a separate effluent capture and storage system.

Progressive farmers have begun incorporating composting shelters into a hybrid indoor-outdoor grazing routine, wherein cows oscillate between the shelter and open pasture. The exact distribution of time hinges on individual farm strategies and goals. Typically, these shelters house cows around-the-clock during winter and throughout the daytime in warmer months. Particularly in regions like the South Island, where winters pose substantial environmental and animal welfare issues, Composting Mootels present a viable alternative to winter grazed crops.

Composting shelters may bolster environmental stewardship, animal welfare, and staff well-being within New Zealand's pasture-centric farming systems, possibly even introducing economic benefits. Despite the plethora of international research on these systems, a comprehensive assessment tailored to the unique nuances of New Zealand farming is still in its infancy. Currently, insights on integrating composting shelters within New Zealand's farming context primarily stem from pioneering farmers' firsthand experiences.

6 METHODOLOGY

Building upon the need for a comprehensive evaluation of composting mootels within the unique context of New Zealand farming, this research set out to fill that knowledge gap. The methodology aimed to study both the biophysical and economic impacts of these systems, alongside insights from farmers who have implemented them.

6.1.1 Case Studies Selection:

The methodology centred on examining three farms located on the West Coast. These farms each constructed their respective composting mootel systems during the latter part of the 2021-2022 dairy season and were thus selected as case studies.

6.1.2 Data Collection:

Both biophysical and economic data were extracted from the three case study farms. Additionally, in-depth interviews were conducted with two of the farm owners to glean insights regarding the development and transition process of the mootels.

6.1.3 Biophysical Analysis:

1. **Environmental Footprint:** An environmental footprint comparison was drawn using OverseerFM modelling, contrasting pre and post-adoption of composting mootel systems.
2. **Compost Health and Management:** This entailed recording and analysing various factors such as compost temperature, moisture content, Carbon:Nitrogen ratios, nutrient analysis, and overall composition.
3. **Animal Health and Welfare:** Biophysical parameters such as cow body condition score, somatic cell count, mastitis and lameness incidence, milk production, death rates, and other relevant factors were analysed by comparing data from before and after the mootel implementation.

6.1.4 Economic Analysis:

1. The financial and physical performance of the three case study farms during the 2022-23 financial year was documented and then analysed using DairyBase.
2. Historical production and other performance metrics were captured to establish a foundation for subsequent analysis.
3. Detailed records were made regarding the capital costs associated with each mootel development.
4. Key assumptions were derived around the projected costs and benefits of the mootel development. These assumptions were based on data collected from farmer interviews, farm visits, additional physical data collection (including DairyBase analysis of the 2022-23 season), and observation of crucial financial and physical parameters over the season.
5. We examined farm working expenses and depreciation before and after the development of the mootel to estimate operational costs.
6. A financial model was prepared using discounted cashflow (DCF) analysis to project potential returns from the mootel development in the future. This modelling based its predictions on the marginal returns and costs associated with the development. A primary outcome of this

analysis was discerning the estimated production increase needed for the mootel investment to break-even for each case study farm.

7. We also performed a simplistic return on assets analysis (RoA) based on the cost of capital development, and anticipated returns. To add depth to our economic analysis, a sensitivity analysis was conducted on the estimated financial returns across several key variables.

6.1.5 Production and Farm System Data:

An in-depth review was conducted focusing on:

- The production benefits, both actual and expected, and the required break-even production.
- Any potential benefits in terms of days in milk.
- Additional pasture that was grown, utilized, or saved, modelling using DairyBase
- Additional costs such as feed, bedding, and finance.
- Differences in team management, necessary skills, labour requirements, and labour advantages.
- Management of the bedding material.

6.1.6 Farmer Interviews

In order to gain a comprehensive understanding of the adoption of composting mootel systems, we conducted in-person interviews with farm owners and, occasionally, their family members and managerial staff. These interviews serve to contextualize the subsequent data analysis and modelling within the report. Two out of the three farms, Mangawaro and Prospect Farms, participated in the interview process. The qualitative insights gathered from these interviews contribute to the report's aim of providing a well-rounded perspective that combines both personal experiences and empirical data.

7 DETAILS OF THE CASE STUDY FARMS

To provide context and detailed insights into the practical implementation of composting mootels, three farms from the West Coast were selected based on their unique characteristics and challenges.

The three farms are Prospect Farm, Mangawaro Enterprises, and Turkey Creek Farm. The following map and tables 1 and 2 provide an overview of their location, key farm information, and a summary of their mootel structure.

Map 1. Case study farm locations

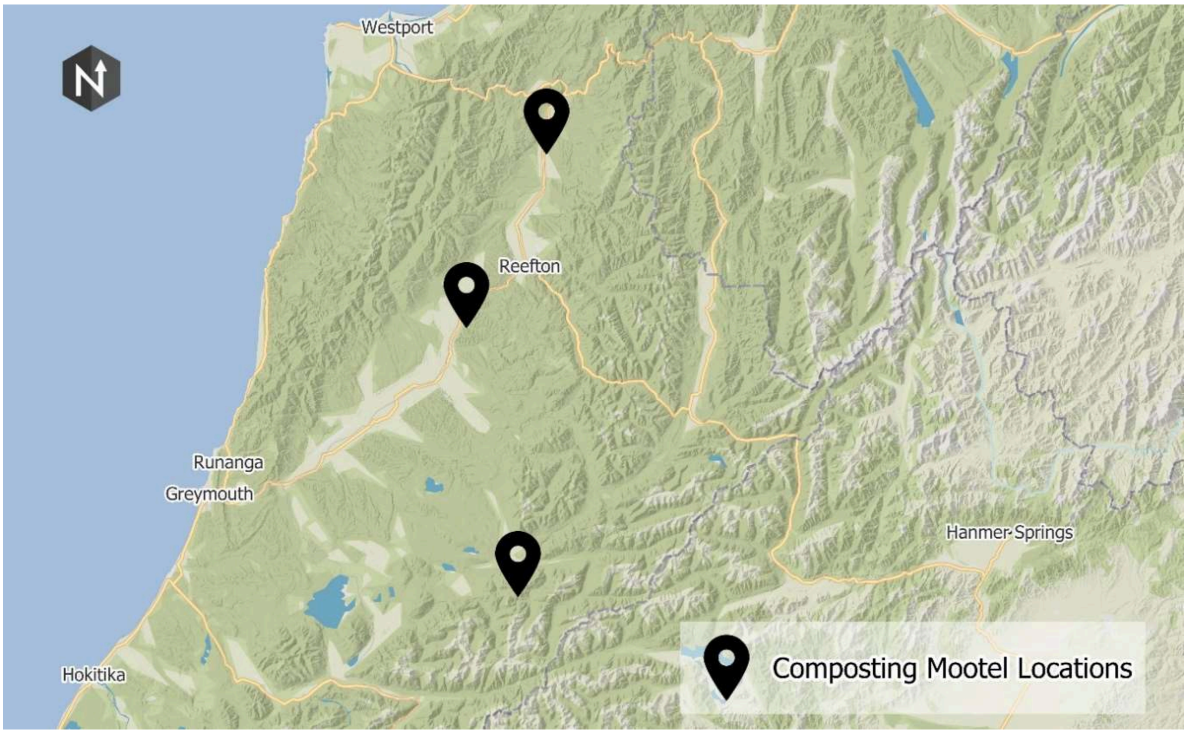


Table 1. Case study farm details

Farm	Prospect Farm	Mangawaro Enterprises	Turkey Creek farm
Location	Haupiri	Inangahua Landing	Mawheraiti
Milking platform area (ha.)	315	185	169
Peak cows (pre-mootel)	800	490	350
Stocking rate	2.5	2.65	2.1
Peak cows (2022-23)	800	540	370
Stocking rate (cows/ha)	2.5	2.9	2.2
Mootel system	2 solid roof mootels	1 solid roof mootel	2 tunnel roof mootels

Table 2. Case study Mootel dimensions

Farm	Quantity	Width	Length	Total M^2	M^2 per cow	Compost volume (m3)
Prospect	2	35	74	5,180	6.5	3,626
Mangawaro	1	35	114	3,990	7.4	2,793
Turkey Creek	2	18	90	3,240	9.3	2,268

Note: areas shown are compost areas, not total roof area.

7.1 Prospect Farm

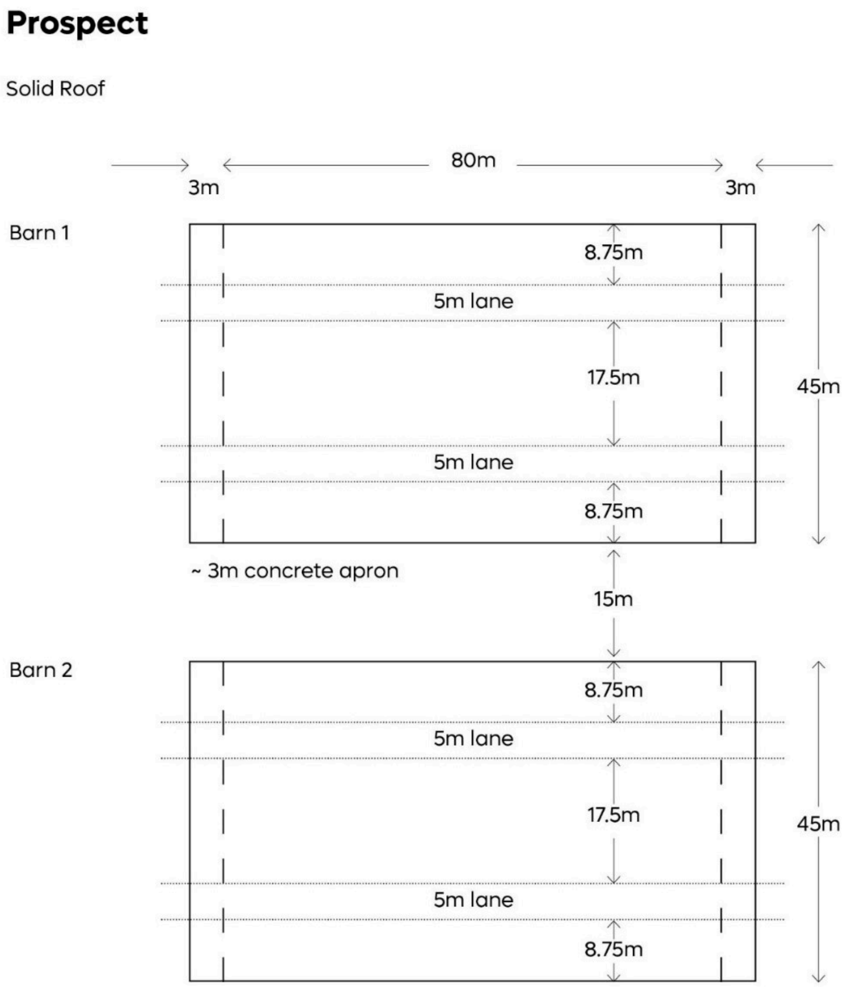
Prospect Farm is located in Haupiri, which is in the headwaters of the Ahaura Valley in the Grey Valley area of the West Coast, approximately 75km inland from Greymouth and sits on the edge of the Southern Alps. Annual rainfall averages 3,000 – 3,250mm, with winters and springs tending to be very wet and cold.

The 2022-23 dairy season at Prospect consisted of a relatively “normal” winter without any excessively wet or cold conditions. Spring was very good, and unusually, there were no prolonged wet periods which are relatively typical for the area. There was a severe and prolonged summer drought in early 2023 which, coupled with the farms first ever outbreak of facial eczema, had a significant impact on pasture and milk production (estimated at up to 20,000kgMS). Following rains in March, the area experienced a very good Autumn.

Mootel site is in an area with relatively good air movement and faces along the prevailing wind. The farmer notes regular dry winds from the East occur, and the Eastern ends of both mootels are dryer that the Western ends. Occasionally extremely strong winds occur from the East on this site.

The farm is owned by Gaye and Murray Coates through their company Prospect Farm Limited and is managed by Murray and his team of 3 full-time staff. It also incorporates a 200-hectare support block located a short distance from the dairy platform.

Figure 1. Prospect Farm Composting Mootel Dimensions

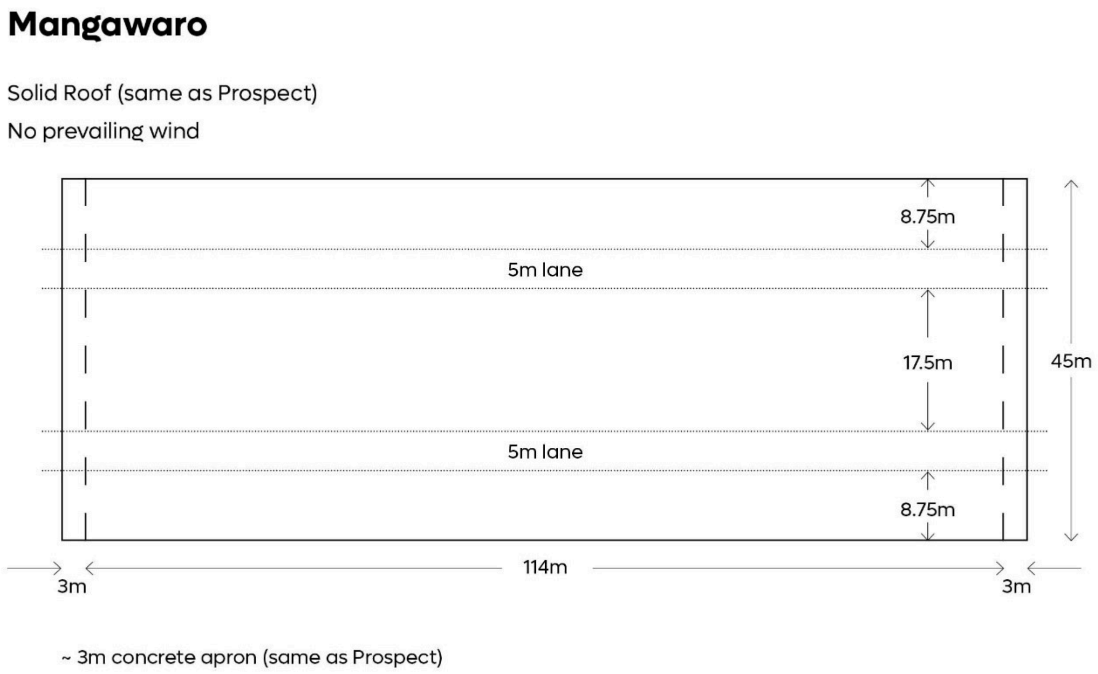


7.2 Mangawaro Enterprises

Located in the Inangahua Valley at Inangahua Landing on State Highway 67, Mangawaro stands approximately 20 km north of Reefton. With an average annual rainfall of 2,300mm, the winters are milder than Prospect Farm due to its elevation being 100m above sea level. The 2022-23 season conditions at Mangawaro resembled those at Prospect, though without the summer drought.

Mangawaro is owned by Carmel and Matt O'Regan. Their contract milkers, Luke and Charlotte Chisnall, operate it with a team of two staff. The property also features an adjoining 135-hectare support block managed by Matt.

Figure 2. Mangawaro Composting Mootel Dimensions

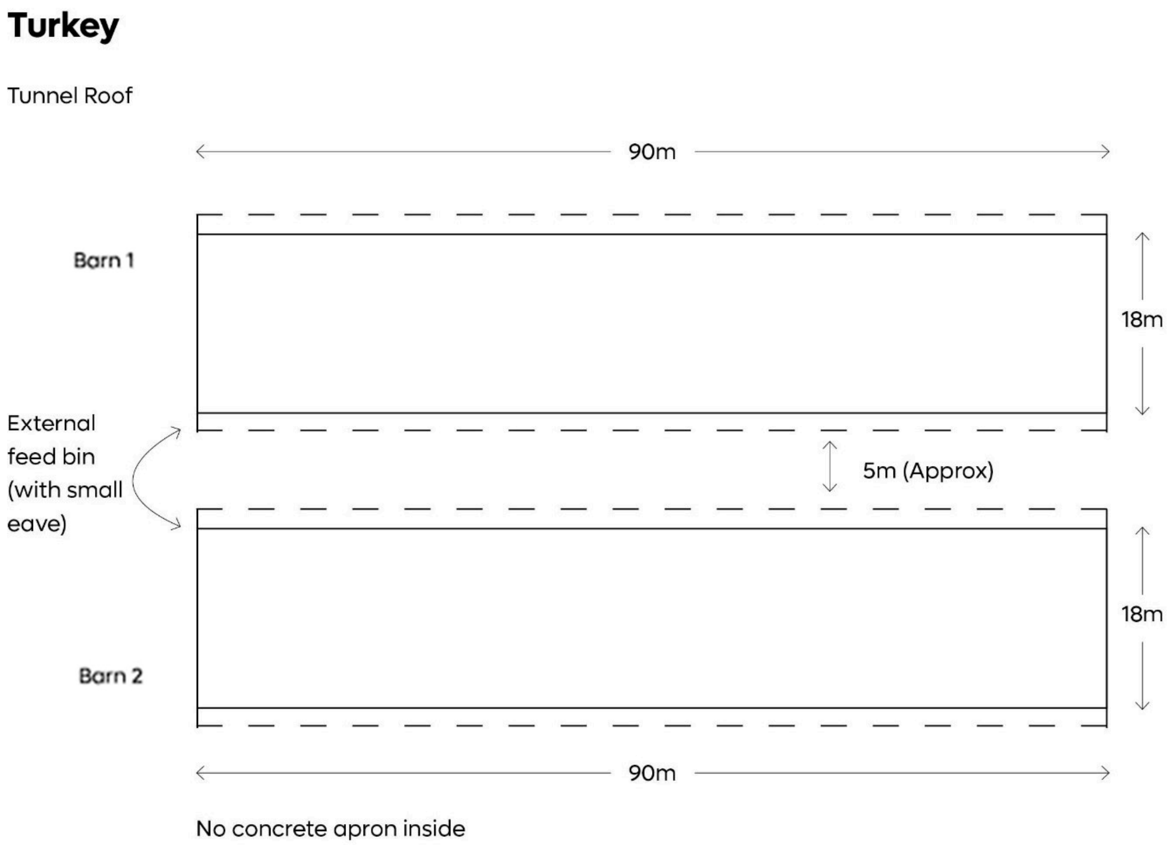


7.3 TURKEY CREEK FARM

Turkey Creek, located at Mawheraiti in the upper Grey Valley, sits approximately 10km South-West of Reefton. With 2,600mm average annual rainfall, the farm rests on a terrace above the Little Grey (Mawheraiti) River. Much of its land is hump and hollowed, and while the Grey Valley can see significant summer dry spells, Turkey Creek does not use irrigation. The 2022-23 seasonal conditions were akin to the other farms, albeit the summer conditions being somewhat intermediate.

Turkey Creek Farm belongs to Wendy and Tegel Oats and is operated by 50-50 Sharemilkers Thomas and Hannah Oats, who experienced their inaugural season on the property in 2022-23.

Figure 3. Turkey Creek Composting Mootel Dimensions



8 Farmer interviews and experiences

To provide a holistic understanding of the adoption of composting mootel systems, we have organized this report to first foreground the personal narratives and insights of the farmers. By doing so, we aim to frame the subsequent analysis and modelling within the context of the very individuals who navigate these systems on a daily basis.

These interviews offer a qualitative lens through which we can appreciate the nuances of the on-ground realities, challenges, and motivations behind adopting composting mootel structures. By beginning with their perspectives, readers are offered a comprehensive view that is both personal and empirical.

Out of the three farms, only Mangawaro and Prospect Farms participated in the interview process. Turkey Creek Farm was a later inclusion in the project and therefore was not a part of the interview series.

Each interview, conducted in-person, predominantly involved the farm owners, although occasionally insights were also provided by family members and farm management teams. An overwhelming passion for the composting mootel structures was evident throughout both interview sessions. This enthusiasm was complemented by a generous willingness to guide and advise fellow farmers contemplating similar system shifts. While a plethora of quantitative data underscores the advantages of composting mootel structures (a portion of which is encapsulated in this report), it is the qualitative boons to the farming enterprises that emerged as the prime influencers. Both respondents candidly shed light on the hurdles encountered and the invaluable lessons learned, aligning seamlessly with the essence of this report – to spotlight these narratives grounded in genuine farmer experiences.

8.1 Interview Themes

For clarity, the principal themes explored during the interviews have been segmented under the following headings:

- Motivators for the Construction of a Composting Mootel.
- Project Financing.
- Mootel Construction and Design.
- Transitioning the Farm System.
- Bedding Management.
- Challenges and Constraints.
- Advantages of the Mootel System.
- Pearls of Wisdom: Advice from One Farmer to Another.

8.2 Motivators for the Construction of a Composting Mootel

This section delves into the driving forces behind each farmer's choice to invest in a composting mootel system. Our exploration aimed to uncover shared incentives or distinct perspectives among the interviewees.

A salient theme emerged from the discussions: financial profitability was not the chief impetus for either farmer. Instead, both emphasized a holistic approach that prioritized the well-being of their herds, environmental stewardship, and the long-term viability of their business.

The farmers acknowledged the mounting regulatory and societal pressures associated with wintering dairy cows on crops. In response, they perceived composting mootels as a strategic measure to not only align with these expectations but also fortify their farm operations and bolster business resilience. One interviewee cleverly remarked, "the second mouse gets the cheese," underlining the prudence in examining various housing alternatives. They believed that, given the empirical evidence from numerous New Zealand farms, these systems, when adeptly managed, promised significant upticks in production efficiency, compensating for the initial outlays.

Another interviewee shared their initial inclination to merely enhance their existing standoff pad. It was only in their subsequent research phases that the composting mootel emerged as an enticing proposition, primarily due to its roofed design, which optimized effluent management. The challenges of managing runoff from their non-roofed standoff pad, especially under the relentless West Coast rainfall, were substantial. Their team's objective was to cultivate a winter management strategy that simultaneously catered to the well-being of the staff, animals, and pasture. In the composting mootel, they found a solution that circumvented issues like soil compaction from intensive winter grazing, which otherwise impacted animal health and pasture rejuvenation. Moreover, the mootel streamlined operations, cutting down the labour-intensive task of managing breaks during winter. As a result, the team could predominantly engage with cows in a sheltered environment, allowing them to commence the milking season revitalized.

Reflecting on their prior practices, one farmer expressed discontent, remarking, "we were not proud of our previous wintering system," which largely relied on forage crops. This sentiment resonated with both farmers, who now take immense pride in their composting mootels. They believe that this system epitomizes their commitment to optimal animal care, environmental responsibility, and providing a conducive workspace for their teams.

8.3 Project Financing

The journey to secure financing for the composting mootel projects was markedly different for each farmer, shedding light on the diverse considerations banks employ when evaluating such ventures.

For one farmer, the financing process was relatively seamless. This ease was largely credited to their longstanding rapport with their bank manager and the substantial equity they held. This meant that they did not need to finance the entirety of the project. The farmer's proven track record and the bank manager's confidence in their capability to execute the project both effectively and lucratively further bolstered this smooth transaction.

Contrastingly, the second farmer's experience was more challenging. Despite a long-established relationship with their initial bank, they faced disappointment when their financing request for the mootel was declined. The bank cited concerns regarding the lower land values on the West Coast relative to other rural regions in New Zealand, questioning the lending security this presented. Persistent in their endeavours, this farmer reached out to four different banks before identifying a lender who resonated with the project's vision.

A key takeaway from both farmers was the paramount importance of due diligence. Before even approaching the banks, they had armed themselves with detailed research on composting structures and supplemented their pitches with case studies that demonstrated successful incorporations of these systems within other New Zealand dairy farms. They unanimously felt that the banks were swayed by the anticipated enhancements in environmental stewardship that the composting mootels promised. Other persuasive factors were the expected uptick in farm saleability and bolstered business resilience.

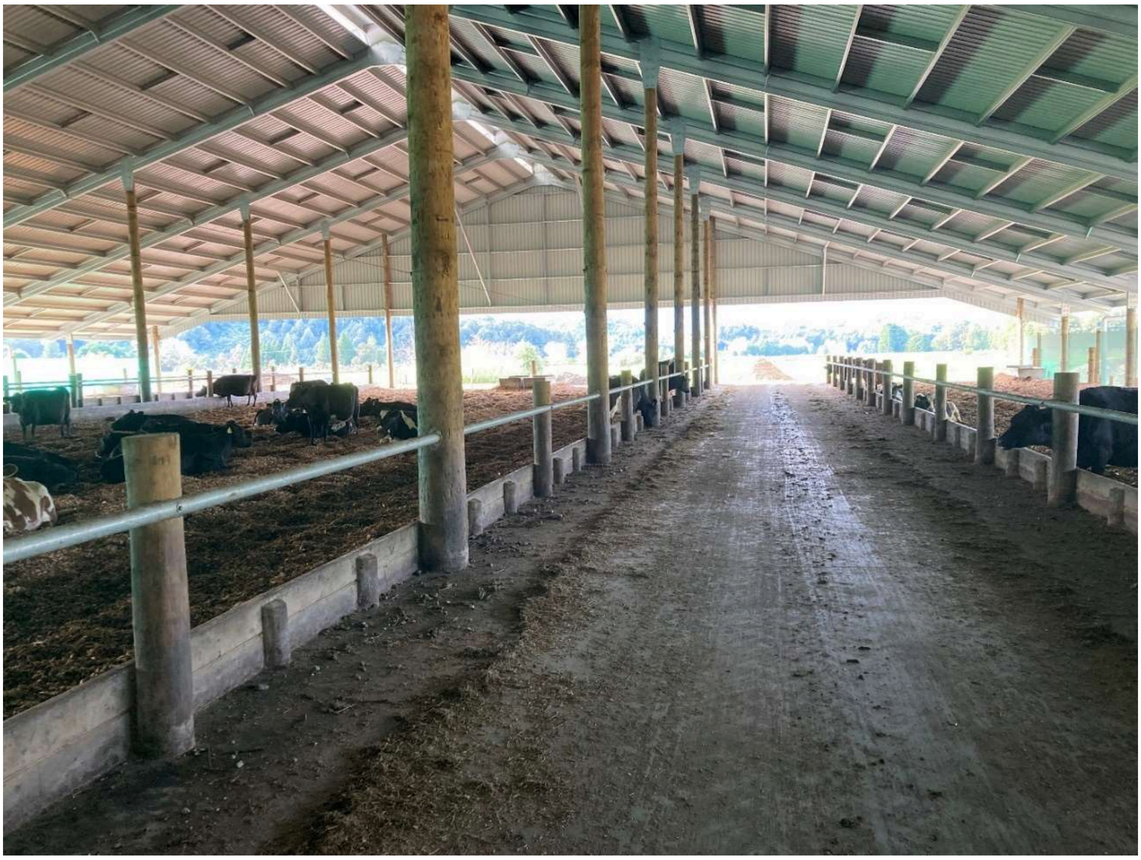
However, both farmers echoed a cautionary note: investing in composting mootels should not be viewed as a panacea for pre-existing business challenges. Neither should such an investment be pursued if it strains the financial health of the business. Given the considerable investment required, due diligence is not just advisable; it is imperative.

8.4 Mootel Construction/Design Phase

The significance of design and construction in the mootel process became evident during our interactions with the farmers. Current research on animal housing underscores the vital role played by internal design in ensuring optimal feeding, resting areas, and floor space usage.

One of the farmers emphasized the utility of internally constructed feed lanes shielded from external weather elements. This approach kept the feed dry, enhancing its utilization, and granted the flexibility of feeding at any time. Figure 4 below depicts this feed lane configuration, a layout common to both farms under study. Furthermore, they pointed out that a more efficient design might consist of two side lanes and a central lane. This modification would optimize the roof-to-resting-area ratio, facilitating an increase in housed cow numbers.

Figure 4. A photo of the internal layout of the mootel (Mangawaro Farm).



Additional insights and recommendations concerning mootel design and arrangement included:

- The value of an 18-degree roof inclination, critical for enhancing airflow—a determinant factor in composting efficiency.

- Consideration of the mootel's orientation, keeping in mind environmental elements like the dominant wind direction.
- Strategically storing supplementary feed nearby for operational efficiency.
- Assessing mootel proximity to the milking shed. One farmer remarked how this closeness facilitated special care for cows flagged with health issues during milking sessions.
- Ensuring the design minimizes moisture infiltration, be it from precipitation or condensation, as this affects both composting efficiency and the cows' overall comfort.

Unique to the West Coast's environment, the sheer volume of water amassed by these vast roofed structures during rain necessitates robust stormwater management systems.

Both farmers were unanimous in their preference for woodchip composting, driven chiefly by concerns about animal welfare. One recounted a visit to a North Island facility with a concrete-floored structure where they witnessed a cow slip, reinforcing their commitment to a safer flooring alternative. If any concrete was used, they recommended a polished finish to prevent mouth sores.

They also underlined the importance of liaising with local and regional councils to familiarize oneself with construction consents and environmental considerations. One farmer pointed out a district stipulation necessitating a switch from Zincalume to Coloursteel roofing—a change that upped their project cost by $115,000.

The topic of project management came up, with one farmer noting that the construction was handled by builders contracted to the material supplier, limiting their oversight during this phase. They opined that, for future projects, they would contemplate self-management.

A recurring sentiment from both interviews was their meticulous due diligence during the mootel design and construction phase. Both farmers were unanimous in asserting the paramount importance of this stage to guarantee a successful on-farm transition.

8.5 Farm System Transition

Transitioning from a grass and winter forage cropping system to a housed environment with mixed diets presented a unique set of challenges and learnings for the farmers. Both interviewees remarked that, on the surface, the transition appeared seamless, symbolized by the simple act of moving cows into the mootel one day. Nonetheless, delving deeper, the maiden season revealed a learning curve, particularly when it came to grasping the nuances of animal feed requirements.

A core realization echoed by both was that, despite the infrastructure changes, they remained rooted in their identity as grass farmers. The shift was not in the essence, but the approach. This adaptability was further showcased when one farmer considered introducing maize cultivation, anticipating enhanced utilization that would render it economically viable within the mootel system. A unanimous sentiment was the anticipated uptick in pasture production due to reduced winter soil compaction and pasture damage. However, one farmer pointed out an emergent challenge, which is the effective utilization of this additional feed.

A vital aspect that demands attention, as underscored by both farmers, is the equipment required for managing the composting mootel system. A mixer wagon's centrality was underscored, with a subsoiler pivotal for the tilling process. Yet, maintaining a dedicated tractor for the mixer wagon is of paramount importance to ensure other farm operations remain unhindered. Additionally, a telescopic handler was recommended for loading the mixer wagon.

Increased mechanisation naturally brings the challenge of finding skilled staff for machinery operation. This niche skill set, both interviewees noted, is challenging to source and, when found, crucial to retain to ensure the system's smooth operation. Both farms felt the need for comprehensive training sessions centred around feed optimization, mixing ratios, and determining composting tilling frequencies. Leveraging the expertise of rural professionals has been invaluable in this upskilling journey.

While mootels offer a fresh perspective on feeding, one farmer highlighted the perpetual importance of efficient pasture harvesting "with mouths" – a nod to traditional grazing. The second farmer emphasized a more nuanced understanding of cow nutrition in the mootel context. They explained that, traditionally, the only pathway to escalating milk solid production was via boosting grass growth. However, with mootels, the heightened focus on detailed cow nutrition and condition management has heralded production efficiencies without altering feed inputs. A key takeaway from their inaugural mootel season was the undeniable importance of seeking expert advice to finetune cow nutrients and feed.

8.6 Bedding Management

The bedding management practices adopted by the case study farms came under scrutiny in relation to optimal approaches and materials for bedding. Both farms initially started with daily tilling of the bedding material, but adjustments have since been made on one farm, which now tills every other day outside the winter season. Notably, there is an observed correlation between daily tilling and compost temperature regulation; increased tilling frequencies seemingly elevate the compost temperature.

Figure 5. Photo of tilled bedding beside feed lanes.

One farm has adopted an approach of only refreshing a third of the bedding material each year. This method helps retain the woodchip's heat and optimizes its use. However, both farmers acknowledged the existing ambiguity surrounding the best practices for managing bedding material to ensure efficient composting. They eagerly await more research to provide clarity in this area. Yet, they also recognise that local weather intricacies can significantly impact composting results.

In terms of bedding material choice, both farms have shown a preference for Pinus radiata wood chip over other alternatives such as sawdust or miscanthus. The chosen material's moderate durability ensures its longevity, whilst still effectively composting. Although securing a consistent woodchip supply poses potential challenges, utilizing widely available materials like Pinus radiata, prevalent in forestry, offers a solution. One farmer emphasized the cost-effectiveness of sourcing logs and then contracting chipping on-site rather than importing pre-chipped material. They cited a ratio of 2.4-3 cubic meters of chip per 1 cubic meter of log. Another advantage of this method is the storage savings; logs can be stored and chipped just before use, as opposed to storing large quantities of pre-chipped wood. Given the hefty expenditure associated with bedding— one farmer mentioned a figure exceeding $150,000 for a complete woodchip replacement—it is vital to find cost-efficient solutions.

A paradigm shift was noted in one farmer's perspective on the primary purpose of composting within the mootel structure. Initially, the farmer saw the mootel as a mechanism to produce valuable compost for reintroducing to the paddocks. However, this viewpoint has evolved. Now, the farmer places more emphasis on the enhanced comfort the system provides to cows. This does not diminish the importance of the composting process—indeed, it is integral to the mootel's success—but it brings into focus the broader system and the welfare of the animals it houses.

8.7 Project Constraints

Several project constraints emerged during the course of establishing the composting mootel systems, as shared by both farmers. However, they were unanimous in their sentiment that these challenges only had a marginal effect on the overall functionality and success of their systems.

A significant concern for one farmer was the process of securing financing. They perceived their decision to transition to the mootel system as a proactive step towards fostering present and future farm resilience, especially in addressing the looming environmental challenges in the sector. The hesitancy exhibited by multiple banks to even consider their proposal was viewed as a potential hurdle for similar future initiatives that seek to mitigate business risks.

Another constraint was the perceived lack of industry support. Surprisingly, one farmer noted the scepticism they encountered from peers. Some fellow farmers expressed concerns that the introduction of innovative systems like the mootel might exert pressure on them to adopt similar investments.

Budgetary constraints inevitably affected certain decisions. Both farmers felt the weight of rising costs and the constant need for cost management in order to adhere to their set budgets.

Another point of contention was the definition of a "grass-fed system." Both farmers recognized the competitive edge this branding offers New Zealand dairy products in the global market. The incorporation of composting mootel structures into this branding paradigm remains an unresolved debate. Yet, both farmers were firm in their stance: while their methods might deviate from the traditional, they still identified primarily as grass farmers.

The human element also emerged as a key component. One farmer emphasized the role of a dedicated and motivated staff in ensuring the smooth operation of the mootel system. They passionately believed that the system's success heavily relied on having a team genuinely invested in its effective management.

8.8 Benefits of a Mootel System

While acknowledging the challenges, the farmers interviewed were also keen to shed light on the multiple advantages they derived from the Mootel farm system. Here is a summary of the distinct benefits they have experienced:

- Enhanced Cow Performance: There was a notable increase in total milk production and the number of days in milk. The farmers attributed this positive change to better management of cow nutrition and their overall condition. This improved management was further reflected in a notable rise in the in-calf rate, decreased empty rates, and more vigorous and higher-surviving calves.
- Decrease in Downer Cows: By offering a more flexible supplement intake and improved calving conditions, the incidence of downer cows—those too weak or sick to stand up—was reduced.
- Staff Satisfaction: Working conditions dramatically improved for farm staff. Operating under a shelter during winter months and calving periods provided a more comfortable working environment, shielding them from harsh weather conditions. This, in turn, likely boosted morale and productivity.
- Management of Heat Stress: During the scorching summer months, the Mootel system provided an environment where heat stress in cows could be effectively managed. This improved condition contributed to the reported reduction in empty rates.
- Optimized Land Use: With cows housed in the barn during winter, there was reduced dependency on winter crops. This shift allowed farmers to utilize more paddocks for supplementary feed production.
- Improved Pasture Management: Wintering cows in the Mootel meant that there was a considerable reduction in the damaging of pastures due to 'pugging' (when cows' hooves sink into wet soil, damaging the pasture). This led to easier pasture maintenance during the sensitive periods of winter and early spring.

8.9 Advice from One Farmer to Another

Transitioning or introducing a mootel system is not a mere change in farming practice but a significant shift in the farm's operational paradigm. Through the shared experiences of the interviewed farmers, prospective adopters can gain insight into the system's intricacies and best practices. Here's a compilation of their key advice:

- Commitment is Essential: Adopting a mootel system is not a decision to be taken lightly. It requires dedication and enthusiasm from both farm owners and staff. The shift necessitates a proactive approach in learning and adapting to the system's unique requirements.
- System Compatibility: One farmer emphasized the importance of integration. Instead of forcefully retrofitting your existing farming methods to accommodate the mootel, ensure the mootel complements and enhances your current system.
- Financial and Long-term Perspective: Beyond the immediate practicalities, it is crucial to assess the financial viability of the system. This includes analysing the mootel's alignment with your farm's long-term strategy, especially if you are considering succession planning.

- Balanced Dependency: While the mootel offers certain conveniences, like potential supplementary feed storage, it is essential not to develop an over-reliance. Pasture and grazing management remain fundamental components of farming, and their significance should not be undermined by the introduction of the mootel.
- Be Realistic about Costs: Setting up and managing a mootel is not without its financial challenges. It is essential to anticipate and budget for additional equipment and machinery costs vital for the mootel's efficient operation.
- Clarity of Purpose: Before making such a significant investment, farmers must reflect upon their core motivations. Understanding the "why" behind the decision will help identify if the mootel is genuinely the best solution or if other, more cost-effective options might be more suitable.
- Invest for Efficiency: One farmer's emphasis on "Mootel efficiency" underscores the importance of thoroughness in all aspects of the system. It is not just about erecting the structure; it is about ensuring that every aspect, from machinery to bedding materials, is of top quality and suited for the purpose. Skimping or cutting corners in one area might jeopardize the system's overall efficiency and effectiveness.

In essence, while a mootel system offers numerous advantages, it is a significant commitment that should be approached with research, clarity, and a clear vision of how it integrates into the broader farming picture.

9 ENVIRONMENTAL ANALYSIS

This section details an environmental analysis performed using the OverseerFM model to compare pre and post composting mootel systems. The model's main metrics of interest were Nitrate, Phosphorus, and Greenhouse Gas losses.

Insights drawn from observed and practical farm systems helped make educated assumptions about overland flow, critical source areas, and the potential risks of contaminant loss. The findings revealed that by using composting mootels, nutrient losses at Prospect Farm and Mangawaro Farm were nearly halved, and at Turkey Creek, the reduction was around 18%. One significant factor in nutrient loss reduction was the minimization of nutrients leaching from urine patches in the soil. Concurrently, all examined farms reduced their nitrogen fertilizer usage. This reduction was attributed to decreased winter crops and more efficient supplementary feed use. Additionally, summer conditions weren't conducive for nitrogen fertilizer application.

Despite its advantages, the OverseerFM model could not assess Nitrous oxide (N_2O) emissions since it lacks the capability to simulate the aerobic composting process inside each Mootel. Nevertheless, we argue that potential N_2O emissions from the composting process would likely be offset by the observed reductions in Nitrogen in the natural Nitrogen cycle.

The model's inability to accurately simulate composting mootels is a limitation. Given mootels novelty in New Zealand and the limited scientific data available, there are inherent constraints in the model. Still, for consistency, this analysis followed the methodology in Rachel Durie’s 2022 analysis.

Table 3 Summary of nitrogen and phosphorus loss by farm

	Total Nitrogen loss (kg)		Nitrogen loss per hectare (kgN/ha)		Total Phosphorus loss		Phosphorus loss per hectare (kgP/ha)	
Season	**21/22**	**22/23**	**21/22**	**22/23**	**21/22**	**22/23**	**21/22**	**22/23**
Prospect Farm	58,323	32,956	85	48	2,764	3,301	4	4.8
Mangawaro	22,861	10,993	66	32	1,357	1,038	3.9	3
Turkey Creek	12,688	10,378	60	49	1,787	1,701	8.4	8

9.1 PROSPECT FARM

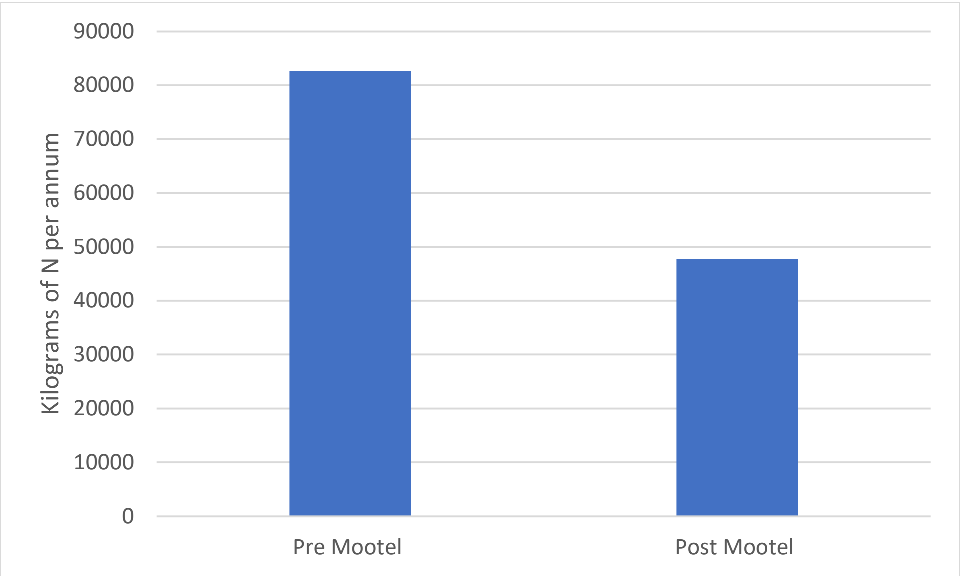
Prospect Farm's environmental performance, both pre and post Mootel introduction, reveals significant environmental enhancements, particularly in reducing total N loss and N loss per hectare.

Table 4. Prospect Farms Environmental Footprint Comparison between pre and post Mootel structure.

Environmental Indicators	Pre Mootel Scenario	Post Mootel Scenario
Nitrogen (N)		
Total N loss (kg N/yr)	58,323	32,956
N Surplus (kg N/ha/yr)	155	140
N Loss Per Hectare (kg N/ha/yr)	85	48
- Urinary N Loss (kg N/ha/yr)	52	30
- Other N Loss (kg N/ha/yr)	33	18
Phosphorus (P)		
Total P Loss (kg P/yr)	2,764	3,301
P Loss Per Hectare (kg P/ha/yr)	4	4.8
Biological Greenhouse Gas Emissions (GHG)		
Methane (t $C0_2$ eq/yr)	2,873.7	3,083.9

Table 5 highlights a 44% decrease in synthetic nitrogen fertilizer usage post Mootel introduction. Other notable changes include a 7% rise in Methane (CH_4) production. This increase is attributed to the OverseerFM model's assumption of increased effluent management due to the mootel's covered wintering structure, resulting in higher CH_4 production. There is also a slight increase in potential Phosphorus loss.

Table 5. Prospect Farm's Synthetic Nitrogen Usage Pre and Post Mootel Structure.



9.2 Mangawaro Farm

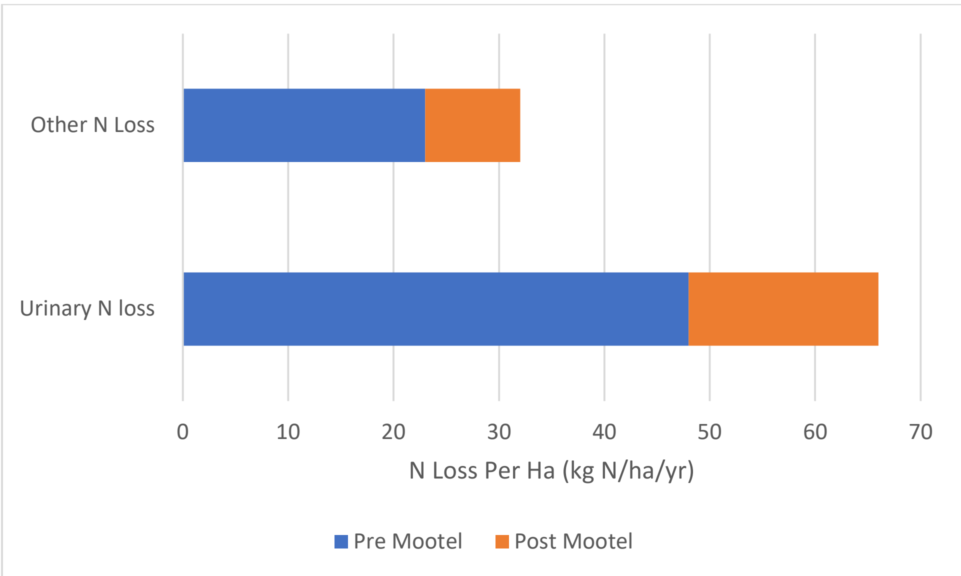
Mangawaro Farm's environmental performance changes mirror those observed at Prospect Farm. Significant reductions in total N loss and N loss per hectare were noted when transitioning from a pre to post mootel system.

Table 6. Mangawaro Farm OverseerFM modelled comparison between pre and post Mootel structure.

Environmental Indicators	Pre Mootel Scenario	Post Mootel Scenario
Nitrogen (N)		
Total N loss (kg N/yr)	22,861	10,993
N Surplus (kg N/ha/yr)	175	143
N Loss Per Hectare (kg N/ha/yr)	66	32
- Urinary N Loss (kg N/ha/yr)	48	23
- Other N Loss (kg N/ha/yr)	18	9
Phosphorus (P)		
Total P Loss (kg P/yr)	1,357	1,038
P Loss Per Hectare (kg P/ha/yr)	3.9	3
Biological Greenhouse Gas Emissions (GHG)		
Methane (t CO_2 eq/yr)	1,449.6	1,875.1

The OverseerFM modelling suggests less risk of urinary N loss, as seen in Table 7, due to the composting structure and subsequent capture of urinary N and a decrease in N surplus of 18%. Each of these factors reduce the amount of available Nitrogen at risk of leaching during the natural N cycle. Similar to the Prospect scenario, synthetic Nitrogen fertiliser use has also declined as part of the incorporation of the Mootel structure due to reduced winter grazing and unsuitable summer conditions.

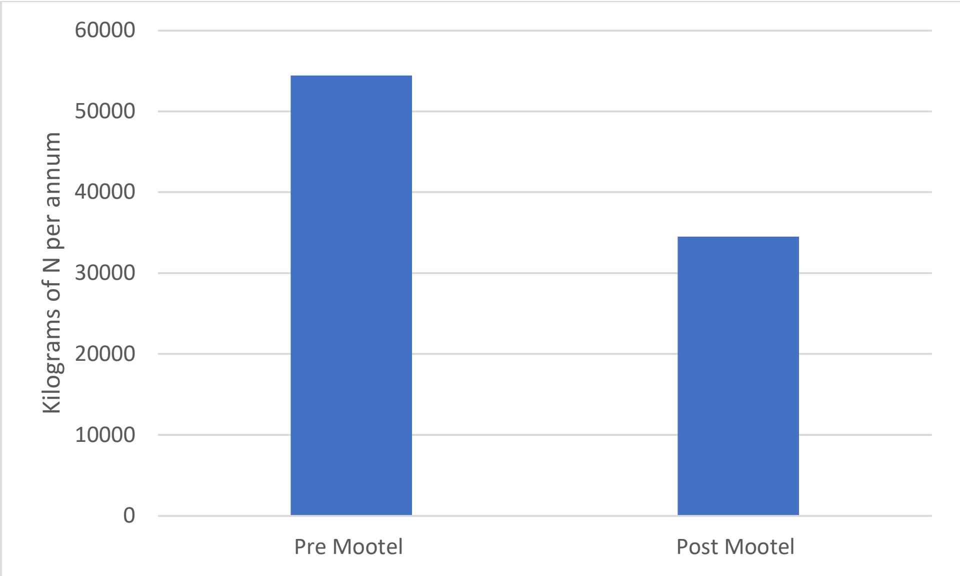
Table 7 Mangawaro Farms Total N Loss Composition.



Prior to the installation of the structure, 54,435kg of Nitrogen fertiliser was being applied to the property per annum (Table 8). Post mootel installation this number has lowered to 34,493kg. This is a 37% decrease in synthetic Nitrogen applied per annum which directly correlates to the amount of

Nitrogen present in the N cycle and therefore the amount that is at risk of leaching below the root zone. Other notable changes include a reduction in Total P loss and P loss per hectare which primarily relates to 62% decrease in synthetic Phosphorus fertiliser use when comparing Pre and Post Mootel farm systems. The modelling did suggest a greater increase in Methane (CH_4) production compared to Prospect farm with a lift of 29% in comparison to Pre Mootel state. This is, however, primarily due to a 22% increase in stocking rate in the post mootel system.

Table 8. Mangawaro Farms Synthetic Nitrogen Usage Pre and Post Mootel Structure.



9.3 Turkey Creek

Table 9 presents a comparison of Turkey Creek's environmental metrics before and after the Mootel implementation, emphasizing the notable reduction in N loss per hectare and the processes leading to this outcome. As observed in other case studies, the primary driver of these reductions was the decrease in urinary N loss.

While there was a decline in both Total N and N/ha, the magnitude of this reduction at Turkey Creek was less significant than that reported in the other two case study farms. Specifically, Total N loss decreased from 12,688kgN to 10,378kgN, marking an 18.2% reduction. Similarly, the N loss per hectare was reduced from 60kgN/ha to 49kgN/ha.

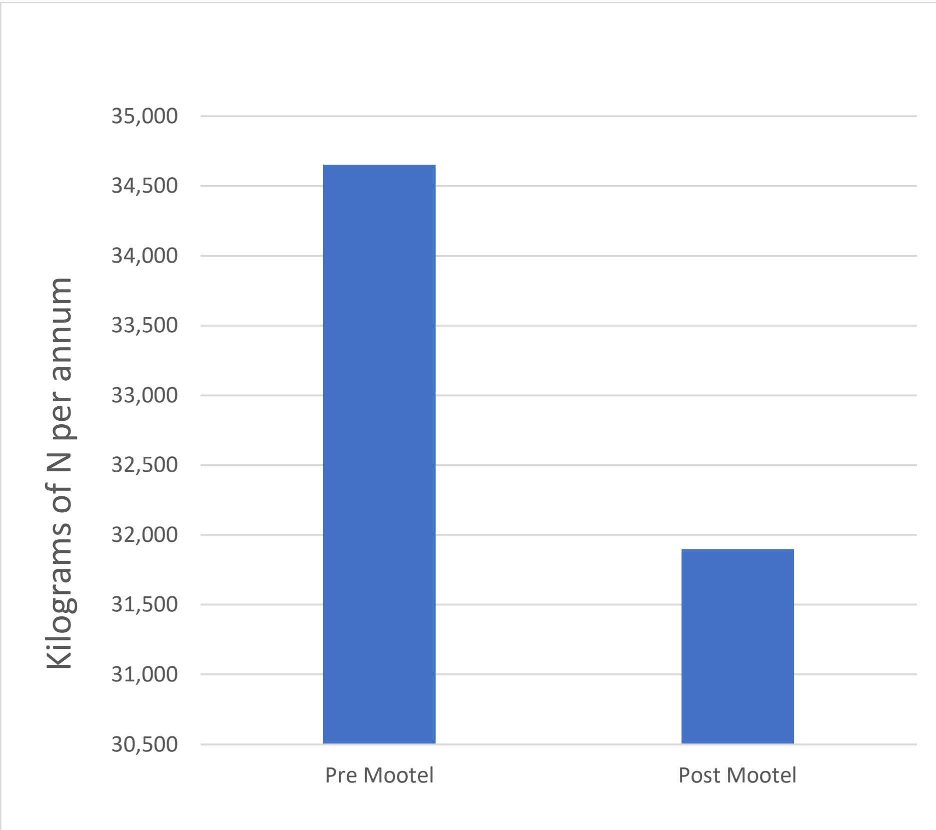
In the context of greenhouse gas emissions, Turkey Creek's methane emissions also rose, in line with trends seen in the other case studies. However, the increase here was relatively subdued, registering at 4.4%.

Table 9. Turkey Creek OverseerFM modelled comparison between pre and post Mootel structure.

Environmental Indicators	Pre Mootel Scenario	Post Mootel Scenario
Nitrogen (N)		
Total N loss (kg N/yr)	12,688	10,378
N Surplus (kg N/ha/yr)	222	234
N Loss Per Hectare (kg N/ha/yr)	60	49
- Urinary N Loss (kg N/ha/yr)	42	36
- Other N Loss (kg N/ha/yr)	18	13
Phosphorus (P)		
Total P Loss (kg P/yr)	1,787	1,701
P Loss Per Hectare (kg P/ha/yr)	8.4	8
Biological Greenhouse Gas Emissions (GHG)		
Methane (t $C0_2$ eq/yr)	1,503.7	1,569.9

As depicted in Table 10, before the introduction of the composting mootel, Turkey Creek applied 34,652kg of synthetic nitrogen annually. However, with the mootel's implementation, this amount decreased to 31,899kg, representing a 7.9% reduction.

Table 10. Turkey Creek Synthetic Nitrogen Usage Pre and Post Mootel Structure.



9.4 Non-OverseerFM modelled environmental changes

Several environmental changes not highlighted in the OverseerFM modelling deserve attention, including overland flow management, critical source areas, the role of winter fodder cropping in contaminant loss, and soil compaction.

Each case study farm has seen a significant decrease in areas dedicated to winter fodder crops after introducing the mootel. This likely translates to a considerable decline in the risk of overland contaminant flow. The farms now sustain a larger portion of their paddocks with permanent vegetation, which reduces the chances of fluvial soil erosion during intense rainfall episodes – a primary source of contaminant losses on the West Coast.

Accompanying the decline in winter fodder crop area, there is a notable decrease in critical source areas needing meticulous management to mitigate contaminant loss. Given this, it is reasonable to infer a subsequent reduction in nutrients and pathogens entering local water bodies.

Soil compaction intensifies the overland contaminant flow risk because it reduces the soil's water infiltration capacity. On all the case study farms, cows are now sheltered in Mootel structures during winter, avoiding the months most prone to compaction. Furthermore, other risk periods, such as during heavy rainfall, can now be handled with added flexibility.

In summary, the modelling clearly demonstrates the potential for notable decreases in both total Nitrogen loss and Nitrogen loss per hectare when incorporating composting Mootel structures. The main driving forces behind these reductions are the reduced dependency on synthetic Nitrogen fertiliser and enhanced capability to manage and spread areas with high N concentration in urine. A deeper exploration is necessary to gauge the impact of the composting process on Nitrous Oxide (N_2O) emissions. Further investigation into feed conversion efficiency (kgDM/kgMS) and reduced cow maintenance requirements over winter is also needed to ensure any gains can be accurately validated and reflected in Methane emissions data.

10 Biophysical Analysis

The following analysis delves into the biophysical changes observed across all three case study farms, examining factors crucial for the vitality and health of mootel compost.

Central to this investigation are moisture and dry matter content, tilling practices, temperature, and nutrient composition. These elements play a pivotal role in the overall health and productivity of the compost. Understanding these dynamics is not only essential for maintaining the compost's optimal performance but also provides invaluable insights for farmers contemplating investing in a composting mootel. Through this section, we aim to offer a well-rounded perspective that bridges the theoretical understanding with practical applications in the field.

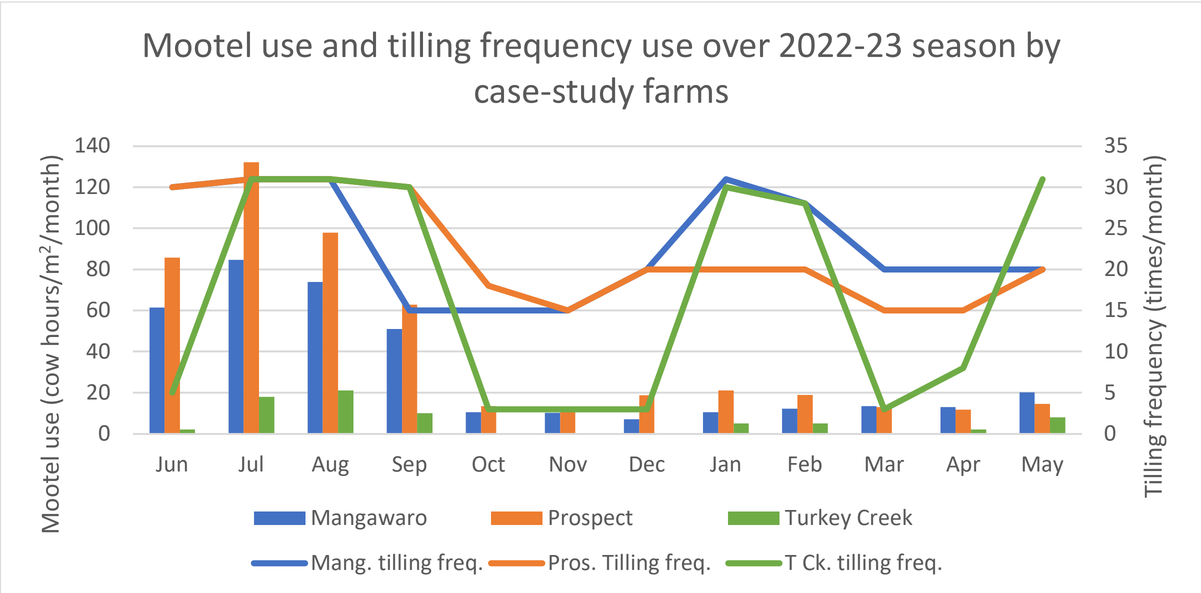
10.1 Compost health, function, and management

10.1.1 Mootel usage

The extent of mootel utilization throughout the season was deduced from various sources: farmer interviews, farm records, and subsequent interviews. The pattern that emerged was one of intensive use, particularly during the colder winter months. Post drying off cows in early to mid-June, mootels saw continuous usage, functioning 24 hours a day. As calving began, cows started spending more time outdoors, leading to a gradual reduction in mootel usage. By late spring, with improved climatic conditions, the cows enjoyed extended outdoor periods. The usage pattern in summer and autumn was less uniform; while one farm opted out of mootel usage for extended durations, others used it daily. Here, the primary aim was efficient supplementary feeding rather than shelter provision. However, all farms agreed on the tactical advantages of mootels during heavy rainfalls (to prevent pasture damage and optimize supplementary feed usage) and during heatwaves (to mitigate heat stress in cows). For a detailed breakdown of mootel usage, see appendix 1.

In Figure 6, mootel usage is depicted farm-wise, expressed in terms of cow hours per m^2 of area monthly. This effectively gives us a mootel "stocking rate". Also featured in the figure is the frequency of tilling, captured as monthly tilling events. A more comprehensive discussion on tilling practices can be found in section 10.1.7.

Figure 6. Mootel use and tilling frequency.



To capture the overall stocking rate for the entire season from June 2022 to May 2023, we have represented it in terms of cow hours for every square meter of compost space. Table 11 below showcases the cumulative compost loading for the year.

Table 11. Annual mootel use (cow hours per square metre) by case study farm during 2022-23 season

Case study farm	Prospect	Mangawaro	Turkey Creek
Stocking rate (cow hours/m^2)	503	439	248

From Figure 6, it is evident that each case study farm had its unique strategy encompassing shed design area, mootel use intent, the degree of feed supplementation inside the mootel, and the real-world implementation of these plans. Each of these strategies is discussed in more detail from an individual farm perspective in the sections that follow.

10.1.1.1 Prospect farm

At Prospect Farm, the cows were housed continuously in the mootel throughout the winter, post their drying off in June. They resumed outdoor grazing around calving. Post-calving mootel usage was influenced by both weather conditions and supplementary feeding necessities. The primary vision at Prospect Farm is to focus on pasture farming, utilizing the mootel chiefly to maximize pasture growth and efficient grazing. Being a high-input, system 5 farm that employs feed supplements all year round, cows often frequented the mootel daily, leveraging it for efficient supplementary feeding. The entire supplementary feeding was either conducted in the mootel or during milking via an in-shed feeding system.

Farm management observed that once the farm staff was well-acquainted with the decision-making parameters surrounding mootel utilization, they confidently decided on its usage without seeking higher approvals, staying true to the farm's policy of being cautious. Any potential risks of pasture damage from damp conditions or impending heat stress saw the cows being relocated to the mootel. Supplementary feeds would be administered if needed.

Heat stress was a primary determinant of barn usage during summer. Collars worn by the cows provided data to assess heat stress levels, guiding decisions about mootel usage. Especially during the drought of the 2023 summer season (spanning December to March), the cows sought the mootel's shelter almost daily, correlating mootel stays with milking schedules. An observation from the farmer underscored the cows' preference for the cool barn during hot spells: "On scorching days they'd dash to the shed, halting instantly once under its shade."

10.1.1.2 Mangawaro

In the 2022/23 season, Mangawaro Farm started using the mootel in June, accommodating the cows for half a day until they were dried off on 14th June 2022. Thereafter, the cows were in the mootel 24 hours/day during the winter. As cows began calving and joined the colostrum group, they were shifted to a 12-hour/day mootel regime. This duration tapered as calving proceeded, eventually reaching an average of 2 hours daily post-calving. This minimal mootel usage persisted through spring and early summer until a shift to a 16-hour milking cycle in mid-January, when cows averaged about 4 hours daily in the mootel, coordinated with milking times. This pattern remained until drying off on 12th June 2023, after which the cows were back to a 24/7 mootel stay.

For the forthcoming 2023 winter (23/24 season), the farm plans to graze 70 cows that will calve later outside the barn, to alleviate pressure on the compost pile. This segment of cows was chosen because they do not need to swiftly gain weight for calving.

10.1.1.3 Turkey Creek

Turkey Creek's wintering strategy mirrored the other two farms, with 24-hour mootel usage. However, this started later, on 24th June 2022. Like the other farms, the cows ventured outdoors more frequently as calving and spring ensued, dictated by the prevailing conditions. Unlike the others farms, Turkey Creek is not routinely dependent on supplementary feed. Hence, as the seasons transitioned, the cows spent extensive periods outdoors, only seeking the mootel's shelter when weather conditions demanded. During spring, the milking herd did not use the mootel at all. Meanwhile, the colostrum herd used it for a mere 5 days. Dry cows and those about to calve remained in the mootel until after calving. After a hiatus spanning October to December, the mootel was again used starting 10th January due to heat stress. However, by March, as the threat of heat stress diminished, mootel usage halted for a while before resuming sporadically in autumn to prevent pasture damage.

For the 2023 winter season (23/24), the plan is to graze between 35 to 40 cows outside, accommodating 350 in the mootel to avert overloading. The mootel is not expected to be used until 24th June 2023.

10.1.2 Temperature and Moisture in mootel bedding

Bedding samples from Prospect and Mangawaro farms were acquired from five unique points on each farm on a transect line between October 2022 and May 2023. For each sample, temperature was measured at three different depths: 200mm, 300mm, and 400mm. Turkey Creek, on the other hand, used one sample site with similar temperature measurement depths, but from November 2022 to May 2023. Please see appendices 2, 3, and 4 for further information.

Furthermore, six sampling points underwent rigorous laboratory testing to determine:

- Dry matter, or moisture content (see appendices 4 and 5)
- Carbon to Nitrogen ratio (see appendices 5 and 6)
- Nutrient content (see appendices 7 and 8)

Table 12 provides details for these sampling sites:

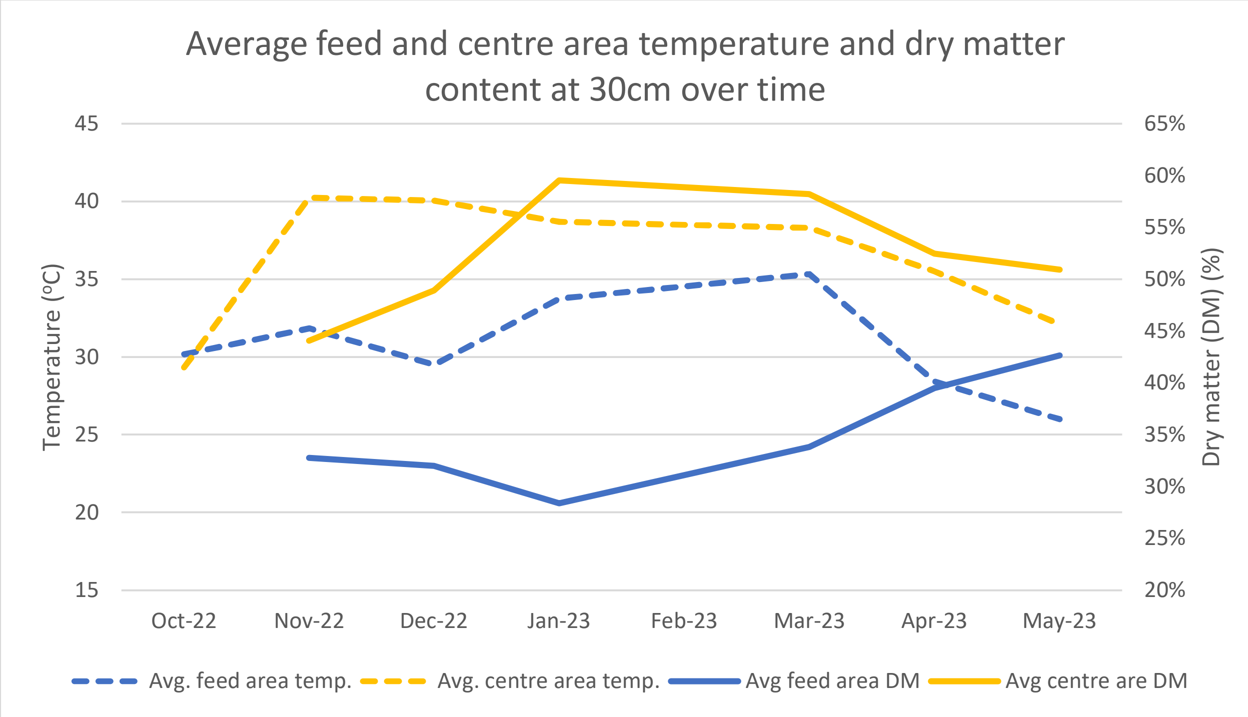
Table 12. Compost sampling site details

Sample point#	**1**	**2**	**3**	**4**	**5**	**6**
Farm	*Mangawaro*	*Mangawaro*	*Mangawaro*	*Prospect*	*Prospect*	*Turkey Creek*
Location	Feed Area	Centre	Centre	Feed area	Centre	Centre

Figure 7 delineates both the average compost temperatures and the dry matter content at 30cm. Notably, temperature data spans across feed areas (n=6) and centre areas (n=5), while the dry matter content is divided between feed areas (n=2) and centre areas (n=4).

An optimal compost temperature at 15-30 cm depth, as suggested by Woodford (2021), ranges between 50 and 60 degrees Celsius. Woodford, Roberts, and Manning (2018) posited that internal compost temperatures of approximately 55 degrees Celsius facilitate the natural evaporation of liquid, given a dry matter content of at least 50%.

Figure 7. Average compost temperatures and dry matter content at 30cm.



However, the data (illustrated in Figure 8) shows none of the sample sites consistently achieving or maintaining temperatures above 50 degrees Celsius. Areas near feed zones showcased noticeable differences: lowered temperatures, increased moisture, and signs of anaerobic composting. Interestingly, these differences were less pronounced at Turkey Creek.

The farmer at Turkey Creek reported occasional temperature spikes in their barn's feed lanes to the 55-60 degrees Celsius range, with visible steam during tilling. This observation contrasts starkly with other farms that saw limited steam instances.

Figure 8. Compost temperature at 30cm across 6 sampling sites

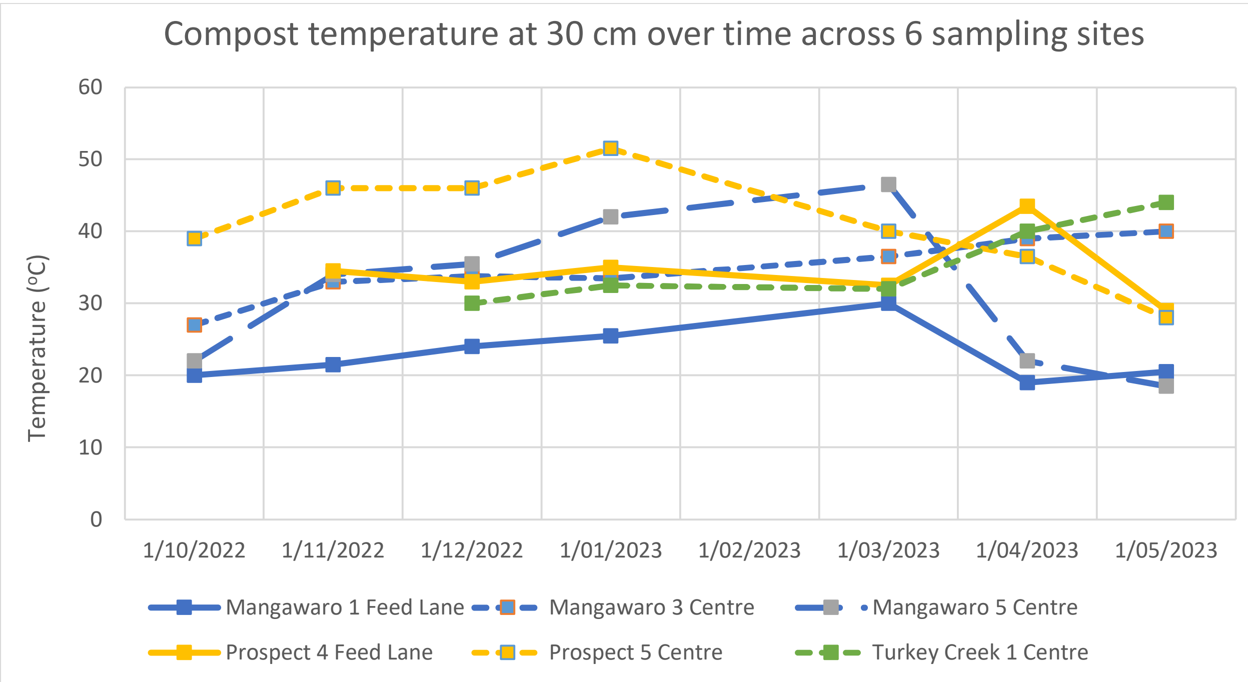


Figure 9 and Figure 10 visually contrast the bedding conditions at Turkey Creek and Mangawaro. While the former displayed consistency across its mootel, the latter exhibited a clear distinction between the feed lane area and the loafing or resting zone.

Figure 9. A photo of Turkey Creek bedding

Figure 10. A photo of Mangawaro farm bedding. Feed lane area clearly visible compared to loafing area.

10.1.2.1 Bedding temperature and moisture analysis

The data implies that composting near feed lanes is relatively inefficient due to the excessive amounts of urine and dung. This aligns with the recommendations of Woodford, Roberts, and Manning (2018) who advise using a concrete strip for feeding to prevent direct urination into the compost. A farmer even expressed an interest in incorporating such a concrete strip if given another opportunity. Nevertheless, this solution brings up other challenges like handling resultant effluent and increased labour or costs.

The difference in compost management at different farms is evident from Figure 11 and Figure 12. While Mangawaro's feed area struggles with excessive moisture and cooler temperatures due to urine and dung overload, the centre area, despite being sub-optimal, maintains conditions sufficient for aerobic composting. Added woodchips have been observed to increase both temperature and moisture content.

Figure 11. Mangawaro sample site 1 – Compost analysis over time

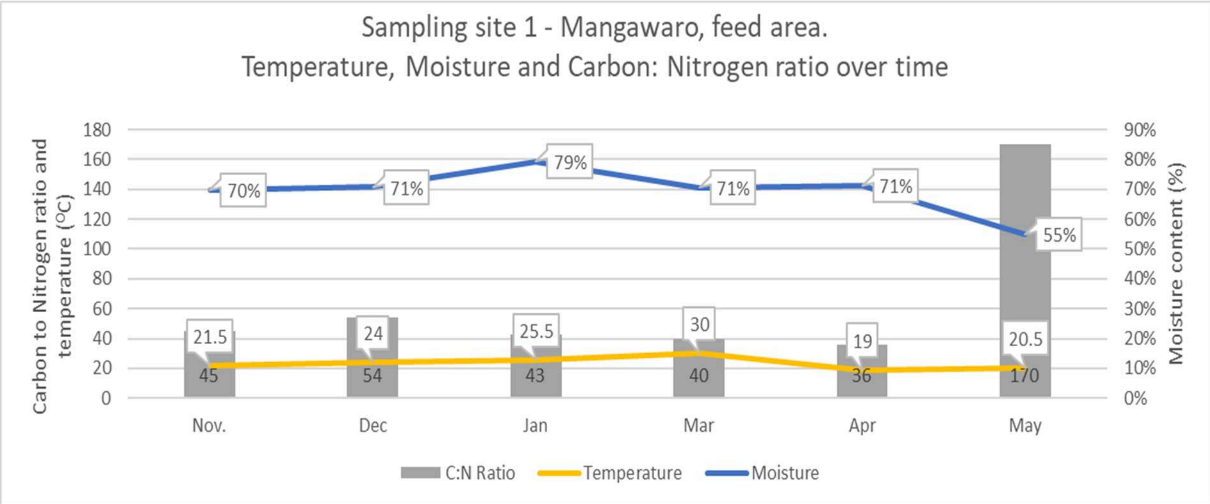
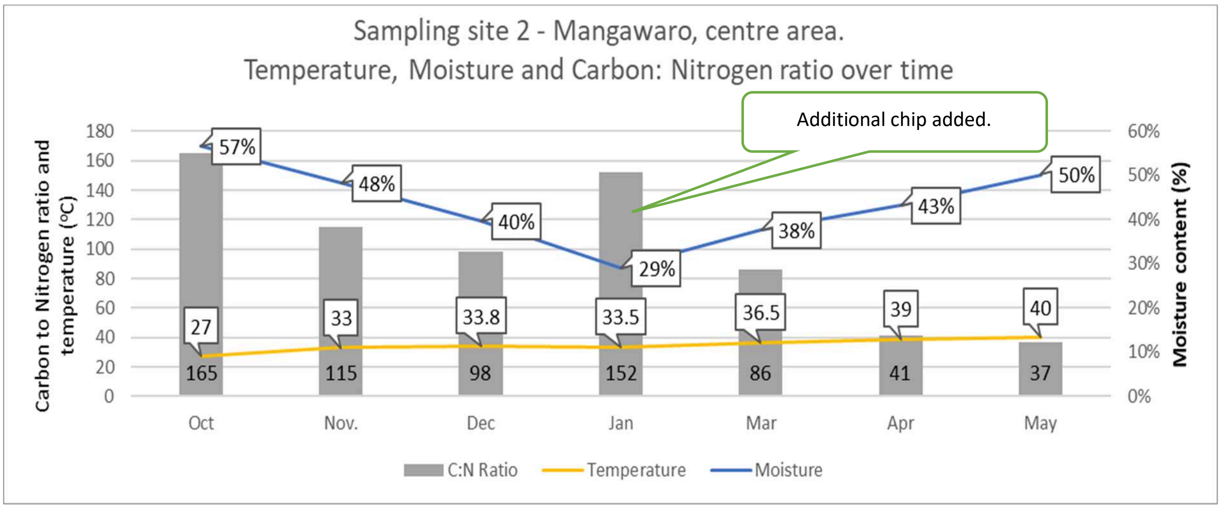


Figure 12. Mangawaro sample site 2 – Compost analysis over time



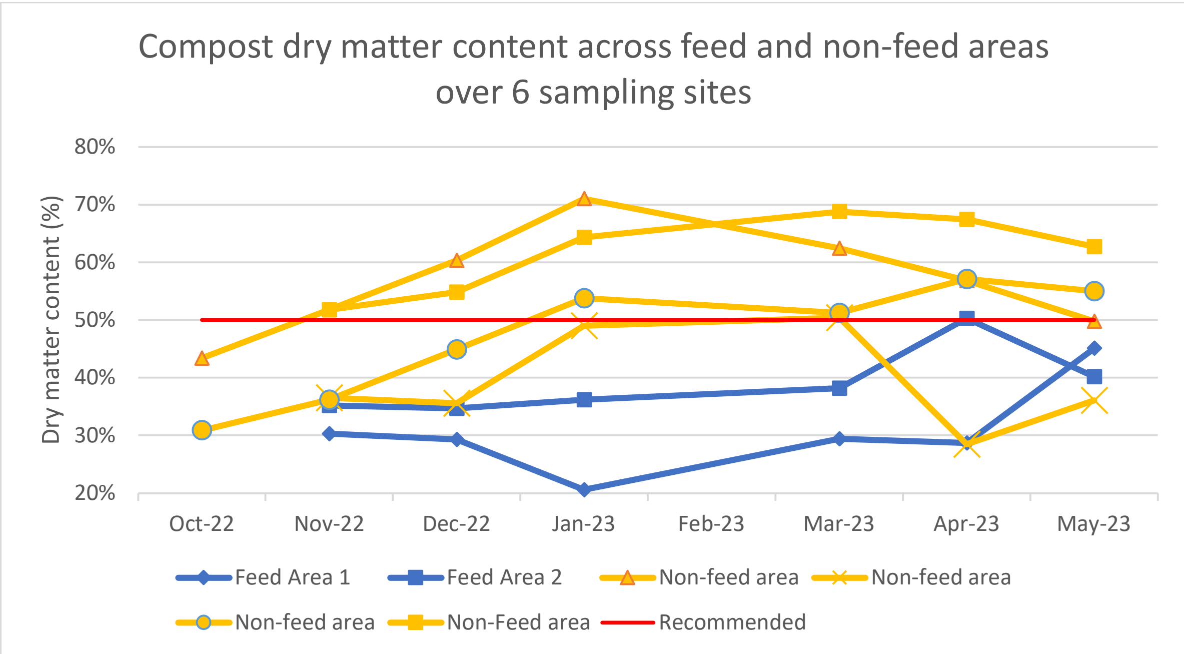
10.1.3 Dry matter content

The dry matter percentage of bedding samples, an inverse measure of moisture content, was recorded throughout the study period across the six sample points. These results are based on laboratory analysis of the submitted samples.

Figure 13, as mentioned in the temperature discussion, illuminates the difference in dry matter content between feed areas and central non-feed areas. The primary observation is that the feed areas, especially in the two relevant samples, generally exhibit lower dry matter content than the central non-feed zones of the barns. This means that these feed areas have higher moisture content, which can be attributed to frequent urination and defecation by the cows in these zones.

The temperature data from the feed areas provides additional insights. For instance, the Mangawaro feed area 1 consistently showcased lower temperatures than other samples. Such low temperatures in these moist zones can be indicative of inadequate composting conditions. Lower temperatures and higher moisture content can create an environment that discourages aerobic bacterial activity, leading to inefficient composting.

Figure 13. Compost dry matter context across 6 sampling sites



10.1.4 Compost stack behaviour

Compost longevity, Carbon to Nitrogen (C:N) ratio, and key nutrient levels were evaluated across six sampling sites. These measurements were essential for tracking composting progress and assessing its maturity, enabling the determination of its readiness as fertiliser in paddocks.

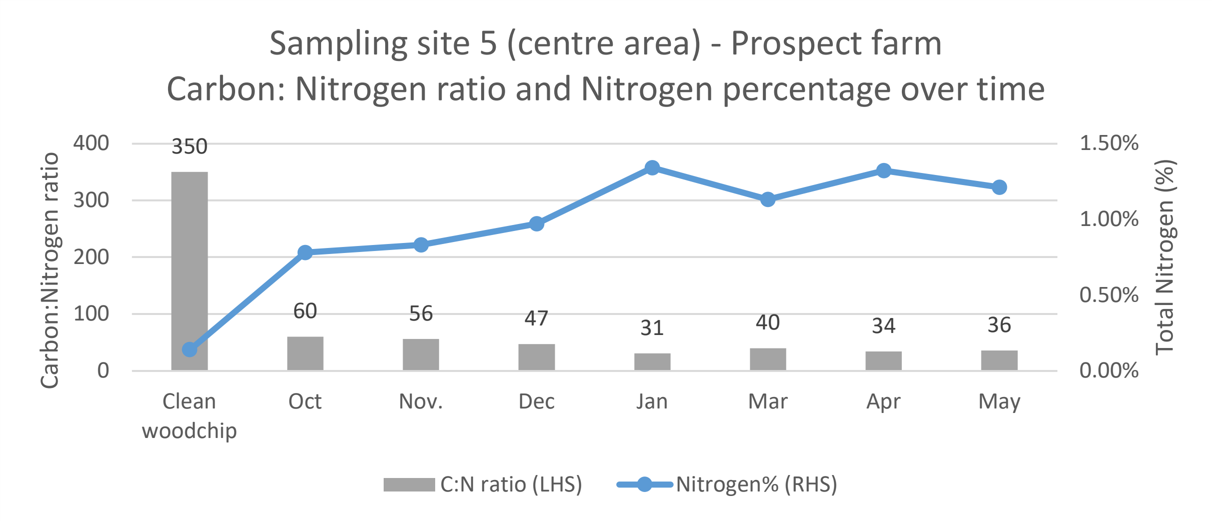
Though there is a rising number of composting barns in New Zealand, evidence about the optimal compost change interval remains scant. It is generally believed that compost needs yearly replacement. However, case study farmers had varied expectations. One farmer initially planned to annually add calf-pen woodchip and shavings, hoping this would maintain compost depth and possibly eliminate the need for full replacements.

In the 2022-23 season, all case study farms added more woodchip bedding to their barns to address moisture content (mainly in feed lanes) and to compensate for compost reduction during the season.

Chrystal et al. (2016) suggests the C:N ratio is a dependable indicator to decide when compost is ripe for replacement or top-up. In this regard, the C:N ratio and total Nitrogen content from each site were examined. For instance, Figure 14 presents data from Sample site 5 on Prospect farm.

Figure 14 illustrates the relationship of the C:N ratio over time, using Sample site 5 as a reference. Fresh woodchip typically has a high C:N ratio due to its low Nitrogen content. As cow urine introduces Nitrogen, the C:N ratio decreases quickly but stabilizes around a ratio of 60. The other five sampling sites confirmed this trend.

Figure 14. Example carbon ration and total carbon from Sample site 5 on Prospect farm



Variations in the C:N ratio and Nitrogen levels across samples can be attributed to tilling, compost stack variability, and management practices, such as adding fresh bedding.

Presently, New Zealand lacks definitive data on the ideal C:N ratio for compost changeover. Nonetheless, Chrystal et al. (2016) in their New Zealand study, discussed C:N ratios in the context of their efficiency as pasture fertilisers. Their findings indicated that manures with a higher C:N ratio (such as 26:1) initially immobilise Nitrogen. This effect diminishes as the C:N ratio decreases. Given this, a target C:N ratio of 12-15:1 is suggested as a benchmark for compost replacement or top-up.

The current study's data suggests compost stacks could last beyond one season, possibly extending to two or more with periodic top-ups. However, the performance during a second winter will be crucial to this assessment. A C:N ratio of 40:1 is equal to 2.5kg N per 100kg of Carbon, whereas at a 15:1 ratio, there is 6.6kg N per 100kg Carbon. This indicates that a ratio of 40 there is still a high N absorption capacity.

Knowing the compost's C:N ratio is beneficial for replacement decisions and its use as fertiliser. We recommend compost mootel farmers consider a basic compost test before making decisions on compost removal, comparable in cost to standard soil tests.

As for using the removed compost, the farmers from the case study aim to mix it into their paddocks. Directly spreading the compost onto pastures is also an option, given the C:N ratio is adequately low to prevent Nitrogen immobilisation. A detailed examination of compost's fertiliser value is in section 10.1.6.

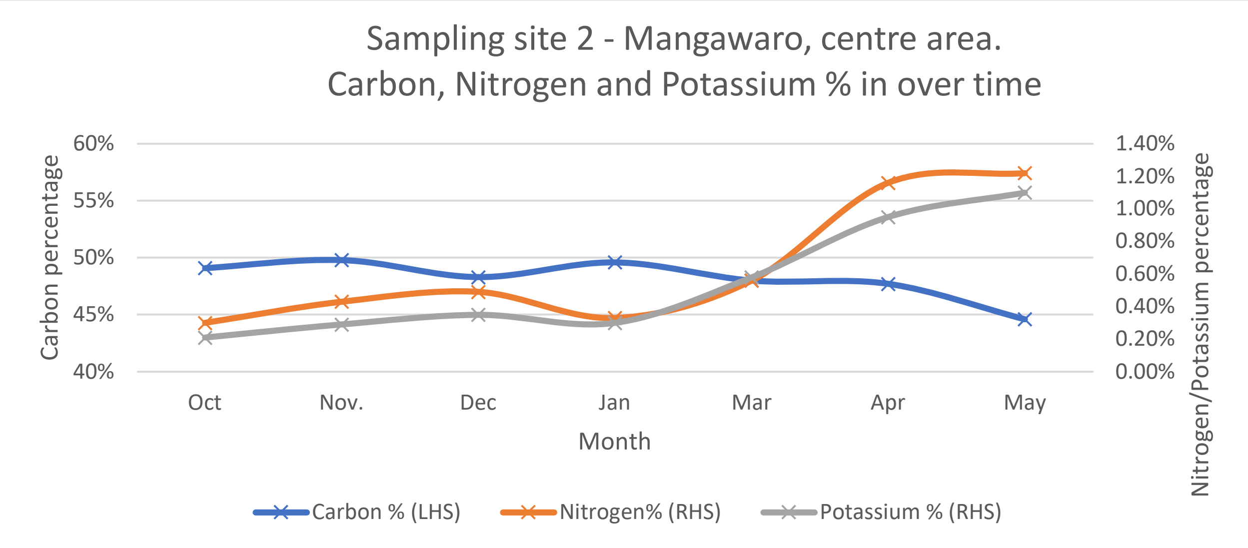
More research is needed, especially regarding the environmental impact of compost carbon and the carbon amount transforming into CO_2 during composting. Also, understanding the Nitrogen component in compost, especially related to Nitrous Oxide (N_2O) production—a potent greenhouse gas—is essential.

10.1.5 Compost nutrient content

The six detailed sample points underwent consistent analyses for eight macro-nutrients: Carbon, Nitrogen, Phosphorus, Potassium, Sulphur, Calcium, Magnesium, and Sodium. Charts for the C:N ratio and the four primary elements (N,P,K,S), were crafted for the six sampling site (appendices 6 and 7). Moisture and dry matter content data for these sampling sites are displayed in Appendices 4 and 5. Notably, the compost samples often presented higher concentrations of Nitrogen and Potassium, whereas Phosphorus and Sulphur appeared in lesser amounts.

Figure 15 illustrates data from the Mangawaro centre area sample site, highlighting Carbon, Nitrogen, and Potassium content. A clear relationship emerges between Nitrogen (and Potassium) concentrations, Carbon levels, and the C:N ratio. As evidenced in Figure 13, the C:N ratio descends in tandem with the rise in N and K percentages, especially during the autumn months. While trace elements like Iron, Manganese, Zinc, Copper, and Boron were also examined during sampling, they are not elaborated upon within the scope of this project.

Figure 15. Mangawaro sample site 2 – Compost carbon, nitrogen, and potassium % over time



For carbon, nitrogen and potassium percentages over time across the six sampling sites, please see appendix 8.

10.1.6 Compost as a fertiliser

From the compost samples taken in May 2023, following about a 12-month usage period, the concentration of the four primary macronutrients in the compost stack was assessed to ascertain the potential value of the compost bedding when utilized as a fertiliser. For every case study farm and each nutrient, these estimates are presented in Table 13.

Table 13. Estimated quantities of key nutrients and value as fertiliser in compost by case study farm

Farm	Total	Nitrogen	Phosphorus	Potassium	Sulphur
Prospect	*Tonnes:*	10.9	3.0	15.5	2.2
	$82,706	$21,954	$16,420	$41,764	$2,568
Mangawaro	*Tonnes:*	7.6	1.4	6.9	1.1
	$42,883	$15,438	$7,635	$18,521	$1,289
Turkey Creek	*Tonnes:*	4.9	1.2	5.5	0.9
	$32,403	$9,832	$6,741	$14,804	$1,025

Table 14. Comparative estimated value of compost nutrients

	Prospect	Mangawaro	Turkey Creek
Total nutrient value ($):	$82,706	$42,883	$32,403
$/cow:	$239.73	$231.80	$191.73
$/ha:	$103.38	$79.41	$92.58
$/kgMS:	$0.23	$0.23	$0.21

The figures in Table 13 originate from fertiliser prices as of late June 2023. These prices incorporate cartage allowances for each property but exclude spreading costs which would differ per farm. It is pertinent to mention that conventional fertiliser spreaders could not be used by the case study farmers for the compost, necessitating a muck or effluent spreader. Due to the substantial material amounts, the spreading costs for extracted compost are expected to considerably surpass those of standard fertilisers. Given the relatively elevated C:N ratio at the sampling time in late May 2023, the compost stack's removal at this juncture seems improbable. However, Table 14 provides an approximate value of a year's worth of nutrient accumulation in the compost stack.

For comparative purposes, Table 15 displays the projected application rates of compost, if employed as a fertiliser, that would be necessary to parallel the rates of typically used chemical fertilisers.

Table 15. Estimate of equivalent amount of compost required to match commonly used rates of conventional fertiliser. (Using Prospect farm as an example)

	Nitrogen	Phosphorus	Potassium	Sulphur
Standard equivalent product	Urea	Superphosphate	Potassium Chloride	Elemental Sulphur
Standard application rate (kg/ha)	65	375	80	33
Rate of nutrient applied	30	34	40	30
Equiv. weight compost (t/ha)	4.5	18.7	4.2	21.8
Equiv. volume compost (m^3/ha)	10	42	9	48
% eff. Area covered by entire stack	105%	25%	113%	22%

From Table 15, it can be inferred that the nutrients accumulated in the compost stack over 12 months could adequately replace a single Nitrogen or Potassium application across the milking platform. Alternatively, it could fulfil around 25% of the yearly Phosphorus or Sulphur maintenance fertiliser needs for the milking platform. A farmer also observed that the composting mootel offered an added round of organic Nitrogen in the Autumn without surpassing the 190 kgN/ha synthetic Nitrogen threshold.

10.1.7 Tilling

Figure 16. Photo of one of the cultivators used for tilling the compost bedding.

Tilling's primary aim is to aerate the compost pack, promoting both aerobic composting and facilitating moisture evaporation. Woodford (2021) advocates for tilling twice daily. However, most farmers currently till once a day, which seems sufficient for many. A successful tilling programme is gauged by the temperature of the compost at 15-30 cm deep. This temperature should be between 50-60 degrees Celsius, indicating effective aerobic composting.

Current science is somewhat lacking in understanding the implications of compost temperatures that fall below this optimal range, necessitating further research. Despite this, the case study farmers were content with the performance of their composting process at these lower temperatures. For them, cow comfort was of higher priority than optimizing the compost by-product. Additionally, the perceived benefits of elevating the compost temperature against the potential costs were seen as minimal. Increasing the temperature might require:

- Regular mechanical shifting of compost between feed lanes and central areas of the mootel,
- Regular and significant additional woodchip applications,
- Reducing the stocking rate by either permanently or semi-permanently removing part of the cow herd, or
- Constructing additional mootel space.

Tilling frequency varied considerably across the case study farms and was closely associated with barn usage. Tilling could be as infrequent as every ten days when mootels were not in use, increasing to daily tilling in winter when the barn was occupied 24/7. Interestingly, none of the farms practiced twice-daily tilling for extended periods. One farmer did attempt twice-daily tilling but soon abandoned it due to the compost becoming “lumpy,” feeling that they were “just moving it around.”

Figure 17. Mootel use and tilling frequency use over 2022-23 season by case-study farm.

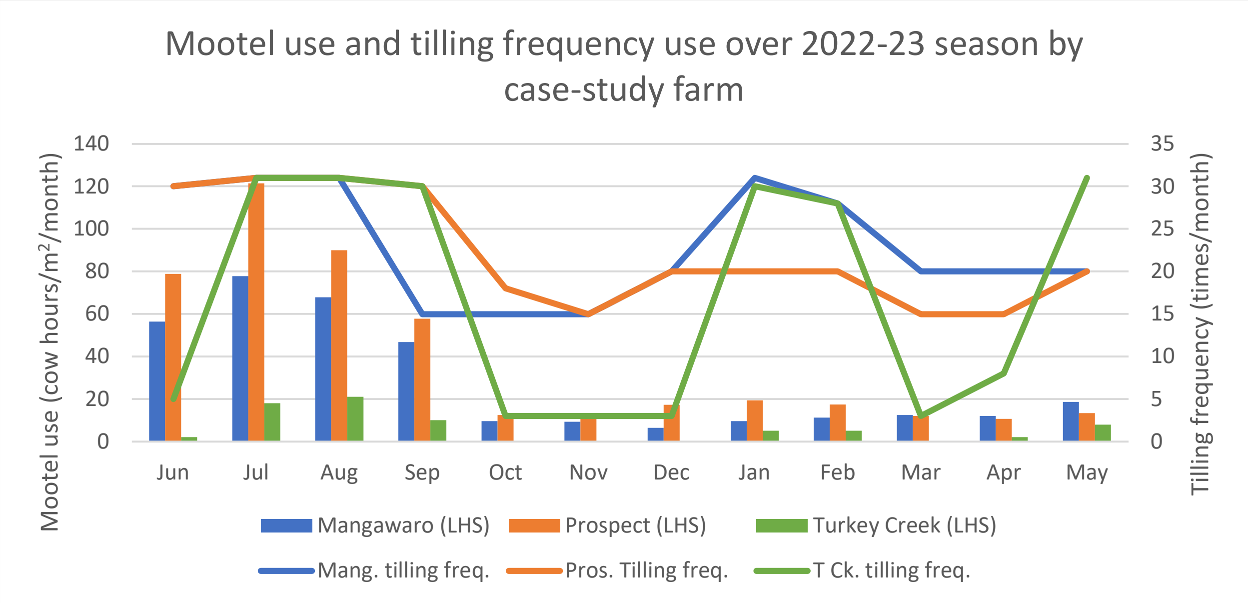


Table 16. Seasonal tilling frequency in relation to mootel stocking rate

Case study farm	Prospect	Mangawaro	Turkey Creek
Annual mootel use (total cow hours/m^2)	462	439	248
Annual tilling events (total tillings/annum)	265	276	206
Tilling ratio (Tillings/cow hour/m^2)	0.57	0.63	0.83

Feed areas consistently posed challenges for the farmers. On all case study farms, these areas, measuring 2.5-3.0 metres from the feed face, were observed to become wetter, colder, and less friable than the mootel’s central parts. Consequently, compost in these areas often formed large wet clods that resisted tilling efforts. Among the strategies employed to mitigate this were:

- Increasing tilling frequency,
- Adding more woodchip or bedding to the feed areas,
- Tilling more deeply,
- Swapping the feed area compost with compost from the centre,
- Spreading compost from the central areas over the feed areas.

One notable strategy was treating the feed area as a pad without tilling. The farmer using this method scraped off the top 100-200mm layers of the lane areas for later use or spreading on the farm. This approach allowed tilling to occur even with cows inside if done during feeding. However, this needed a skilled machine operator to avoid cow injuries.

Some farmers contemplated the idea of replacing feed areas with concrete but were concerned about the slipping risk for cows. Additionally, maintaining such a concrete strip could increase workload due to the need for cleaning and managing the extracted effluent.

As of the winter of 2023, feedback from the farmers incorporated learnings from both the autumn and winter periods. One farmer expressed their unpreparedness for dry conditions in the mootel during Autumn and how subsequent wet conditions proved challenging. This led to them considering adjustments to the feed types used in the mootels. The underlying idea was to manage moisture levels and prevent high moisture content from entering the mootel, especially from pasture-based diets. Such decisions could influence mootel operating costs. Thus, farmers contemplating integrating composting mootels into their systems should remain vigilant to potential "system creep" where unforeseen challenges necessitate unplanned management adaptations.

Figure 18. Turkey Creek tiller

10.1.8 Bedding material/ Woodchip

All participating case study farmers voiced concerns about the future availability and sustained supply of high-quality woodchip or bedding materials. With the potential rise in demand due to increased popularity of composting mootels, there was added anxiety. Compounding this, competition from other woodchip consumers, like those in fibreboard production or biomass boilers, might stress an already limited supply. Nonetheless, the bedding material supply is not currently viewed as an immediate problem by the farmers involved.

The research's data collection period Is somewhat restricted, covering less than a year (9 months). Thus, pinpointing an accurate annual demand for bedding materials is challenging. There is hope that this research will expand in future years for more detailed insights. Initially, mootels required 5.2 to 7 cubic metres of woodchip per cow. However, by the season's end in June, this quantity fluctuated between 1.2 to 4.0 cubic metres per cow, considering the essential pre-winter replenishment. Prospect farm anticipates a steady yearly demand of 3-4 cubic meters per cow.

Corroborating our initial findings, Woodford, Roberts, and Manning (2018) also project an annual bedding material requirement of 3 cubic meters per cow. Based on this, Table 17 lays out the estimated annual needs and associated costs for each farm.

Table 17. Annual estimated volume and cost of bedding material

Farm	Cow no.	Volume @ 3 m^3/cow	Cost @ \$25/m^3	Cost -\$/kgMS
Prospect	800	2,400	60,000	$0.17
Mangawaro	540	1,620	40,500	$0.18
Turkey Creek	350	1,050	26,250	$0.17

Table 17 indicates that, for a composting mootel development, there's an estimated additional operating cost of 17 to 18 cents per kilogramme of milk solids. This should be incorporated into the budget. However, since the inception of this report, the range has increased slightly. As of now, farmers are advised to budget between 17 to 20 cents per kilogramme of milk solids, allowing for bedding material to reach \$28/m^3. The sources and costs of bedding materials utilized during the case study are detailed in Table 18.

In the 2022-23 season, a local contractor introduced a tractor-powered log chipper, expanding the bedding material supply options. This innovation allowed farmers to utilize their own wood resources for mootel bedding. Additionally, this contractor offers chipping in various sizes tailored to the farmers' needs and can deliver the woodchip directly to the barn using a silage loader wagon.

Table 18. Bedding material costs

Farm	Date	Source	Cost/M^3
Prospect	Mar. 2022	Forestry waste ex sawmill	$22.50-$25.00[2]
	Mar 2023	Forestry waste ex sawmill	$25
	Jun 2023	Forestry waste chipped by local contractor	$30
	Spring 2023	Forestry waste ex sawmill	-
Mangawaro	Jan 2023	Sawmill waste	$30
	May 2023	Forestry waste chipped by local contractor	$28
Turkey Creek	Feb. 2023	Forestry waste chipped by local contractor	$28

Farmers from the case study observed that storing logs for a minimum of 12 months permitted some drying of the wood. This resulted in drier woodchips when added to the compost stack, consequently reducing the necessary evaporation. One farmer highlighted an immediate rise in compost temperature when introducing woodchips from seasoned, stored logs in contrast to those from freshly cut woodchip. This underscores the relationship between moisture management and effective composting.

The conversion rate of logs or forestry waste (commonly referred to as 'slash') to woodchip is gauged at 2.2-3.0m^3 per tonne of wood (personal communication, J. Dronfield, F. Croft). Based on this rate, the estimated annual bedding requirement would amount to one tonne of wood for each

[2] the cost includes freight, hence the range.

cow. Assuming a yield of 550 tonnes per hectare for Pinus radiata at harvest (or 480 tonnes for Beech Forest, contingent upon local consenting provisions), a single hectare of forest could adequately supply bedding for approximately 400-550 cows each year. An extended table presenting projected annual bedding expenses for every case study farm, considering various prices and compost durations, can be found in Appendix 9.

The prospect of using Miscanthus (Miscanthus sinensis) for bedding has been suggested by Woodford (2021) among others. Interestingly, one of the case study farmers has a small stand of this plant on their land. Nonetheless, the purview of this research does not encompass an in-depth analysis of Miscanthus as a bedding substrate. It is understood that procuring rhizomes or plantlets on a vast scale poses challenges (personal communication, A. Yeoman, 2022). The farmer with the Miscanthus stand indicated his reluctance to employ it for future use, primarily because it would necessitate allocating a paddock away from milk production. A more comprehensive exploration into Miscanthus utilization, along with other potential bedding crops, is recommended.

10.1.9 Ventilation

Effective ventilation is paramount for successful composting and composting mootel operations, ensuring that moisture from the composting process can dissipate properly. All the farmers involved in the case studies gave due attention to ventilation during the mootel design phase. The mootels with solid roofs (as depicted in Figure 19) incorporated ridge venting and a roof pitch optimized for ventilation. The tunnel roof construction of the mootel at Turkey Creek was designed with open ends to facilitate maximum ventilation.

Figure 19. Photo of Mangawaro mootel

Figure 20. Photo of the Mootel roof at Turkey Creek farm

The positioning and orientation of the mootels at Prospect farm, being on a typically windier site compared to the other case study locations, further enhances ventilation. The farmer observed that both summer and most autumn days were windy. The prevalent easterly wind aligns with the mootel orientation, boosting ventilation. Notably, the eastern ends of the mootels were drier than their western counterparts. While this disparity is anticipated to favour the composting process, current data is insufficient to precisely measure the effect. Wind was a noticeable factor during over half of the sampling visits to Prospect farm.

In contrast, Mangawaro farm is nestled in a relatively tranquil North-South running valley with minimal wind. Fog is a common occurrence in the Inangahua Valley, with the Mangawaro site often enveloped from April through September. The farmer observed that on particular days, fog could be seen extending the length of the mootel, potentially due to elevated moisture levels. All sampling visits to Mangawaro farm occurred on calm days.

Turkey Creek farm's mootels are positioned on a raised site in an expansive valley. The farmer remarked that the location is relatively windy, ensuring good ventilation – an observation corroborated by sampling visits.

Farmers contemplating a composting mootel are advised to conduct thorough research into the local micro-climate. Understanding its impact on ventilation, in tandem with the intrinsic ventilation properties of the mootel structure, is crucial.

10.1.10 Mootel Sizing

The ideal size for a compost mootel, or the best area per cow, lacks a standard specification, with opinions on minimum and optimum sizes varying. Optimal mootel size, or composting area, is influenced by factors such as mootel design, overall stocking rate, seasonal usage, bedding type and depth, frequency of bedding refreshes or additions, compost temperature, tilling practices, ventilation, local climate, feed moisture content, and other management practices. Considering the substantial construction expenses, the perfect mootel area will likely be a compromise between cost and availability of capital.

The sizes referenced in this study range from 5.5 m^2 to 11 m^2 per cow. Within a New Zealand context, there is still not enough data to recommend a specific mootel size, especially with respect to specific regions. The areas of the case study farms range between 6.5 to 9.3 m^2 per cow, and 250-500 cow hours/ m^2, as illustrated in Table 19.

Table 19 Mootel areas, stocking rates and construction costs.

	Prospect	Mangawaro	Turkey Creek
Compost area (m^2/cow)	6.5	7.4	9.3
Stocking rate (cow hours/m^2/p.a.)	503	439	248
Construction costs of mootel (\$/m^2)	471	434	347

DairyNZ's "Dairy cow housing" (2015) suggests 9-11 m^2 per cow for wintering or long-term use systems. There are discussions implying that this recommended area should exclude feed lane spaces, which would significantly increase the total composting (or loafing) area. Woodford (2021) highlights that a Waikato farmer successfully composts with 5.5 m^2 per cow and 600 cow/hours/ m^2/p.a. He also mentions that other mootels typically operate around 7 m^2 per cow. Feedback from several South Island farmers and consultants indicates that an area closer to 10-11 m^2 per cow is more conducive for efficient composting, especially in colder and damper regions. Initial insights from this study suggest that composting in highly stocked mootels can occasionally be subpar during the season, particularly in feeding areas. Therefore, a minimum composting mootel size might hover between 7.5-8.0 m^2 per cow. In conclusion, it is advised that prospective composting mootel farmers build as large a mootel as their budget allows, and to also consider omitting feed lanes from loafing area computations.

Further supporting decision-making, Table 20 provides cost per square meter of mootel space across varied cow areas and construction costs per square meter. Additionally, to convey the full cost, Table 21 depicts the total amount for a hypothetical 500-cow farm. Note: a spectrum of costs per square meter are included to account for probable construction cost hikes since the case study mootels' completion.

Table 20 Cost per cow across a range of construction costs and area per cow

	Mootel size (m^2/cow)				
Cost \$/ m^2	6.5	7.5	8.5	9.5	10.5
350	2275	2625	2975	3325	3675
400	2600	3000	3400	3800	4200
450	2925	3375	3825	4275	4725
500	3250	3750	4250	4750	5250
550	3575	4125	4675	5225	5775
600	3900	4500	5100	5700	6300

Table 21 Total cost for a sample 500 cow farm across a range of construction costs and areas/cow

	Mootel size (m²/cow)				
Cost $/m²	6.5	7.5	8.5	9.5	10.5
350	1,137,500	1,312,500	1,487,500	1,662,500	1,837,500
400	1,300,000	1,500,000	1,700,000	1,900,000	2,100,000
450	1,462,500	1,687,500	1,912,500	2,137,500	2,362,500
500	1,625,000	1,875,000	2,125,000	2,375,000	2,625,000
550	1,787,500	2,062,500	2,337,500	2,612,500	2,887,500
600	1,950,000	2,250,000	2,550,000	2,850,000	3,150,000

It is paramount for prospective mootel farmers to thoroughly vet and analyse the proposed size of any composting mootel, discussing it extensively with their financial backers. For herds surpassing 300 cows, two smaller mootels might be more suitable. This could allow the second mootel to be designed based on insights from the first, spreading out the capital expenditure over an extended period. Woodford (2021) supports this approach, recommending units of about 300 cows and expressing a preference against elongated, slim sheds.

10.1.11 Odour

Odour from dairy farm housing and effluent disposal facilities can be a concern. If this odour is prominent enough to be detected beyond property boundaries it can lead to compliance issues and negatively affect public perception. Throughout the season, no odour was discernible from the mootels during sampling. Similarly, farmers did not observe any malodours, except for a brief period when a section of a mootel became overly wet due to a water trough leak. One farmer did remark on a compost-like smell (which was not unpleasant) when tilling the feed lanes inside the mootel, signifying effective aerobic composting. Minor odours suggesting anaerobic decomposition were occasionally noticed when collecting compost samples from the damper feed lane areas, which were at ambient temperatures. However, these odours were not discernible when merely walking around or standing in the sheds. Occasionally, a damp pine woodchip smell was evident after the introduction of fresh wood chips. It is reasonable to assume that, barring any severe defects in the composting system, odour will not be a concern outside a composting mootel.

10.1.12 Drainage

Drainage and disposal of effluent from cow dung and urine are significant factors in traditional dairy farm housing and infrastructure. In theory, composting mootels eliminate the need for effluent drainage by absorbing liquids into the compost. This absorption is followed by evaporation facilitated by regular tilling and the elevated temperatures within the compost.

Given that mootels are relatively novel in New Zealand, the case study farmers and their advisors knew during the planning phase that they would need to address potential drainage issues, to ease concerns of the Regional Council (which gives consent) and the public. Consequently, all farmers opted for a cautious (and pricier) approach, implementing drainage systems to capture any effluent from the base of the compost stacks. Both Prospect and Mangawaro farms installed closed sumps, anticipating the potential need to pump away drainage. Meanwhile, Turkey Creek set up a piped system leading to plantings near the mootel, allowing for observation and, if necessary, future sump installation.

Throughout the season, Mangawaro did not exhibit any drainage, and its sump remained vacant. Similarly, no drainage flowed into Prospect's sump, though this sump was accidentally damaged during the season and did collect rainwater from the surrounding area. At Turkey Creek, a negligible flow was observed in their drainage pipe, but this was attributed to groundwater seeping into the novaflow pipe shortly after leaving the mootel, before reaching the planted zone. Drawing from these observations, it is concluded that the case study mootels produce negligible to zero drainage from their base.

10.1.13 Plant and Machinery

Figure 21. Photo of Mangawaro mootel machinery.

Dairy farm housing developments typically necessitate significant investment in associated plant and machinery. For composting mootels, this might include feed mixing wagons, a tractor for the mixer wagon, additional tractors or telehandlers for managing supplementary feeding systems, tilling equipment, equipment for pushing up feed in the lanes, muck spreaders, and other supplementary gear. The case study farms varied in their machinery strategies: Prospect and Mangawaro leaned towards a higher input strategy with more supplementary feeding and corresponding higher capital cost, while Turkey Creek opted for a lower capital cost approach, limiting extra machinery. Table 22 showcases the additional machinery each farm utilized. Capital costs related to these are discussed in section 11.2.

Table 22. Additional Plant and equipment requirements for each case study farm

Prospect	Mangawaro	Turkey Creek
- Mixer wagon - Telehandler - Mixer wagon tractor - Subsoiler for tilling - Tyre pusher - Silage grab	- Mixer wagon - Loader/ripper tractor - Mixer wagon tractor - Compost deep ripper - Scraper for front-end loader - Muck spreader	- Nil - (used existing tractor, ripper and side-feed silage wagon)

Farmers eyeing an investment in composting mootels should clarify their strategy up front and conduct comprehensive due diligence regarding machinery requirements. Machinery can account for 12-15% of the total capital cost, and full machinery needs might not be clear until the facility is operational. Due diligence should encompass conversations with current composting mootel farmers.

Figure 22. A muck spreader

After initial development, one farmer procured a muck spreader for compost dispersal as the pre-existing fertiliser spreader was inadequate. Both Prospect and Mangawaro farms acquired feed mixing wagons, deeming them vital to mootel operations, especially for consistently delivering targeted additives like minerals, or in future daily feeding of methane inhibitors such as 3-NOP. In contrast, Turkey Creek used an already-owned side-feed silage wagon for feeding, finding it adequate.

Figure 23. Mixer Wagon

10.2 Animal Health and Welfare

All farmers and their staff unanimously reported that after mootel installation, their cows appeared calmer, healthier, and less stressed. Observations made during data collection and body condition scoring visits support these claims. It is believed that the enhanced feeding accuracy during crucial periods like winter, calving transitions in spring, and dry summer spells, significantly contributes to improved general health. Additionally, cows were observed to be more content in the mootel during heat stress and heavy rainfall. Interestingly, there was an indication that contented cows led to happier staff. However, there are potential concerns about the mootel's impact on lameness and *E.coli* mastitis incidence, but conclusive data is lacking.

Figure 24. Happy cows

10.2.1 Cow Body Condition Score

Cow body condition scores were tracked monthly from the start of the project in October 2022 until May 2023 by scoring a representative sample of cows. Average scores for each herd are depicted in Figure 25, and the range of scores on 20th May 2023 is presented in Figure 26. The range of average body condition score on 20th May 2023 across the case study farms was from 4.63 to 4.81.

Figure 25. Average cow body condition score over time by case-study farm

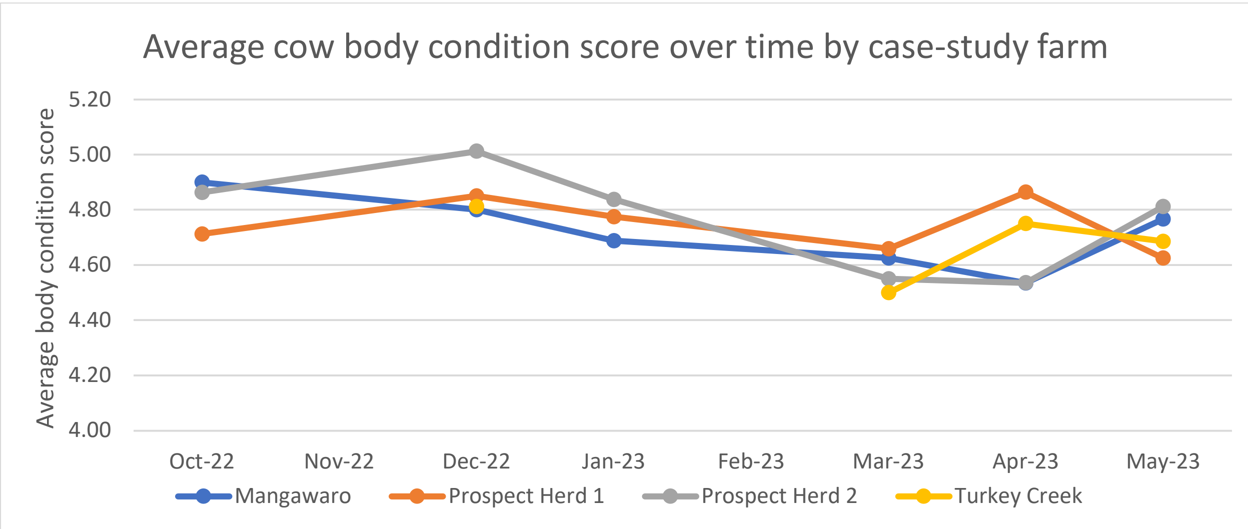
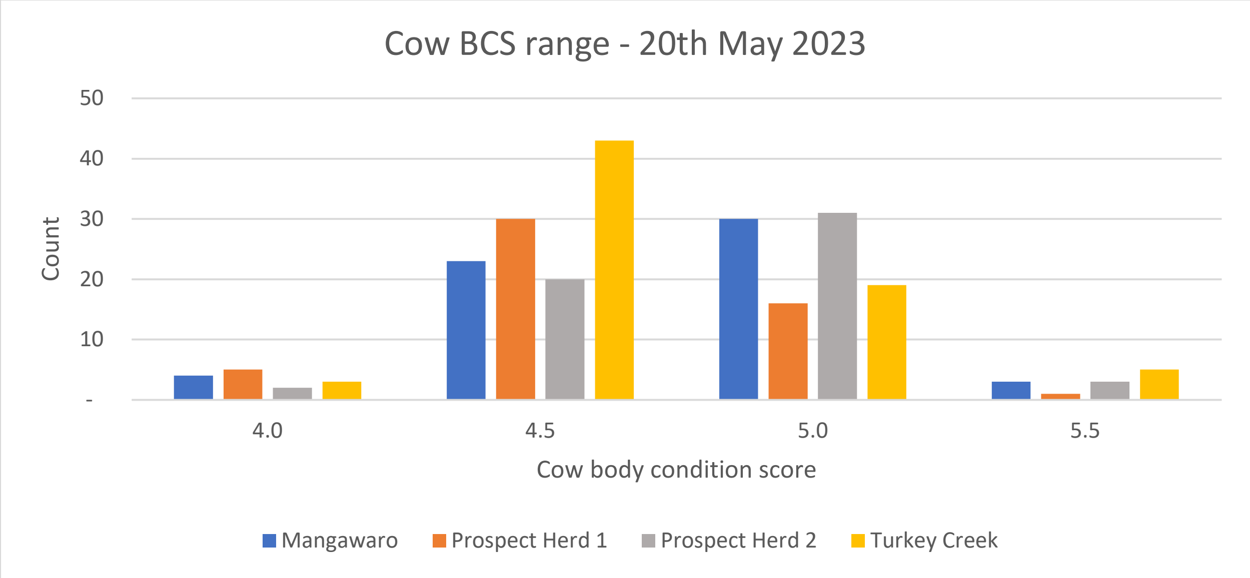


Figure 26. Cow BCS range – 20th May 2023



There is insufficient data to draw any firm conclusions from the condition scoring throughout the season. Additionally, there is no data available from previous seasons for comparison. There is no hard evidence to date suggesting that the introduction of a composting mootel has led to an increase in average BCS on any of the case study farms. However, the case study farmers have all indicated that their cows are in better condition on average than in pre-mootel seasons. Observations of cows during body condition scoring over the season, coupled with the results of this scoring, display a gradual tightening of the range of scores over the season, with fewer light and very fat cows (as seen in Figure 26). By the end of the season, average scores were all above 4.6. This indicates that there are only 0.4-0.9 BCS units to be added to cows over the winter dry period, based on a target score of 5.0 for mixed-age cows and 5.5 for 2nd-calving cows. Anecdotally, the 4 herds scored as part of the case study are between 0.25-0.5 scores above other West Coast herds. However, the region has experienced an exceptionally good autumn, which might have contributed to higher-than-usual average scores regionally. The most significant impact of introducing a composting mootel, in relation to cow body condition score, is likely the ability to control and maximize cow intakes. This results in BCS gain over winter due to a consistent feed supply and very high feed utilization in the mootel. All the case study farmers have indicated that this was a primary reason behind their decision to install a composting mootel.

10.2.2 Mastitis

Table 23 displays the mastitis incidence for each of the case study farms over the last 2-3 seasons, as illustrated by the average seasonal somatic cell count. Although there is insufficient evidence from just one season's data to determine any link between the use of a composting mootel and somatic cell count, introducing a composting mootel into the dairy system appears to have had no discernible positive or negative impact on the somatic cell count.

Table 23. Average seasonal somatic cell count by case study farm.

Farm	2022-23	2021-21	2020-21
Prospect	123,738	125,671	103,159
Mangawaro	215,672	219,466	207,433
Turkey Creek	134,000	138,000	-

None of the case study farms reported an increase in somatic cell count, mastitis incidence, or treatments throughout the season that could be attributed to the composting mootel. The exception is *Escherichia coli (E. coli)*, which will be discussed next.

10.2.3 E. coli

E. coli mastitis is a form of mastitis that can result in severe infections or even death. There is an associated risk with composting mootels since cows may be exposed to it by resting in compost, especially poorly performing or decomposing compost (Woodford, 2021). During the 9-month case study, *E. coli* mastitis incidence was closely monitored by the farmers. Turkey Creek reported 12 instances of *E. coli* mastitis, and the farmer believes these may be linked to the mootel, given that no such incidents had been previously encountered on the farm. Tragically, one of these cases led to the death of a cow despite undergoing treatment – it is worth noting that this was the sole cow death on the farm that spring. The other eleven cows did not receive antibiotic treatments but still recovered. This outcome is unexpected, especially considering that the Turkey Creek mootel had a lower stocking rate and was typically drier and less laden with dung and urine. Meanwhile, Prospect farm, equipped with a mas-detect device to pinpoint the causative mastitis pathogen, had three instances of *E. coli* mastitis, but all treated cows recovered. Mangawaro did not report any cases of *E. coli* mastitis. Given this information, it is inferred that integrating a composting mootel system could potentially elevate the occurrence of *E. coli* mastitis. Hence, this should be contemplated seriously by any farmer pondering an investment in such a system.

Throughout the case study, a handful of *E. coli* tests were conducted as a component of the sampling procedure, but the findings remained inconclusive. While a microbiological test can furnish a basic indication of *E. coli* prevalence, there is no available guidance regarding a risk threshold or ideal level. This ambiguity complicates the process of determining the exact risk of *E. coli* mastitis exposure cows faced in the composting mootels over the course of the season. Comprehensive research, tailored to the New Zealand context, is imperative to elucidate whether composting mootels correlate with a spike in *E. coli* mastitis incidents and to better understand the connected risk factors and thresholds.

10.2.4 Lameness

The impact of composting mootels on lameness has not been conclusively determined within the New Zealand context. Durie (2022) alluded to potential benefits of mootels on lameness due to their soft and comfortable bedding surfaces, especially if these mootels replace concrete feed-pads or similar hard surfaces. This case study could not conclusively establish a connection between lameness and mootel usage; however, several observations were provided by the participating farmers.

The Turkey Creek farm reported 15-20 instances where woodchips became wedged between the cow’s hoof claws. While this did not result in immediate problems due to prompt detection, it would likely have developed into an issue if left unattended. Prospect farm observed a decline in lameness incidence, attributing this improvement to transitioning from their older, gravel-surfaced feed-pad, described as “a bit nasty”, to the composting mootel. The daily walking distance for cows at Prospect remained comparable to the pre-mootel routine. On the other hand, Mangawaro observed a relatively high incidence of lameness, including an uptick in both general lameness and foot-rot. The farmer suspects this increase is linked to the mootel use, especially given potential pathogens in the compost, as walking distances had not significantly changed since the mootel was introduced. In this context, the farmer pointed out instances of having to trim or treat an average of 2 cows daily for certain periods.

Although the available data is limited, introducing a composting mootel into a farming system could possibly elevate the incidence of lameness. This observation underscores the need for more extensive research on the subject.

10.2.5 Heat Stress

The optimal ambient temperature range for cows is between 4-20 degrees Celsius. On all the case study farms, summer temperatures frequently surpassed 25 degrees Celsius and often reached above 30 degrees Celsius. Notably, none of these farms had significant shade trees or areas available for their cows.

Each of the case study farms utilized their composting mootels as a means of providing shade during the hot summer days. Turkey Creek noted that temperatures inside the mootel, which features a translucent plastic roof, were typically 3-4 degrees Celsius cooler than outside conditions. According to the farmers, employing the mootels during peak heat hours conferred several advantages, including:

- A decrease in cow body temperature, leading to heightened comfort.
- More relaxed and less agitated cows.
- An increased likelihood of cows consuming supplements if offered, compared to when they are exposed to direct heat.
- A reduction in walk time during the hottest parts of the day.
- A decrease in overgrazing of pastures during dry summer periods.
- Enhanced morale among staff, knowing their cows were more comfortable than they would be outside.

While it is plausible that there would be an increase in milk production due to the mitigation of heat stress and associated increased feed intakes, the data from this study is insufficient to quantify this effect. Nonetheless, it is indisputable that the relief from heat stress in the summer months stands as a significant advantage following the integration of a composting mootel.

10.2.6 Metabolic issues

Every farmer in the case study reported a decrease in metabolic problems among cows during the calving period in comparison to seasons prior to mootel integration. Feedback suggests this improvement can be attributed to several factors:

- Enhanced ability to monitor cows closely during high-risk periods.
- Improved and individualized transition strategies during the calving period.
- The capability to provide precise nutrition, including more accurate mineral supplementation.

At Prospect farm, the use of a mixer wagon was credited for the decline in metabolic issues. The farm could consistently mix minerals into the feed, ensuring cows received their nutrients “with every mouthful.” Remarkably, no incidents of downer cows were recorded in the spring of 2022.

Another farm highlighted a substantial reduction in treating cows for metabolic problems at the time of calving. Prior to mootel adoption, 50-60 cows (which equates to 10-12% of the herd) required treatment. However, after introducing the mootel, this number dramatically dropped to only 3 to 4 cows. This farm also credited the loss of merely one cow out of a 540-cow herd during the calving period to the ability to closely monitor cows within the mootel, enabling prompt and effective intervention when potential issues surfaced.

10.2.7 Reproductive performance

The integration of a composting mootel into the farming system is anticipated by the case study farmers to yield potential benefits to reproductive performance. However, conclusions regarding any associations from the case study farms remain preliminary. Primary reproductive performance indicators for each of the case study farms are detailed in Table 24. The main purpose of this table is to monitor these indicators across subsequent seasons to ascertain if there is any change in performance.

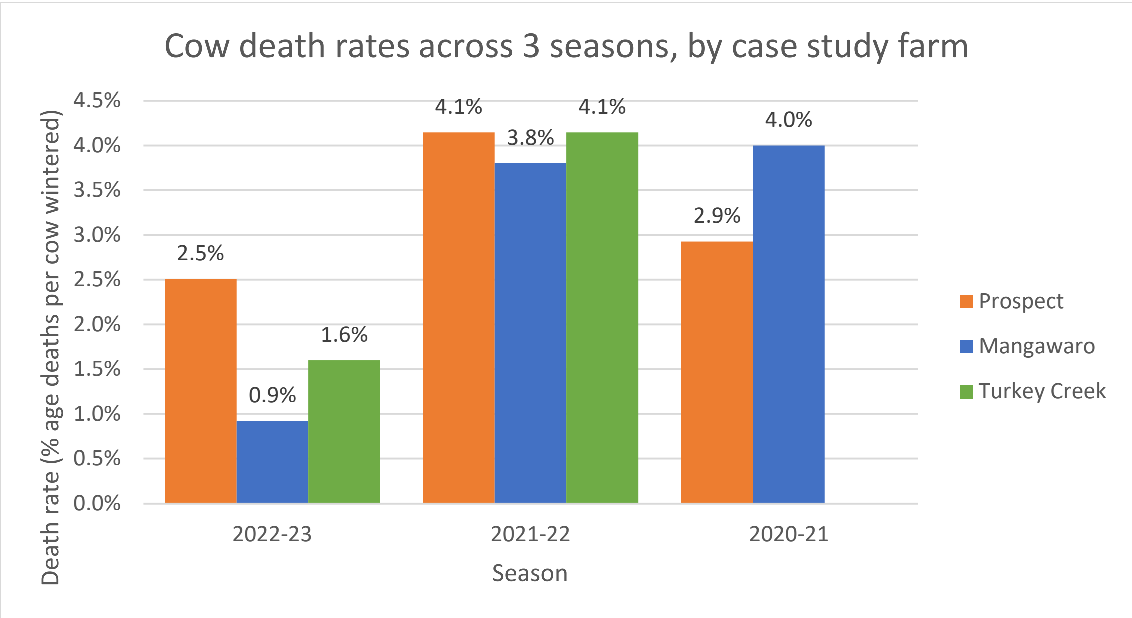
Table 24. Case study farm reproductive performance

Farm	Parameter	2022-23	2021-22	2020-21
Prospect	6 week in-calf-rate	70%	68%	70%
	Not-in-calf-rate	12%	15%	16%
Mangawaro	6 week in-calf-rate	72%	60%	68%
	Not-in-calf-rate	8%	14%	9%
Turkey Creek	6 week in-calf-rate	77%	78%	86%
	Not-in-calf-rate	11%	9%	9%

10.2.8 Death rates

Cow death rate data was captured during the study and for two seasons prior through DairyBase (only one season prior for Turkey Creek). Death rates included cows lost for any reason, encompassing cows lost during winter and those euthanized due to poor health. Rates are illustrated by farm and season in figure 27 below.

Figure 27. Cow death rates across three seasons by case study farm.



From the data provided, it is evident that all farms experienced a considerable decrease in cow death rates following the introduction of the mootel, especially notable in the cases of Mangawaro and Turkey Creek. However, several factors should be considered:

- Only one season's data post-mootel is available, which is insufficient to make definitive conclusions regarding the impact of composting mootels on seasonal cow death rates.
- The Turkey Creek farm transitioned from a contract-milking system in 2021-22 to a 50-50 sharemilking system in 2022-23, coinciding with a change in management. This shift could have influenced cow death rates.
- Both Prospect and Mangawaro farms retained consistent management across the observed seasons.

All participating farmers highlighted that the composting mootel system enhanced their capacity—and that of their teams—to monitor, identify, and address animal welfare issues. While they did not explicitly attribute reduced death rates as a direct benefit of the composting mootel system, it seems that integrating a composting mootel system might contribute significantly to decreasing cow losses, especially during the calving period.

10.3 PASTURES AND FEEDING

One major motivation for the case study farmers to adopt a composting mootel was the potential enhancement of pasture health and productivity. This improvement is anticipated from mitigating pasture damage during wet conditions, as well as preventing overgrazing during summer drought periods. Theoretically, a composting mootel offers the advantage of "duration-controlled grazing", which facilitates the removal of the milking herd from pastures during high-risk periods. This strategy ensures maintained feed intakes, even if it necessitates the addition of supplementary feeds while the herd is off pasture.

The case study farmers anticipated a growth in pasture production, expecting an increment ranging from 1-2 tonnes of dry matter per hectare upon integrating a composting mootel. In fact, this estimated increase was essential for them to secure a satisfactory return on their investment.

Another potential advantage of transitioning to a mootel system is the enhanced utilization of home-grown feed. This is especially pronounced when the farming system transitions from in-situ winter crop grazing (like kale or swedes, with supplements provided in the paddock alongside the crop) to leveraging the former winter crop area for producing supplementary feeds such as pasture silage intended for mootel use. Considering the inherently low utilization levels associated with winter crop grazing on the West Coast—likely around 50-70%, depending on ground conditions—in contrast to the significantly higher utilization levels (anticipated to be around 90-98%) when employing a cut & carry system on the same area, there is evident potential for substantial improvements in feed utilization and subsequent profitability. However, realising this potential hinges on the comparative costs of each feed type.

10.3.1 Pasture Harvested

On-farm pasture measurement data from the case study farms was not accurate enough to derive reliable pasture growth data. Therefore, an estimate of pasture eaten was formulated using detailed DairyBase physical analyses. These analyses were completed for the two seasons before mootel development (only one season for Turkey Creek) and for the first complete mootel season (2022-23). Besides pasture harvested and eaten, data on imported supplements (both externally, from support blocks or purchased, and internally, made on the dairy platform), dry-cow winter grazing, and replacement stock grazing were also recorded. The results are presented in Table 25 below.

Table 25: Pasture harvested and feed eaten analysis across 3 seasons, by case study farm.

	Prospect			Mangawaro			Turkey Creek	
Season	22-23	21-22	20-21	22-23	21-22	20-21	22-23	21-22
Pasture & Crop Harvested	9.5	7.0	9.9	11.0	10.9	11.6	10.8	10.1
Pasture & crop eaten	9.3	7.0	9.9	10.7	10.9	11.6	10.8	10.1
Imported supplements eaten (externally sourced)	3.0	3.6	2.1	4.5	0.2	0.4	2.5	2.4
Imported supplements eaten (internally sourced)	0.0	0.2	0.0	0.1	0.0	0.4	0.0	0.0
Off-farm dry cow winter grazing	0.0	1.6	1.6	0.0	1.6	1.3	0.0	0.0
Total feed eaten excl. repl. Stock grazing	12.3	12.1	13.6	15.3	12.7	13.1	13.3	12.5

	Prospect			Mangawaro			Turkey Creek	
Milk production (kgMS/ha)	1,137	1,086	1,148	1,211	971	1,025	1,104	918
Off-farm replacement stock grazing	2.1	2.1	2.1	2.2	2.2	2.0	0.6	0.5
Total feed eaten including replacement stock	14.5	14.3	15.6	17.5	14.8	15.2	13.9	12.9

Table Notes:

- *Pasture harvested and pasture eaten can differ due to feed being exported from one season to a subsequent season.*
- *externally sourced supplements include supplements imported from support blocks, as well as purchased.*
- *internally sourced supplements include supplements made on the milking platform.*

Table 25 indicates a 2.0 t DM/ha increase in pasture harvested at Prospect farm compared to the preceding season, but no significant change compared to the 2020-21 season. Although it is not definitively possible to attribute this growth to the mootel's influence, the data suggests some positive effects within the realm of seasonal variability. For Mangawaro, there is no considerable shift from past seasons, showing a minor decline since 2020-21. Turkey Creek data hints at a 0.7 t/ha (or 7%) rise in pasture harvested in the inaugural mootel use season. However, several qualifying remarks are worth noting:

- A solitary post-mootel season, combined with typical inter-seasonal fluctuations, makes it challenging to discern any potential trends concerning mootel-induced pasture growth.
- The managerial transition at Turkey Creek, along with other key metrics like production and death rates, likely had a substantial effect on pasture harvested.
- Alterations in the farm system due to mootel incorporation, especially in supplementary feeding practices, might obscure genuine changes in pasture harvested.
- To truly grasp the impacts of composting mootels on pasture growth in a West Coast setting, further studies are necessary.

Yet, at this preliminary juncture, given the limited data, it seems the mootel developments have brought minimal benefits in terms of pasture harvested quantity.

10.3.2 Farm System Changes

The inclusion of a composting mootel in the farm systems prompted alterations to varying degrees across the case study farms. For both Prospect and Turkey Creek farms, the overarching farming operations and associated inputs mostly stayed consistent. The primary modification was the integration of the mootel for wintering and practicing duration-controlled grazing. In contrast, Mangawaro underwent a more extensive shift. It transitioned from a modest input system to a system 5. A notable aspect of this transition was that a significant portion of the extra feed, now required due to the system's intensification, was sourced from the support block (SB). This new arrangement allowed for supporting lactation and wintering in the mootel, negating the previous practice of relocating cows to the support block during winter.

A comparative overview of the farm system changes caused by the integration of a composting mootel across the case study farms is detailed in Table 26.

Table 26: Case study farm system changes due to compost mootel development.

	Prospect	Mangawaro	Turkey Creek
Farm System	No change – system 4/5 ≈ 25% feed imported	Change from system 3 to system 5. ≈ 30% feed imported, but mostly grown on SB	No change – system 3 ≈ 19% Feed imported
Management	No change – Farm owner-operator	No change – owner with contract milker	Change from contract milker to 50-50 sharemilker
Cow numbers	No change (800)	Increased by 40 (8%) to 540	No Change (350)
Pastures	Duration-controlled grazing is practised by all case study farms following the mootel construction		
Pasture harvested/eaten	No significant change in pasture harvested or eaten to date, but significant summer drought in 22-23.	No significant change in pasture harvested or eaten to date	7% lift in pasture harvested and eaten
Imported supplements	Decreased from previous (poor) season, but higher than 20/21 season. ≈ 15% from SB	Significant increase from ≈ 0.2-0.4t/ha to 4.5t/ha. Predominantly from SB.	No change in total amounts fed.
Wintering	Cows wintered in mootel. Previously wintered on support block (SB)	Cows wintered in mootel. Previously wintered on SB	Cows wintered in mootel. Previously wintered on platform
Wintering diet	Balage, silage from SB plus imported supplements. Previously Swedes, Balage, Straw	Maize silage from SB plus imported supplements. Previously Maize silage + crop on SB	Pasture and Maize silage.
Replacement stock	No change – grown out on SB	No Change – grown out on SB	No change – grown out on platform, but on SB from 6 to 13 months of age

10.3.3 Feed Utilisation

The incorporation of a composting mootel into dairy farming is predicated on its potential to significantly elevate supplementary feed utilisation. This system offers the advantage of feeding cows in designated lanes or troughs irrespective of weather conditions. As a result, there is a marked reduction in wasted feed due to issues such as trampling, pugging, or cows resting on it. A challenge faced during the study period was the inability to precisely measure feed utilisation directly. Thus, estimations had to be based on a Level 2 DairyBase analysis. The presented utilisation figures are post-harvest, that is, they account for the feed's condition from the moment it arrives at the mootel, but not any wastage during its initial harvesting.

Table 27: average estimated utilisation of all supplementary feed

Case study farm	% Increase ('22 to '23)	2022-23	2021-22	2020-21
Prospect	12%	95%	83%	90%
Mangawaro	26%	96%	70%	73%
Turkey Creek	7%	96%	89%	

Following the feed utilisation estimations, an illustrative analysis was carried out to determine the potential savings resulting from the heightened levels of utilisation, attributable to the composting mootels. As shown in Table 28, this analysis assumes a consistent amount of supplement used but leverages the earlier utilisation rates to gauge potential savings. It is pivotal to treat this analysis as a broad indication, not a precise measure. Furthermore, while composting mootels do offer benefits in terms of feed utilisation, they are not the only method to attain such improvements.

Table 28: Demonstration of potential savings from increased supplement utilisation.

Case study farm	Supps. Used (total t/DM)	Utilisation gain	Potential saving	$/kgMS	$/cow
Prospect	1,101	12%	$64,739	0.18	81
Mangawaro	868	26%	$51,038	0.23	95
Turkey Creek	453	7%	$26,636	0.14	72

These tables showcase the prospective impact of composting mootels on feed utilisation across varying farms. The data showcases notable strides in feed utilisation owing to the adoption of the composting mootel system.

10.3.4 Milk Production Drivers

For the farms involved in the study, increasing milk solids (MS) production was a primary objective and a significant driving factor behind the adoption of the composting mootel system. Historical and current data that highlights the driving factors of milk production is outlined in table 29.

Table 29: Summary of milk production drivers

	Prospect			Mangawaro			Turkey Creek	
	22-23	21-22	20-21	22-23	21-22	20-21	22-23	21-22
Day in milk	278	262	275	285	274	259	270	235
Avg. MS prodn. (kgMS/cow/day)	1.60	1.60	1.64	1.46	1.34	1.49	1.87	1.89
Milk-solids per cow	446	419	452	416	366	387	506	443
Stocking rate (cows/ha)	2.6	2.5	2.5	2.9	2.6	2.6	2.2	2.1
Milk solids per hectare	1,137	1,086	1,148	1,211	971	1,025	1,104	918
Milk solids as % of cow liveweight (estimated)	94%	88%	102%	93%	81%	86%	106%	93%

10.3.5 Days-in-milk

A notable trend across all farms is the increment in days-in-milk from the past season. For Mangawaro and Turkey Creek, this increment extends beyond a 10-day average from their previous records. One contributing factor is the extended milking duration into autumn, made possible by the assurance of improving cow body condition scores during winter with the assistance of the composting mootel. Prospect farm's history of milking late into autumn indicates a reduced potential for increasing days-in-milk via extended autumn lactation. While there is not yet conclusive evidence to prove the mootel's impact on enhancing 6-week-in-calf rates, the overarching expectation is a rise in days-in-milk, approximated at about 10 days.

10.3.6 Per-cow Production

There is a marked rise in per-cow production for both Mangawaro and Turkey Creek farms. Mangawaro's increase can be credited to both enhanced days-in-milk and an elevated average per-cow production across the season, likely influenced by augmented supplementation. For Turkey Creek, the principal driver was the days-in-milk, as the seasonal average per-cow production stayed consistent. (Note: Only one prior season's data is available for this farm.) In contrast, Prospect farm's per-cow production does not show a noteworthy increase when juxtaposed with its extensive historical data.

10.3.7 Per-hectare Production

Mangawaro's increase in per hectare production can be attributed to two principal factors: the rise in per-cow production and a hike in stocking rate, moving from 2.6 to 2.9 cows per hectare. In Turkey Creek's scenario, the chief contributors were the amplification in per-cow production coupled with a marginal increase in the stocking rate.

11 Financial Analysis

To assess the financial ramifications of implementing a composting mootel, this project employed financial modelling with a discounted cashflow (DCF) analysis. This method was used to estimate future returns from the mootel development, drawing on projected marginal returns and developmental costs for each case study farm. A primary goal of this financial model was to ascertain the necessary surge in milk production (or revenue) to offset the comprehensive developmental costs. These costs encompass the initial capital outlay, augmented farm operational expenses, accrued depreciation, and financing charges. The term used to describe this essential production uptick is the “break-even production increase” for each highlighted farm.

It is important to note that as of the study's conclusion on 30th June 2023, the financial records for the 2022-23 season for all participating farms were inaccessible since the season had just ended. Consequently, our financial modelling hinges on presumed figures rather than definitive operating costs, returns, and inputs. While the model employs the DCF analysis to illustrate anticipated returns, the presented results are structured to be readily understood by any farmer evaluating the potential of a composting mootel investment.

This analysis deliberately omits specific financing and debt data pertaining to the case study farms. However, there are overarching remarks about financing in section 8.3 and insights into the balance sheet repercussions in section 11.11. Emphasizing clarity, all analytical undertakings focus on the operating profit, or EBIT (Earnings Before Interest and Taxation) level.

11.1 Milk solids production

During the due diligence phase of their development, it was anticipated that the primary financial return from the incorporation of a composting mootel for all the case study farms would stem from an increase in milk production, as opposed to a decrease in operational costs. All involved farms had a predetermined increment in milk production in mind that, based on their calculations, was essential to ensure that their investments paid off. These production goals spanned between 11% and 23% and were aimed to be achieved over 2 to 4 seasons. Likewise, the financial model applied in this case study aims to showcase the required break-even production increase for each case study farm, ensuring they are not financially disadvantaged.

The past milk solids production data for each participating farm is detailed in Table 30. Production for the 2022-23 season, which marks the first full season utilizing the mootel, is juxtaposed with the output of the prior five seasons. Woodford, (pers. com) notes that production in subsequent years tends to improve. The table also highlights the production growth percentage compared to the average of these preceding five seasons.

Table 30. Historical milk production.

	%'age	Season						
	increase	2023	5yr avg.	2022	2021	2020	2019	2018
Prospect	0.5%	358,013	356,355	341,979	361,563	373,510	352,417	352,306
Mangawaro	20.4%	223,997	186,064	179,558	189,681	195,320	189,600	176,160
Turkey Creek	14.9%	186,570	162,438	155,192	162,000	162,000	165,000	168,000

The data from a single production season is insufficient to conclusively verify the long-term advantages tied to the adoption of a composting mootel. Nonetheless, two of the farms showcased a notable rise in production, departing from their previously consistent long-term averages post the mootel's introduction. However, variables such as alterations in feed inputs (notably supplements), cow population, and managerial changes in one instance make it challenging to unequivocally attribute this production surge to the mootel's incorporation.

The 2022-23 production season experienced predominantly favourable weather conditions on the West Coast. Numerous veteran farmers noted that this was, to paraphrase, "The best spring in three decades." This period was characterized by its consistent mild weather, devoid of the extended cold or wet spells that are commonplace in this region. The summer months, however, were marked by a dry spell from late December to March, the impact of which varied across the farms.

Prospect farm had a subpar season due to a myriad of reasons. This included the mentioned drought which affected the Haupiri region more than the Inangahua and Mawheraiti/Upper Grey zones. The farm also grappled with its inaugural outbreak of Facial Eczema, which would have detrimentally affected milk production. The farmer estimated that the cumulative impact of the drought and Facial Eczema resulted in a decrease of 20,000 kgMS in that season's output. The drought also plagued Turkey Creek, leading to an estimated loss of 6,000 kilograms of milk solids. Conversely, Mangawaro experienced milder seasonal conditions, with minimal impacts from the drought which afflicted the other farms. This is evident in their production data.

For the sake of financial modelling, the average production over the past five seasons has been chosen as the benchmark for gauging the benefits associated with the composting mootel's installation.

11.2 Capital costs.

The notable capital expenditure required for a substantial infrastructure initiative like a mootel often deters many farmers, especially when considering the funding prerequisites. The three farms involved in the case study adopted diverse capital development strategies: two farms (Prospect and Mangawaro) opted for a higher capital investment and input approach, while Turkey Creek farm went for a more frugal capital cost plan.

Detailed capital costs for every development were gleaned from farmer interviews and scrutiny of financial statements. The transparency and cooperation of the case study farmers in disclosing their financial details is commendable. The entire capital expenditure of the development has been incorporated into the financial analysis. This includes all the supplementary machinery required for every operation, the initial woodchip procurement, and any supplementary needs such as extra concrete spaces or other infrastructure essentials. It is pertinent to mention that both Mangawaro and Turkey Creek farms utilized their own excavators and manpower for a considerable part of the groundwork, likely reducing the overall external cash expenses of the development. The capital expenditures for each farm are summarized in Tables 31 and 32.

Table 31. Capital expenditure cost for case study each farm (GST exclusive).

Capital Item	Prospect	Mangawaro	Turkey Creek
Mootel building	1,841,090	1,683,000	784,820
Siteworks and concrete	663,512	50,000	338,220
Woodchip	115,591	127,000	77,917
Plant & Equipment	353,710	311,600	-
Total capital costs:	***2,909,920***	***2,171,600***	***1,200,957***

Table 32. Capital costs per square metre of compost space, per cow and per effective hectare.

Case study farm	Prospect	Mangawaro	Turkey Creek
Cost/sq. M	562	544	371
Cost/cow	3,637	4,021	3,246
Cost/ eff. Ha	8,435	11,738	7,106

The full capital expenditure for the mootel development project varied between $3,250 and $4,000 for every cow. The final cost was contingent on factors including (but not limited to) size, construction type, extent of groundwork, and machinery needed. It is imperative to note that capital costs may have escalated since the construction of these mootels, possibly surging at or beyond the inflation rate and could exceed the figures cited above. Consequently, farmers contemplating the integration of a composting mootel into their operations might foresee total project costs ranging from $3,500 to $6,000 per cow. However, recent developments in imported customised kitset buildings may allow reduced construction costs for mootel structures.

11.3 Forecast milk price and other income

The volatility of historical milk prices makes it challenging to forecast future prices, and such predictions fall outside the purview of this study. To derive a plausible projection of future milk prices, we have relied on the DairyNZ Economics tracking tool (DairyNZ website, July 2023). The implications of fluctuations in the milk price have also been addressed and can be found in section 11.10.

For the discounted cashflow analysis, a milk price of $8.69/kgMS is used, which represents the forecast for the 2022-23 season. We also conducted a comparative analysis using the 2023-24 price forecast of $8.16/kgMS. Since the financial models were finalized, it is important to note that the milk price has witnessed a significant decline from these anticipated levels.

Other inputs, primarily stemming from livestock income, are projected based on historical rates when expressed as a per kilogramme of milk solids figure. Even though the case study farmers harbour strong hopes of seeing improved parameters like in-calf rates, replacement rates, and the liveweight of cull cows due to the adoption of the composting mootel system, there is not enough empirical evidence to back these claims at this juncture. As a result, these anticipated benefits have been excluded from the financial models. However, it is worth noting that a preliminary analysis of the potential advantages of an increase in cull cow liveweight at Mangawaro suggests that this could enhance the rate of return by 0.3% over the span of 25 years in the model.

11.4 Forecast operating costs

The financial model employs projected alterations in operating expenses to determine expected cash flow from the development. From this, we can deduce the necessary production surge for achieving a break-even result. Approaching these projected cost structures requires caution; it is not uncommon in infrastructure developments to observe system drift and other unpredicted factors that can escalate costs beyond initial projections, leading to diminished returns.

Table 33, presented below, outlines the anticipated broad effects of the mootel development on farm operating expenses, categorized as either increasing, neutral, or decreasing. This categorisation is informed by both the expectations of the case study farmers and observations from the first year of mootel usage. An in-depth breakdown, demonstrating the projected impact of mootel development on individual farm costs, can be found in Appendix 10.

Table 33. Expected impact of mootel development on farm working expenses.

Farm Working Expense	Mootel effect	Comment
Wages and Salaries	Neutral	Non-cash wages of management not included in modelled analysis
Animal health	Neutral	
Breeding & Herd improvement	Neutral	
Farm dairy expenses	Neutral	
Electricity	Neutral	
Feed expenses		
Winter/summer feed crops	Decrease	Winter feed crops no longer used on CS farms
Supplements imported	Increase	Variable, see appendix 10
Supplements made on farm (or support block)	Increase	Variable, see appendix 10
Grazing & support block expenses		
Young stock grazing	Neutral	
Winter cow grazing	Decrease	
Support block expenses	Decrease	Variable, with substitution between winter crop savings and supplement cost increases
Fertiliser	Neutral	Effect of mootel development uncertain
Nitrogen	Neutral	Effect of mootel development uncertain
Regrassing	Decrease	Variable, decrease of $0-0.01/kgMS
Weed & Pest	Neutral	
Vehicles	Increase	Increase of $0.02-0.03/kgMS assumed
Fuel	Increase	Increase of $0.02/kgMS assumed
R & M – Land & buildings	Increase	See appendix 10
R & M – Plant & equipment	Increase	See appendix 10
Freight & General	Neutral	
Administration	Neutral	
Insurance	Increase	Small increase of $0.01/kgMS assumed
Rates	Neutral	
Additional mootel costs		
Annual woodchip @ 3m^3/cow	Increase	$0.17-0.18/kgMS
Other mootel costs	Neutral	Captured in other categories above

Generally, the balance between cost reductions and cost escalations from the mootel development is estimated to induce an increase in farm working expenses ranging from $0.12 to $0.22 per kilogram of milk solids. This is primarily due to bedding costs. However, this figure significantly hinges on the savings achieved by foregoing activities like winter cropping and the added costs of extra supplements cultivated in the erstwhile winter cropping areas and further supplements imported for mootel supplementation.

From discussions with farmers on wages, salaries, fertiliser, and nitrogen:

- They anticipate no change in staffing levels. However, tasks allocated to staff are expected to vary, leaning towards being simpler. This allows staff more flexibility for leave or time-off.
- Currently, the effect of the mootel development on the utilization of fertilizers and nitrogen remains ambiguous. While a reduction in nitrogen fertilizer was noted in the first year, establishing a concrete trend demands continued research.

11.5 Base case financial modelling assumptions

The base case financial modelling focuses on the net effect of mootel development on the farm's operational finances. Specifically, the model captures the marginal changes—those incremental differences from the base operation before introducing the mootel development. This approach is essential to understand how a mootel impacts the farm's finances relative to a non-mootel setup.

Table 34 delineates the assumptions for each farm. The costs are shown both as the amount per kilogram of milk solids (kgMS) and as a percentage increase from the base. Key insights are as follows:

Prospect Farm:

- **Farm Working Expenses:** A moderate increase is noted at 12c/kgMS, or 2.0%. This is mainly attributed to notable savings in winter cropping expenses. However, there is an offset due to the increase in silage/baleage making on the support block.
- **Depreciation:** Here, the increase is slightly more pronounced at 22c/kgMS, translating to a 27% rise. This is credited to the mootel's depreciation combined with the equipment needed to run it.

Mangawaro Farm:

- **Farm Working Expenses:** There is a spike of 19c/kgMS or 3.0%. The woodchip's cost, at 18c/kgMS, is a significant contributor. While there are certain cost savings like reduced wintering expenses, they are counteracted by other increases.
- **Depreciation:** It registers a sizable increase of 27c/kgMS. This hike can be credited not only to the mootel but also to the considerable investment in new equipment, a necessity for transitioning from a lower input system to the mootel.

Turkey Creek:

- **Farm Working Expenses:** The projected rise is 22c/kgMS or 4.5%. Similar to other farms, woodchip costs (17c/kgMS) form a significant portion. Added costs also arise due to the introduction of maize silage and its feeding.
- **Depreciation:** Here, there is a rise of 15c/kgMS, translating to a 36% increase. While this may seem moderate in absolute terms, given Turkey Creek's lower base, the percentage increase is substantial.

Table 34: Farm specific base case modelling assumptions

Marginal cost	Prospect		Mangawaro		Turkey Creek	
	$/kgMS	***%'age***	***$/kgMS***	***%'age***	***$/kgMS***	***%'age***
Farm working expenses marginal increase	0.12	2.0%	0.19	3.0%	0.22	4.5%
Depreciation/operating capital marginal inc.	0.22	27%	0.27	109%	0.15	36%

11.6 Depreciation

Due to the substantial capital investment involved in mootel development, the associated depreciation will account for a significant portion of future additional costs, despite depreciation being a non-cash expense. It is essential to understand that all businesses must periodically invest in asset replacement, particularly as plant and equipment deteriorate and depreciate over time. Consequently, the financial models in this study factor in depreciation as an operational cost.

Table 35 provides a breakdown of the estimated additional depreciation costs per kgMS for each case study farm:

Table 35. Estimated additional depreciation costs per kgMS by case study farm.

	Prospect	Mangawaro	Turkey Creek
Mootel depreciation ($/kgMS/yr.)	0.14	0.15	0.15
Plant & Equipment Depreciation ($/kgMS/yr.)	0.08	0.12	0.00

The depreciation estimates presented above make several assumptions:

- **Mootel Structures:** Solid roof structures are assumed to have a 50-year lifespan, depreciating on a straight-line basis to zero value by the end of that period. For tunnel roof structures, while the main building structure and concrete are depreciated over 50 years, the roof fabric is depreciated over a 20-year span. This differentiation is based on consultations with the building contractor, estimating the roof fabric to constitute 10% of the total construction cost.

- **Plant & Equipment:** These assets are depreciated based on IRD values, assuming a 15.5-year lifespan and an 8.5% annual straight-line depreciation rate. Given the swift depreciation that can occur with machinery in regular use, this estimation for plant and equipment might be on the conservative side.

It is vital to emphasise that these figures are preliminary estimates. Any farmer contemplating an investment in a composting mootel system should seek specialised advice from their accountant to gain a comprehensive understanding of depreciation's financial implications.

11.7 Salvage value of investment.

Estimating the salvage value of a composting mootel attached to a farm after 25 years of use presents challenges. While based on the predetermined depreciation rates, the mootel would retain approximately 50% of its original capital cost after this period, there is significant uncertainty regarding the mootel's actual resale value separate from its associated farm. It is also improbable that the mootel would be dismantled and sold for more than a negligible amount. Due to these considerations, our financial model provides an analysis both with and without a salvage value at the 25-year mark.

For the purposes of our model, plant and equipment are assumed to have no salvage value after the 25-year period.

The impact of including a salvage value in the model at year 25 can be seen in Table 36:

Table 36: Influence of Salvage Value on Financial Returns (Determined by Break-even Production Increase)

Case study Farm	Break-even Prodn. Increase	With salvage value at yr. 25		Without salvage value	
		NPV	IRR	NPV	IRR
Prospect	+ 11.3%	0	8.0%	-172,377	7.2%
Mangawaro	+ 15.9%	0	8.0%	-144,057	7.1%
Turkey Creek	+ 11.0%	0	8.0%	-76,350	7.1%

11.8 Expected rate of return

In the Discounted Cash Flow (DCF) analysis, an 8% base case discount rate or desired rate of return is employed. This figure is grounded in anticipated market yields for investments comparable in nature and industry competitiveness. For context, such a rate is indicative of the return threshold at which an external party might contemplate an investment in this specific industry. Additionally, this rate reflects the recent upswing in interest rates.

For many farmers, especially those participating in our case studies, a return below the stated 8% might be deemed acceptable. This acceptance is primarily attributed to the myriad non-financial advantages that emerge from such a venture. In these instances, pure financial returns were not the primary motivator behind their decisions.

Nevertheless, we have anchored our analyses to this 8% rate. It serves as a critical marker, highlighting the juncture where financial rewards might coalesce with the non-financial benefits that accompany an investment in a mootel. It is essential to recognize this balance, ensuring that investors are aware of both tangible and intangible returns before committing to such projects.

11.9 Financial modelling results

The outcomes of our financial models for each farm are encapsulated in Figure 28. Drawing from the previously established assumptions, to attain an 8% rate of return (where Net-present Value, or NPV, zeroes out), the necessary surge in milk production fluctuates between farms: 11% for Turkey Creek, 11.3% for Prospect Farm, and a heightened 15.9% for Mangawaro. Put simply, for mootel investments of similar nature to be deemed financially sound, a milk production spike ranging from 10% to 16% is imperative. Interestingly, these figures, deduced from our models, either align with or undercut the anticipations set forth by the case study farmers. Barring Prospect farm, the other farms managed to achieve, and in some cases, surpass these required augmentations in milk production during the maiden season of mootel utilization in 2022-23.

Figure 28. Graph illustrating the necessary increase in milk solids to surpass the 8% benchmark, stratified by each farm.

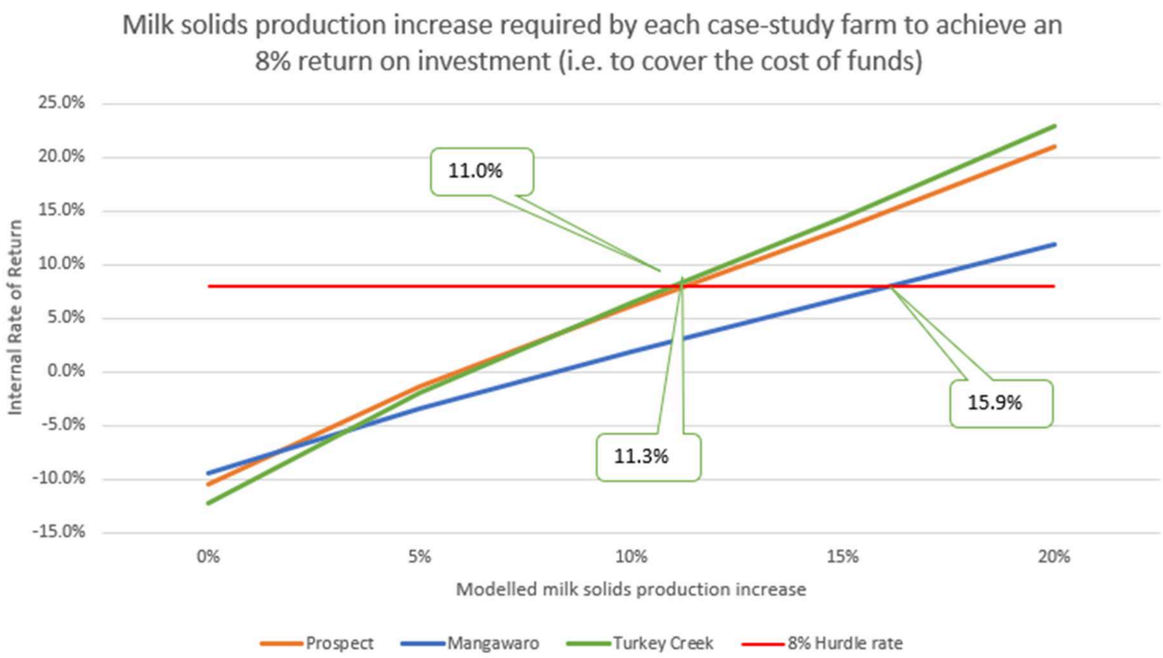


Table 37. A comparative analysis of anticipated, modelled, and actual increases in milk solids production.

Production increase (over 5yr avg.)	Prospect	Mangawaro	Turkey creek
Farmers expectation	11%	23%	12%
Modelled figure	11.3%	15.9%	11%
2022-23 season result	0.5%	20.4%	14.9%

11.10 Sensitivity Analysis

The Sensitivity Analysis section is crucial as it examines how varying factors can influence the expected outcomes. By understanding how sensitive the financial model is to different inputs, one can assess risks and make more informed decisions.

For our case study farms, we have illustrated the effect of individual variables on projected returns using tornado charts, depicted in Figure 29 through Figure 31. From our modelling:

- **Milk Revenue:** This variable stands out as having the most significant influence on projected returns. It is crucial to note that milk revenue is a composite of both production and milk price. These two factors exhibit equal sensitivity, meaning a shift in either can notably sway outcomes.
- **Farm Working Expenses:** These expenses appear to have a minimal impact on the modelled outcomes, suggesting that fluctuations in these costs would not drastically alter the profitability metrics.
- **Discount Rate:** Often equated to interest costs, the discount rate holds moderate influence over the financial outcomes. As this rate goes up, it reduces the present value of future revenues, potentially making investments seem less attractive.

Figure 29 Prospect Farm Sensitivity Analysis

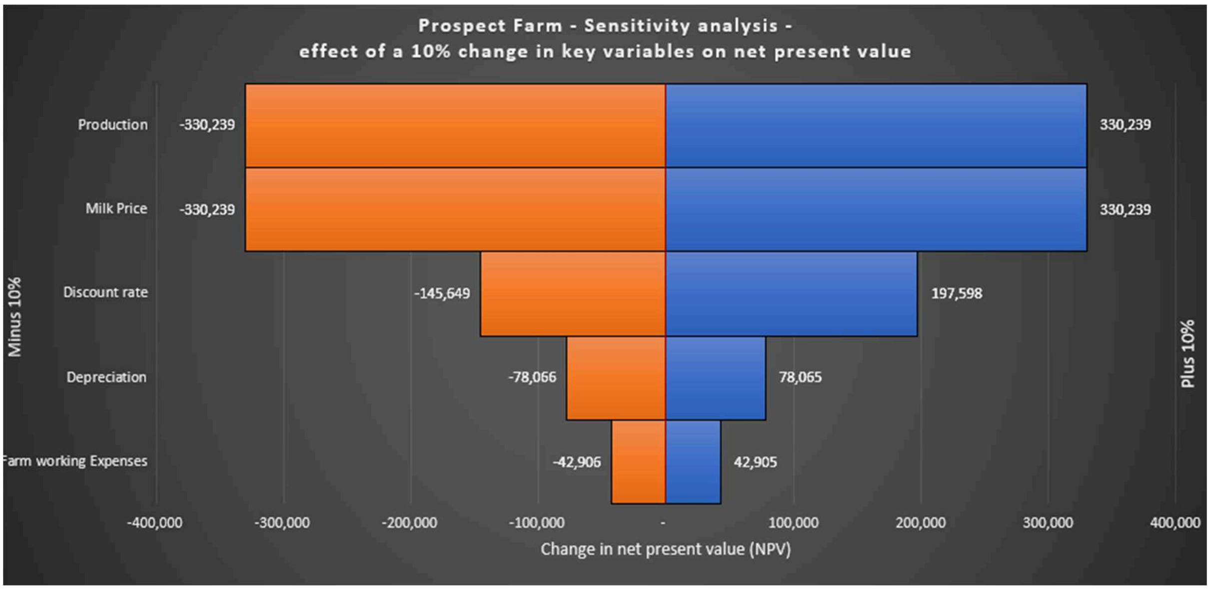


Figure 30 Mangawaro farm sensitivity analysis

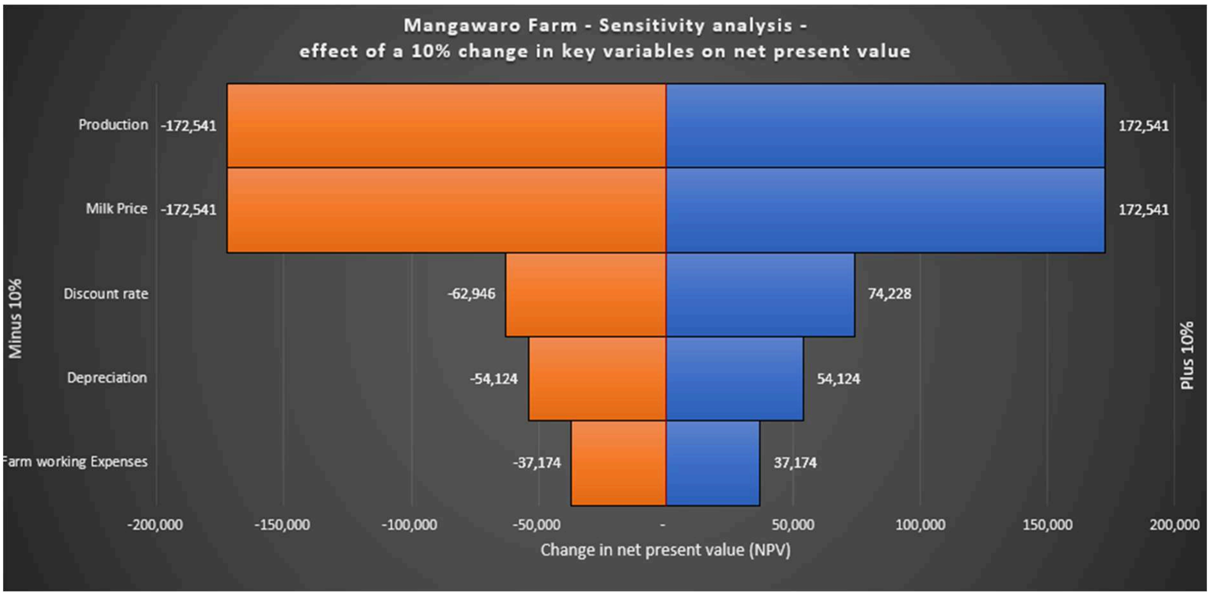
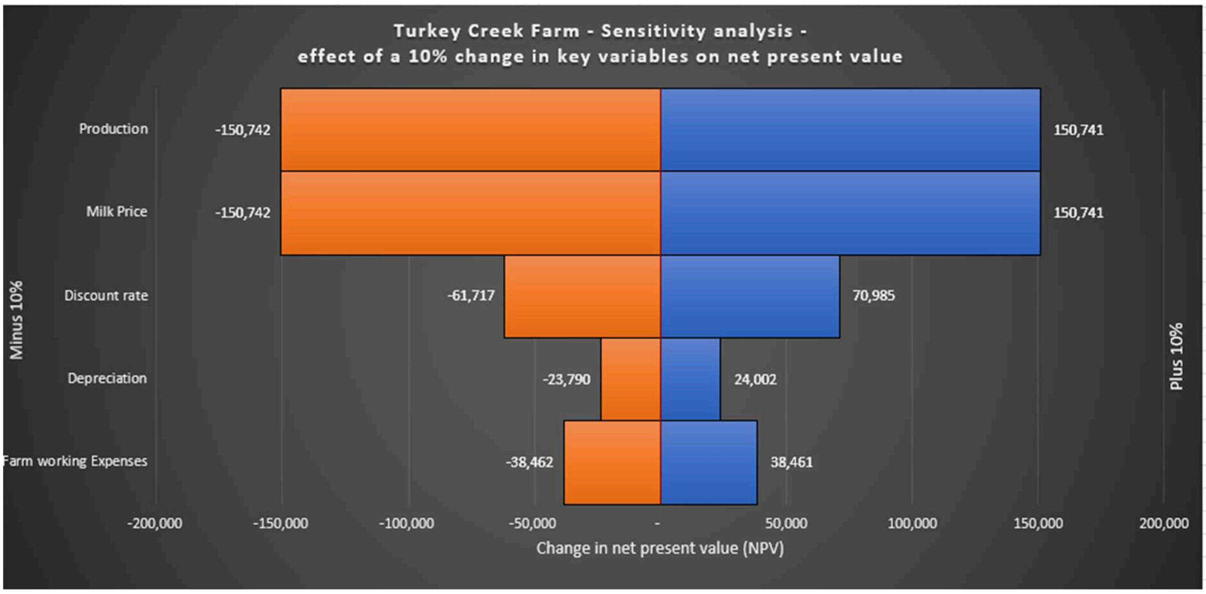


Figure 31 Turkey Creek farm sensitivity analysis



Of the three, Turkey Creek offers an interesting case. It, too, remains highly sensitive to shifts in milk price or production. Yet, its exposure to depreciation fluctuations is less pronounced than its counterparts. This is primarily because Turkey Creek has a lesser capital commitment towards mootel and associated equipment. Another distinguishing feature for Turkey Creek is the heightened sensitivity of farm working expenses. The reason for this heightened sensitivity can be traced back to the proportionally larger surge in these expenses post the introduction of the mootel.

While overarching trends exist, each farm, due to its unique set of circumstances, exhibits distinct sensitivities. Being aware of these nuances is essential for tailored risk management and strategic planning.

11.11 Farm Value Impact

Embarking on a composting mootel development strategy inevitably leads to a noticeable financial impact, regardless of the capital investment's scale. As of the 2021-22 fiscal year, the projected capital cost for such a development ranged from $3,259 to $5,000 per cow. When evaluated on an effective hectare basis, the cost ranged between $6,000 and $12,000, amounting to a significant $1 to $2 million for the average farm.

It is essential to recognise that the full expenditure may not be wholly represented by an increase in the farms value. Historical data has shown instances where substantial infrastructure investments have not garnered equivalent returns during farm sales. In certain scenarios, these assets sold at significant discounts, and in more extreme cases, they did not add any incremental value at all.

However, a broader perspective reveals the numerous non-financial benefits a mootel infrastructure offers – whether related to environmental conservation, animal welfare, or staff well-being. Over time, these advantages may incrementally enhance the farm's value. Moreover, a well-established infrastructure often increases a farm's appeal in the market, positioning it as a lucrative venture for potential buyers, thereby boosting its saleability.

In our case study, one farm provided valuations for periods before and after mootel implementation. The outcome showcased an increase in value, reflecting between 41% to 70% of the complete mootel capital outlay (excluding aspects like woodchip, plant, and equipment). Another participating farmer estimated that roughly half of their expenditure would find representation on their balance sheet.

In conclusion, the immediate financial ramifications of infrastructure ventures like mootels may not always mirror the initial investment. However, the plethora of indirect benefits they bring can substantially bolster the farm business's long-term valuation and appeal.

12 Conclusion

In the West Coast, the persistent challenge of high rainfall, particularly during winter and spring, presents significant hurdles for farming. Precipitation during these months can cause pronounced pugging in winter crops and pastures, leading to substantial nutrient losses that leach beyond the root zone. This chain of events culminates in sediment, phosphorus, and *E. coli* runoff into waterways, detrimentally affecting the environment, animal health, and staff welfare, and ultimately impinging on the farm's profitability. Within this challenging landscape, composting mootels have emerged as a beacon of innovation for dairy farmers.

This study delves into the experiences and outcomes of three West Coast dairy farms that incorporated composting mootels into their operational strategies. The research methodology was multifaceted, encompassing farmer interviews, Overseer modelling, biophysical sampling, and financial scrutiny to holistically evaluate the potential merits and pitfalls of composting mootels.

At a national scale, composting mootels have piqued the interest of a diverse audience, spanning farmers, bankers, and rural professionals. This research serves as an initial foundational layer, providing crucial data and acting as a reference point. While this study establishes a preliminary understanding, the dynamism of farming necessitates its continual supplementation with progressive research, ensuring that farmers remain equipped with evolving insights to make well-informed decisions about mootel adoption.

The effectiveness of a mootel is intricately tied to its design. Strategic considerations around optimizing feeding and loafing areas, maximizing floor space, and ensuring efficient ventilation and airflow (which bear direct implications for the composting process) are paramount. Furthermore, the region's penchant for heavy rainfalls accentuates the importance of robust stormwater systems in mootel design.

Discussing mootels from a financial perspective unveils a complex landscape. Initial investments are substantial, encompassing mootel infrastructure, site preparations, and essential materials like woodchips. However, future financial trajectories are influenced by a plethora of factors including fluctuating interest rates, variable bedding material costs, and asset depreciation. Interestingly, while the economic imperative suggests that production should increase to justify mootel investments, farmers' motivations were not purely financial. For many, the pivot towards mootels reflects a strategic move to bolster business resilience, anticipating and adapting to a shifting social license around winter grazing.

The biophysical aspects of composting mootels warrant deeper investigation. Established research underscores the optimal composting conditions: temperatures oscillating between 50 and 60 degrees Celsius, and dry matter content consistently surpassing 50%. Yet, these conditions remained elusive for the case study farms, often due to design nuances. In particular, the feed areas within mootels emerged as a pivotal concern, with their current design facilitating uneven urine distribution, thereby hindering the composting process. Achieving a uniform distribution of dung and urine within the mootel presents a significant challenge, deserving further research. Additionally, studies focusing on the ideal C:N ratio of the compost and the optimal frequency of tillage will significantly enhance the understanding of the biophysical dimensions of mootels.

Mootels were anticipated to be catalysts for enhanced milk solids production. Though two farms documented significant boosts, one farm's results were more tempered. A multitude of external variables – alterations in feed supplements, variations in herd size, and unpredictable seasonal changes – make it difficult to properly measure the effect of mootels on milk solid production, suggesting that further research is imperative to parse out mootels' direct influence.

Animal health within the mootel ecosystem displayed a dichotomy. On the bright side, mootels offer a sanctuary during peak summers and have shown potential in mitigating metabolic issues during calving periods. However, there is risk in the form of *E. coli* mastitis, with experiences varying across the farms studied. Expanding research horizons to encompass mastitis, alongside other health indicators including reproductive performance, is essential.

From our case studies, composting mootels show potential for West Coast dairy farms, offering a trifecta of environmental, health, and financial benefits. Yet, the sizable capital requisites mean that decisions cannot be taken lightly. It is of paramount importance for farmers to actively engage with experts, conducting thorough due diligence to discern whether mootels resonate with their farm's unique ethos and objectives.

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14 APPENDICES

Appendix 1: Mootel Usage.

Table of Mootel Usage data

Prospect (LHS)	area:	5180										
Month	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Days	30	31	31	30	31	30	31	31	28	31	30	31
Cow numbers	850	845	835	830	827	824	822	810	805	800	740	740
Hours/day (average over month)	16	24	18	12	2.5	2.5	3.5	4	4	2.5	2.5	3
total hours/month	480	744	558	360	78	75	109	124	112	78	75	93
Total cow hours/month	408,000	628,680	465,930	298,800	64,093	61,800	89,187	100,440	90,160	62,000	55,500	68,820
Total cow hours per m^2/month	79	121	90	58	12	12	17	19	17	12	11	13
Tilling frequency (times/month)	30	31	31	30	18	15	20	20	20	15	15	20

Mangawaro (LHS)	area:	3990										
Month	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Days	30	31	31	30	31	30	31	31	28	31	30	31
Cow numbers	541	541	540	539	538	538	538	537	517	517	517	517
Hours/day (average)	18	24	21	15	3	3	2	3	4	4	4	6
total hours/month	540	744	651	450	93	90	62	93	112	124	120	186
Total cow hours/month	292,140	402,504	351,540	242,550	50,034	48,420	33,356	49,941	57,904	64,108	62,040	96,162
Total cow hours per m^2/month	56	78	68	47	10	9	6	10	11	12	12	19
Tilling frequency (times/month)	30	31	31	15	15	15	20	31	28	20	20	20

Turkey Creek (LHS)	area:	3240										
Month	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Days	30	31	31	30	31	30	31	31	28	31	30	31
Cow numbers	375	375	373	370	369	369	367	367	365	360	360	360
Hours/day (average)	2	18	21	10	0	0	0	5	5	0	2	8
total hours/month	60	558	651	300	0	0	0	155	140	0	60	248
Total cow hours/month	22,500	209,250	242,823	111,000	-	-	-	56,885	51,100	-	21,600	89,280
Total cow hours per m^2/month	4	40	47	21	0	0	0	11	10	0	4	17
Tilling												
Frequency (times/month)	5	31	31	30	3	3	3	30	28	3	8	31

Appendix 2: Temperature

Mootel temperature records – all sites and depths

Mootel temperature records									
Farm	Site	Depth	17/10/2022	15/11/2022	22/12/2022	24/01/2023	11/03/2023	16/04/2023	20/05/2023
Mangawaro	1	200	19	21	23	24	21	15	19
	Lane	300	20	21.5	24	25.5	30	19	20.5
		400	19	21.5	24	26	30	20	19
Mangawaro	2	200	36	32	25	27	33.5	14	20
	lane	300	36.5	33	27	31.5	42.5	19	21.5
		400	32	32	27	32.5	43	23	20
Mangawaro	3	200	27	33	34.5	31.5	33	31	35
	centre	300	27	33	33.8	33.5	36.5	39	40
		400	26	32	37.5	33	41.5	42	42
Mangawaro	4	200	33	33	24.5	32	31.5	21	21
	lane	300	34	34	25	34	35	25	22
		400	30	33	26	32.5	36.5	26	21.5
Mangawaro	5	200	20	33	35.5	38.5	38	18	20
	centre	300	22	34	35.5	42	46.5	22	18.5
		400	19	33	35	42	50.5	23	18.5
Prospect	1	200		35	26	35	34.5	24	29
	Lane	300		34.5	29	37	31.5	27	30.5
		400		31.5	29	36	31	28.5	29.5
Prospect	2	200		34	35	36	40	33	30
	Lane	300		33.5	39	39.5	40.5	37	32.5
		400		30	37	37.5	38	38	33
Prospect	3	200		42	47	30.5	34.5	35	27.5
	Centre	300		48	55	34	36.5	40	30
		400		43.5	55	37	36.5	41	32
Prospect	4	200		32	30	33	33.5	43	25
	Lane	300		34.5	33	35	32.5	43.5	29
		400		34.5	33.5	34.5	31.5	40.5	30
Prospect	5	200	36	37.5	41.5	48.5	40	32	25.5
	Centre	300	39	46	46	51.5	40	36.5	28
		400	33	46	45	56	38	36.5	29.5
Turkey Creek	1	200			27	28	29	33	36.5
	centre	300			30	32.5	32	40	44
		400			33.5	35	35	44	47
	2	200				31.5			
	Lane	300				32.5			
		400				32			

Appendix 3: Temperature

Mootel temperature records – detailed sampling sites at 300mm depth

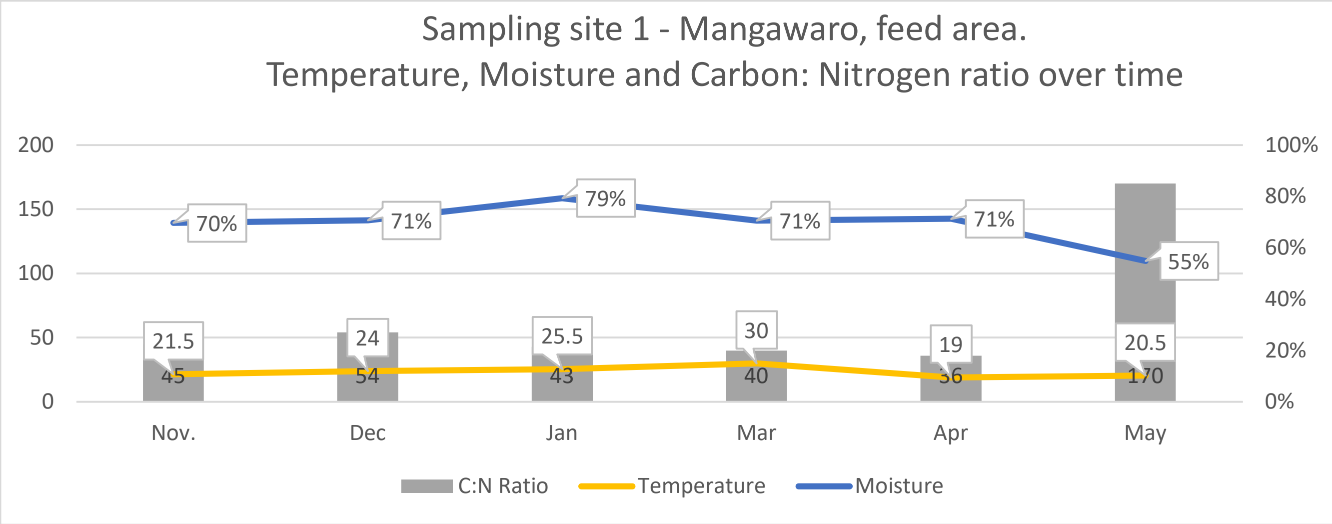
Farm	Site			Depth	17/10/2022	17/10/2022	15/11/2022	22/12/2022	24/01/2023	11/03/2023	16/04/2023	20/05/2023
Mangawaro	1	Feed Lane	Temp.	300		20	21.5	24	25.5	30	19	20.5
Mangawaro	3	Centre	Temp.	300		27	33	33.8	33.5	36.5	39	40
Mangawaro	5	Centre	Temp.	300		22	34	35.5	42	46.5	22	18.5
Prospect	4	Feed Lane	Temp.	300			34.5	33	35	32.5	43.5	29
Prospect	5	Centre	Temp.	300		39	46	46	51.5	40	36.5	28
Turkey Creek	1	Centre	Temp.	300			29.5	30	32.5	32	40	44

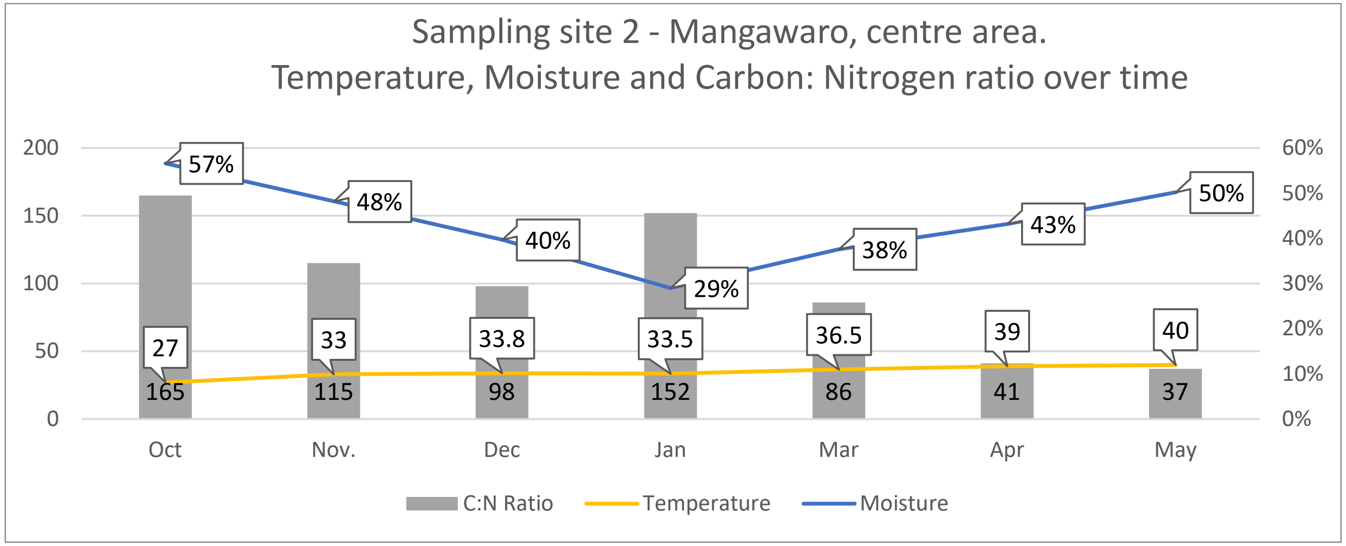
Appendix 4: Moisture

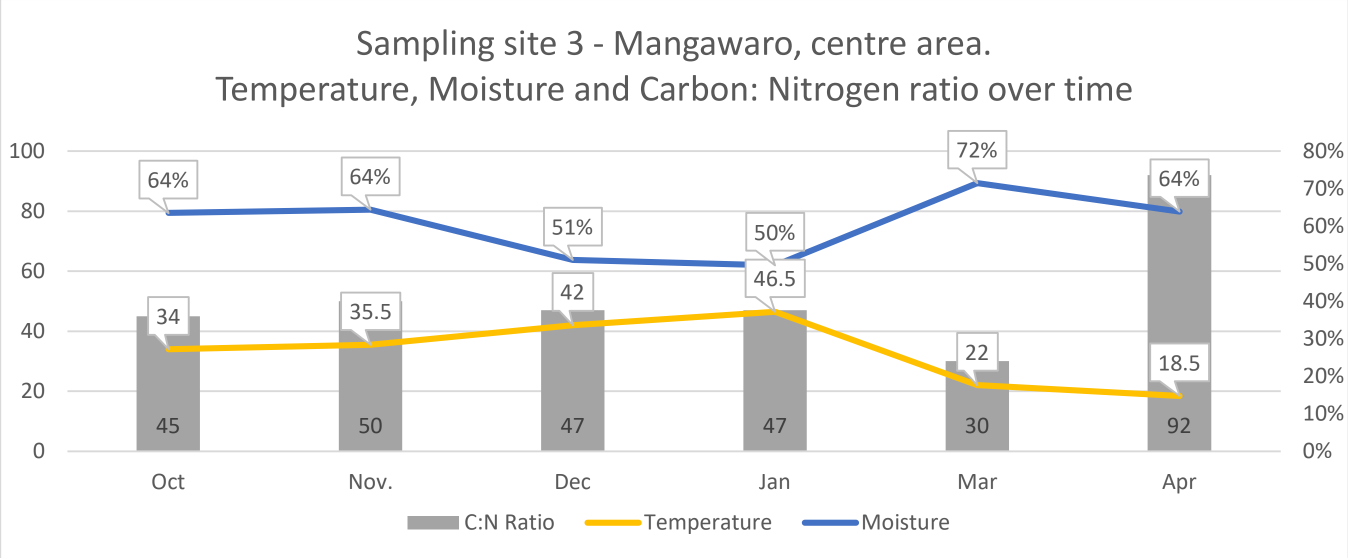
Dry matter percentage of detailed sampling sites over time.

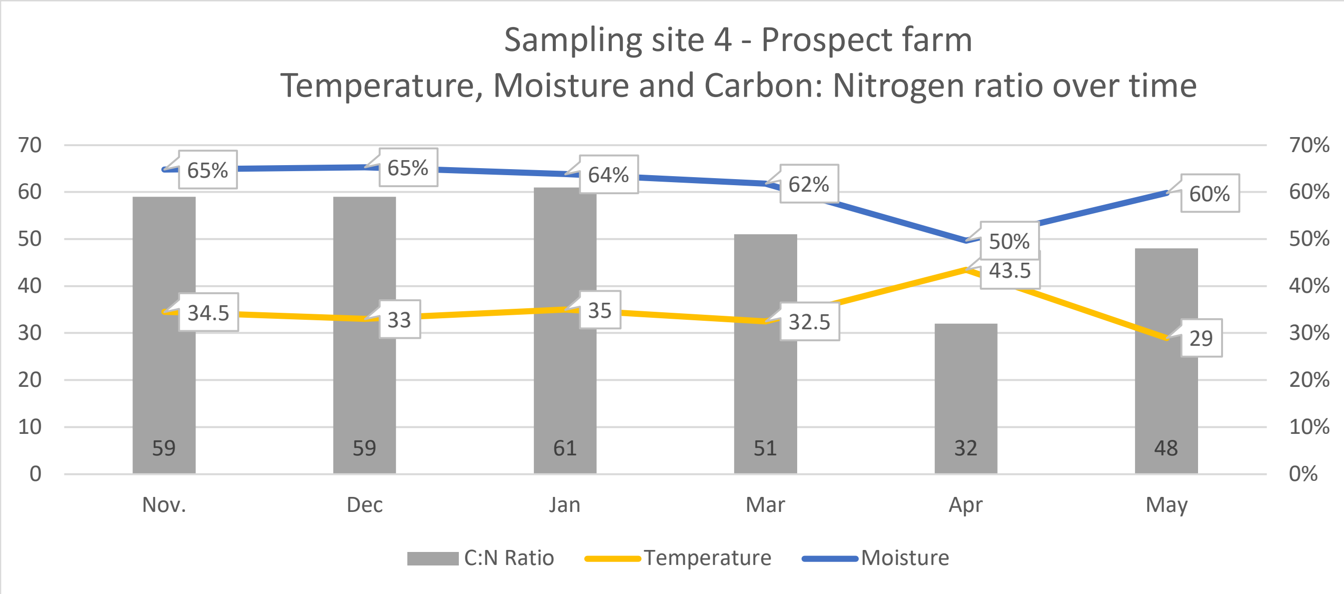
DRY MATTER %					clean chip							
Farm	Site			Depth	17/10/2022	Oct-22	Nov-22	Dec-22	Jan-23	Mar-23	Apr-23	May-23
Mangawaro	1	Feed Lane	Dry matt	300			30%	29%	21%	29%	29%	45%
Mangawaro	3	Centre	Dry matt	300		43%	52%	60%	71%	62%	57%	50%
Mangawaro	5	Centre	Dry matt	300			37%	36%	49%	50%	29%	36%
Prospect	4	Feed Lane	Dry matt	300			35%	35%	36%	38%	50%	40%
Prospect	5	Centre	Dry matt	300	45%	31%	36%	45%	54%	51%	57%	55%
Turkey Creek	1	Centre	Dry matt	300			52%	55%	64%	69%	67%	63%
					Recom.:	50%	50%	50%	50%	50%	50%	50%

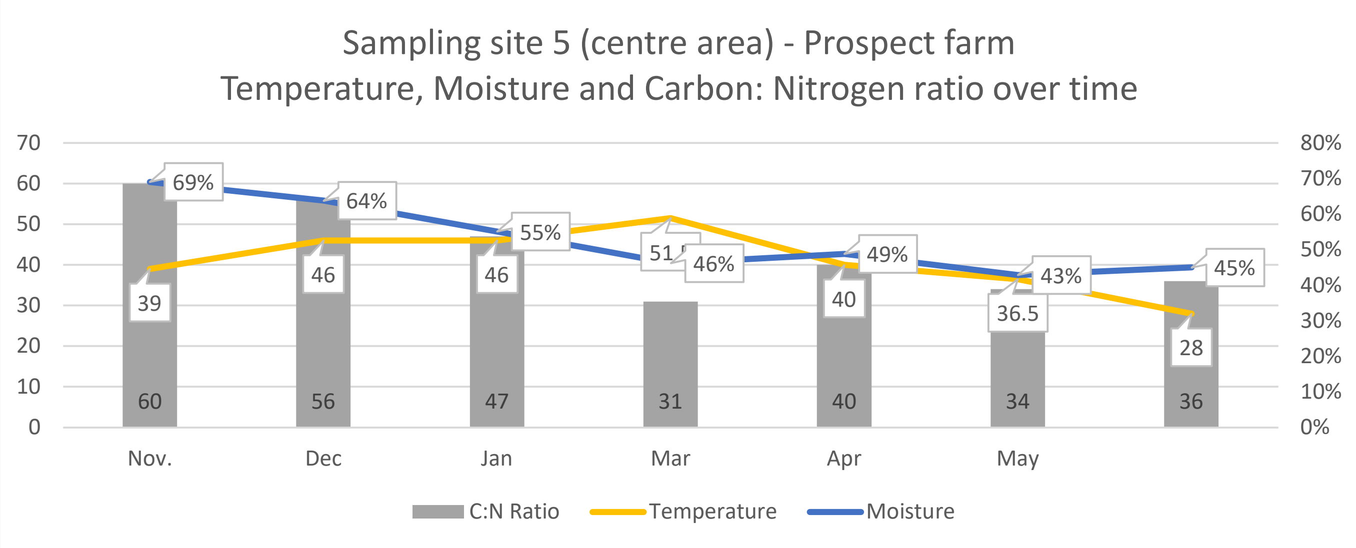
Appendix 5: Temperature, moisture, and Carbon: Nitrogen ratios by sampling site

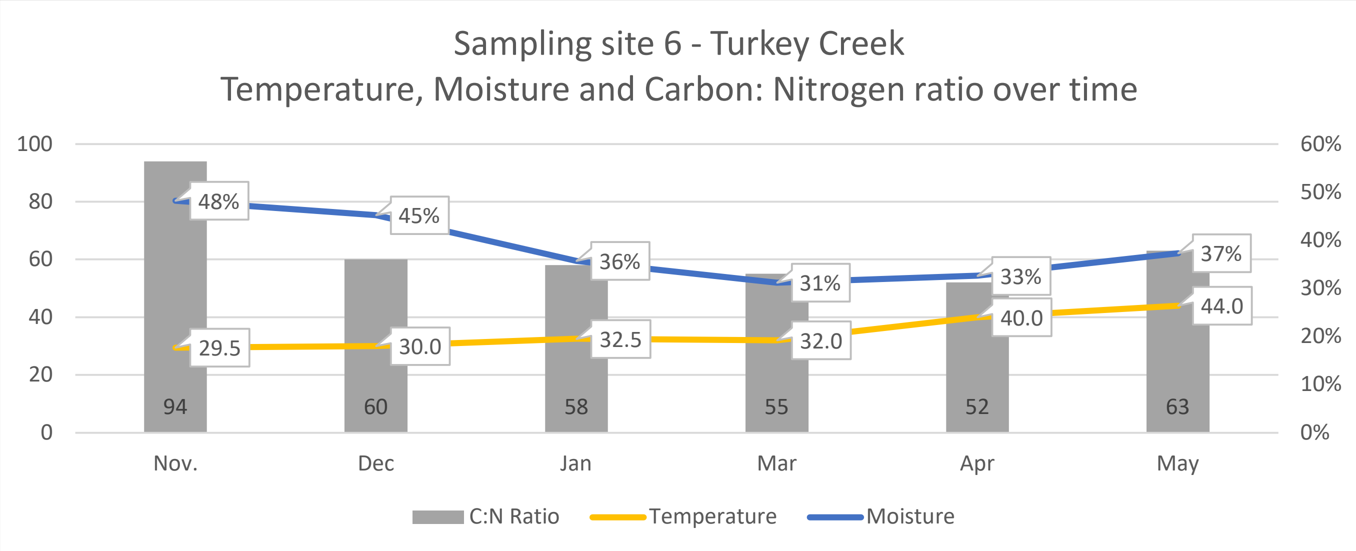





Sampling site 3 - Mangawaro, centre area.
Temperature, Moisture and Carbon: Nitrogen ratio over time
100
80
60
40
20
0
80%
70%
60%
50%
40%
30%
20%
10%
0%
64%
64%
51%
50%
72%
64%
34
35.5
42
46.5
22
18.5
45
50
47
47
30
92
Oct
Nov.
Dec
Jan
Mar
Apr
C:N Ratio
Temperature
Moisture


Sampling site 4 - Prospect farm
Temperature, Moisture and Carbon: Nitrogen ratio over time
70
60
50
40
30
20
10
0
70%
60%
50%
40%
30%
20%
10%
0%
65%
65%
64%
62%
50%
60%
34.5
33
35
32.5
43.5
29
59
59
61
51
32
48
Nov.
Dec
Jan
Mar
Apr
May
C:N Ratio
Temperature
Moisture


Sampling site 5 (centre area) - Prospect farm
Temperature, Moisture and Carbon: Nitrogen ratio over time
70
60
50
40
30
20
10
0
80%
70%
60%
50%
40%
30%
20%
10%
0%
69%
64%
55%
51
46%
49%
43%
45%
39
46
46
40
36.5
28
60
56
47
31
40
34
36
Nov.
Dec
Jan
Mar
Apr
May
C:N Ratio
Temperature
Moisture

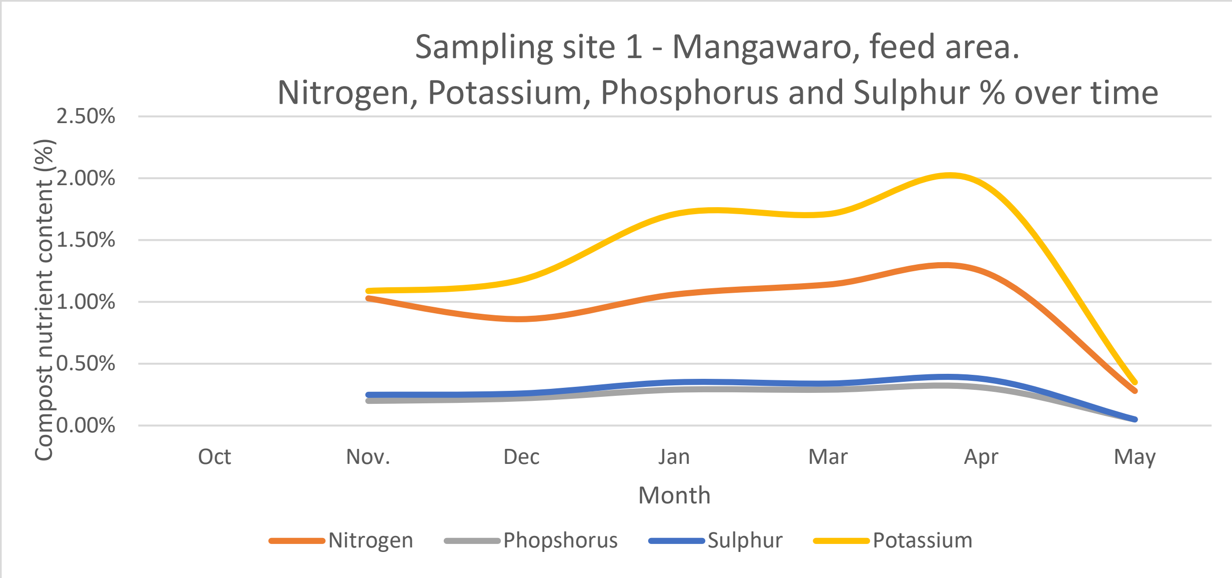

Sampling site 6 - Turkey Creek
Temperature, Moisture and Carbon: Nitrogen ratio over time
100
80
60
40
20
0
60%
50%
40%
30%
20%
10%
0%
48%
45%
36%
31%
33%
37%
29.5
30.0
32.5
32.0
40.0
44.0
94
60
58
55
52
63
Nov.
Dec
Jan
Mar
Apr
May
C:N Ratio
Temperature
Moisture

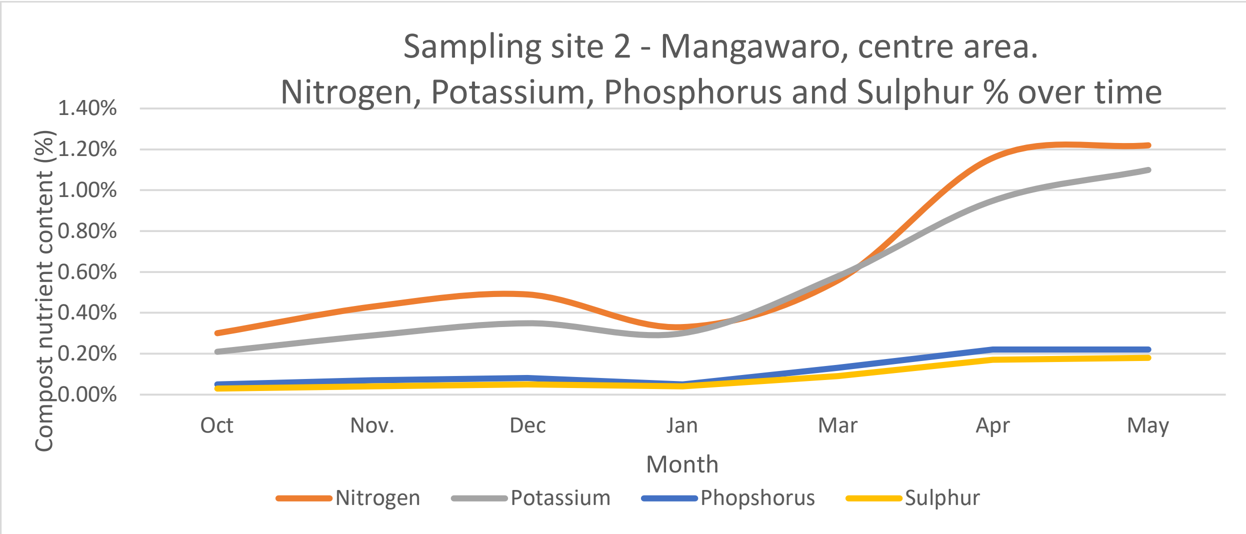
Appendix 6: Carbon to Nitrogen ratio

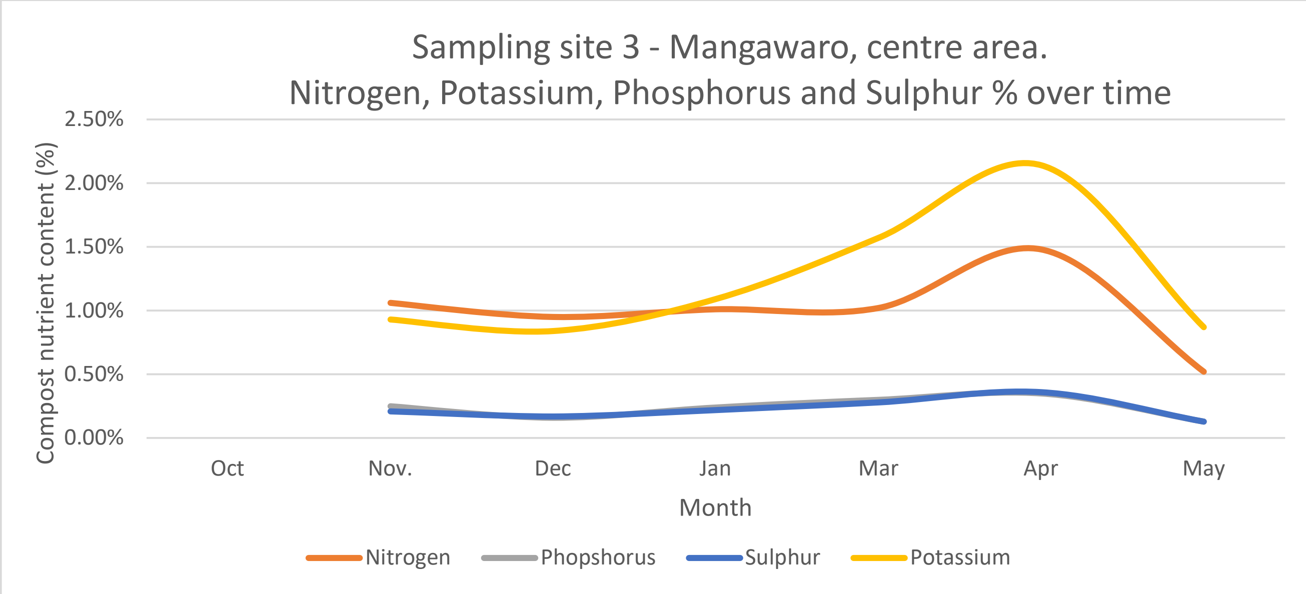
C:N ratio over time for detailed sampling sites.

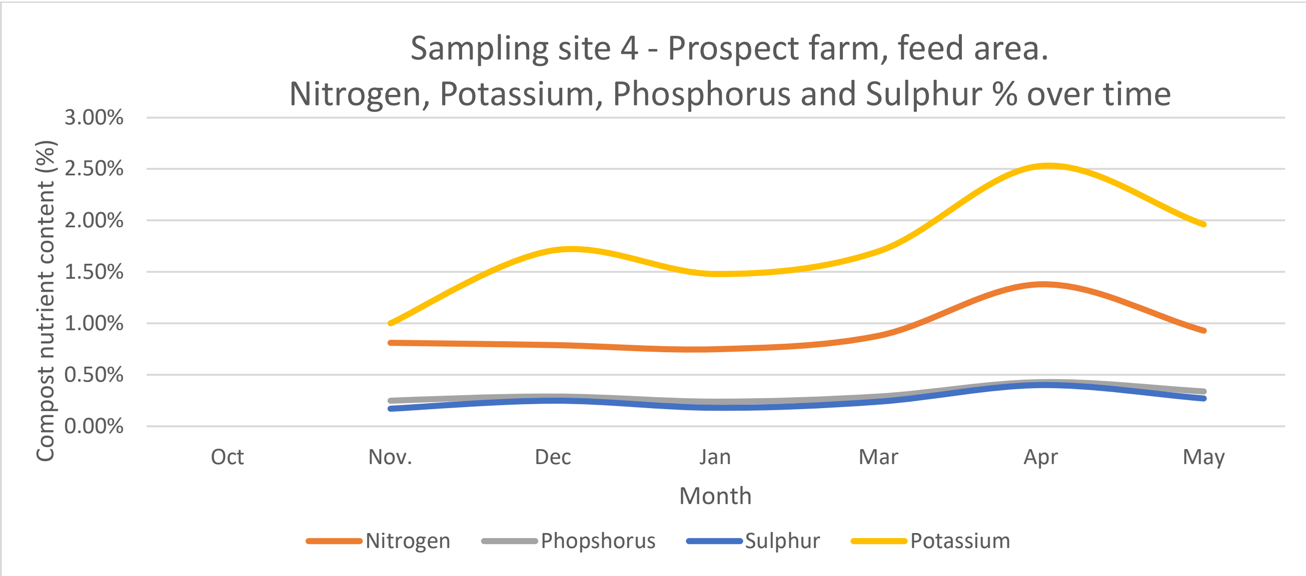
CARBON:NITROGEN RATIO						17/10/2022	15/11/2022	22/12/2022	24/01/2023	11/03/2023	16/04/2023	20/05/2023
Mangawaro	1	Feed Lane		300			45	54	43	40	36	170
Mangawaro	3	Centre		300		165	115	98	152	86	41	37
Mangawaro	5	Centre		300			45	50	47	47	30	92
Prospect	4	Feed Lane		300			59	59	61	51	32	48
Prospect	5	Centre		300	350	60	56	47	31	40	34	36
Turkey Creek	1	Centre		300			94	60	58	55	52	63
Coates new chip											430	

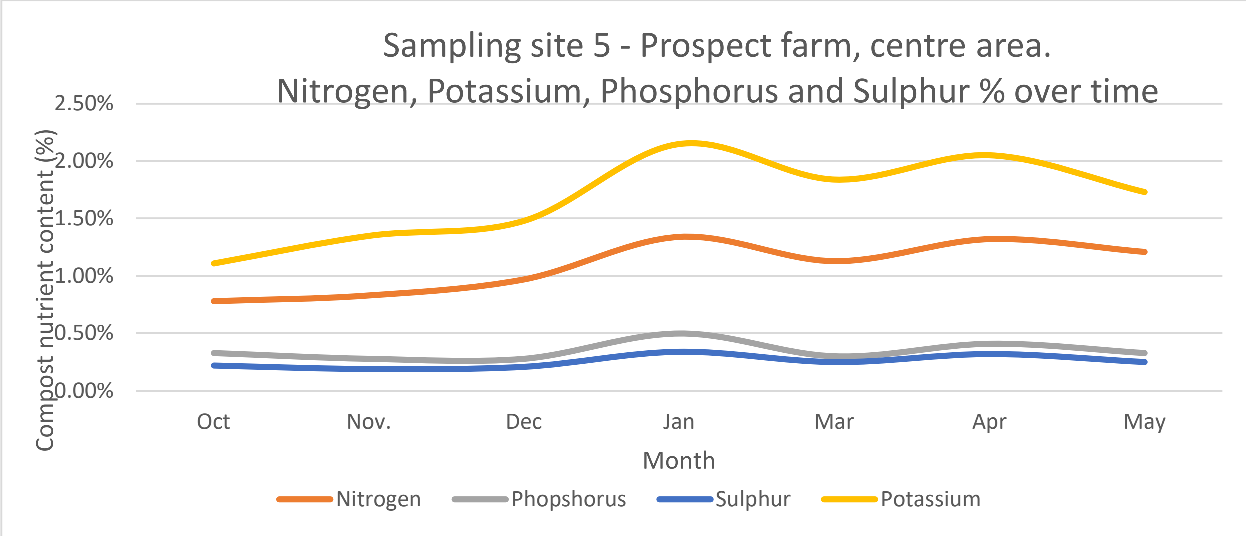
Appendix 7: Nitrogen, Potassium, Phosphorus and Sulphur (NPKS) percentages over time, by detailed sampling site.

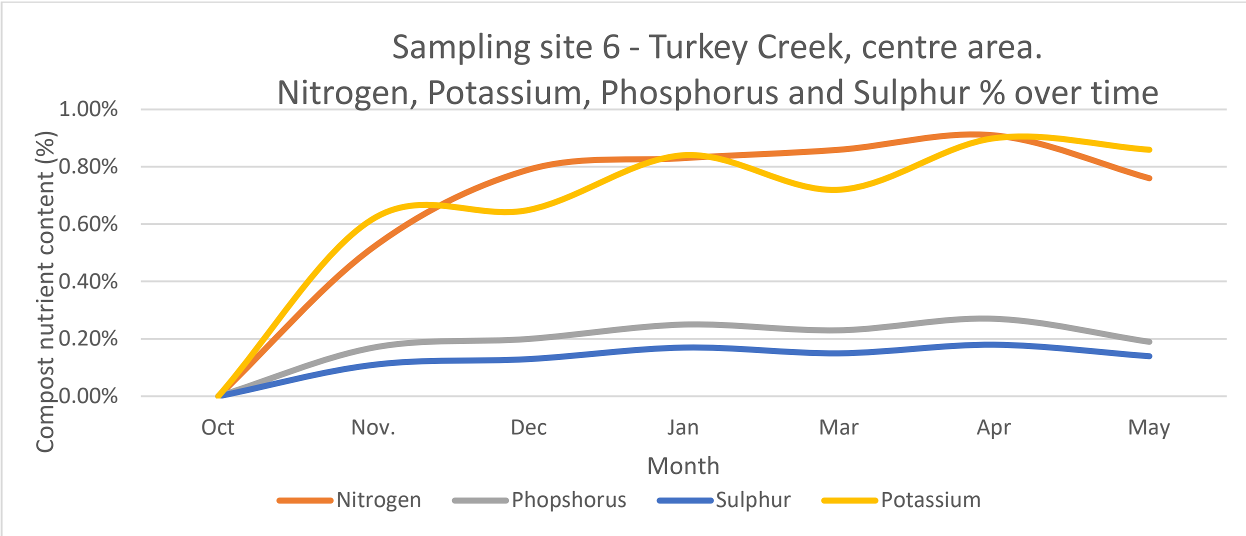





Sampling site 3 - Mangawaro, centre area.
Nitrogen, Potassium, Phosphorus and Sulphur % over time
Compost nutrient content (%)
2.50%
2.00%
1.50%
1.00%
0.50%
0.00%
Oct
Nov.
Dec
Jan
Mar
Apr
May
Month
Nitrogen
Phopshorus
Sulphur
Potassium

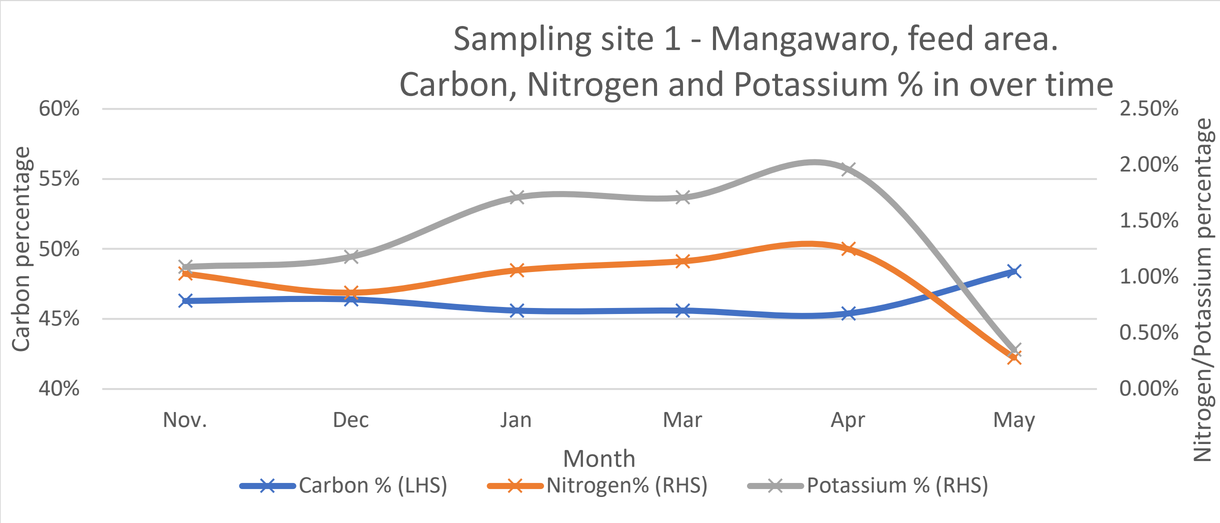

Sampling site 4 - Prospect farm, feed area.
Nitrogen, Potassium, Phosphorus and Sulphur % over time
Compost nutrient content (%)
3.00%
2.50%
2.00%
1.50%
1.00%
0.50%
0.00%
Oct
Nov.
Dec
Jan
Mar
Apr
May
Month
Nitrogen
Phopshorus
Sulphur
Potassium

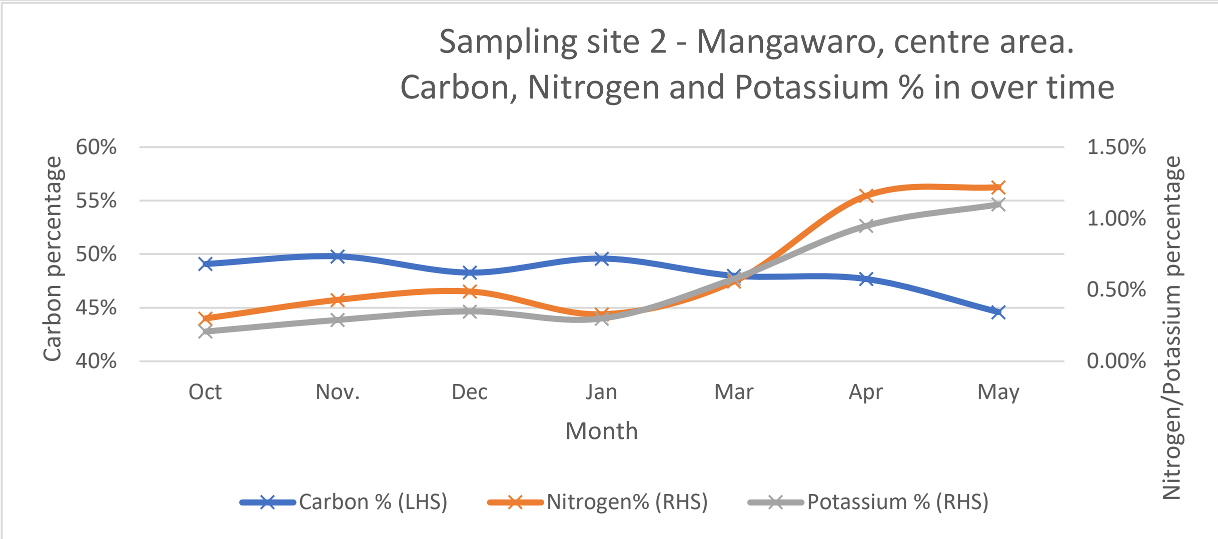

Sampling site 5 - Prospect farm, centre area.
Nitrogen, Potassium, Phosphorus and Sulphur % over time
2.50%
2.00%
1.50%
1.00%
0.50%
0.00%
Compost nutrient content (%)
Oct
Nov.
Dec
Jan
Mar
Apr
May
Month
Nitrogen
Phopshorus
Sulphur
Potassium

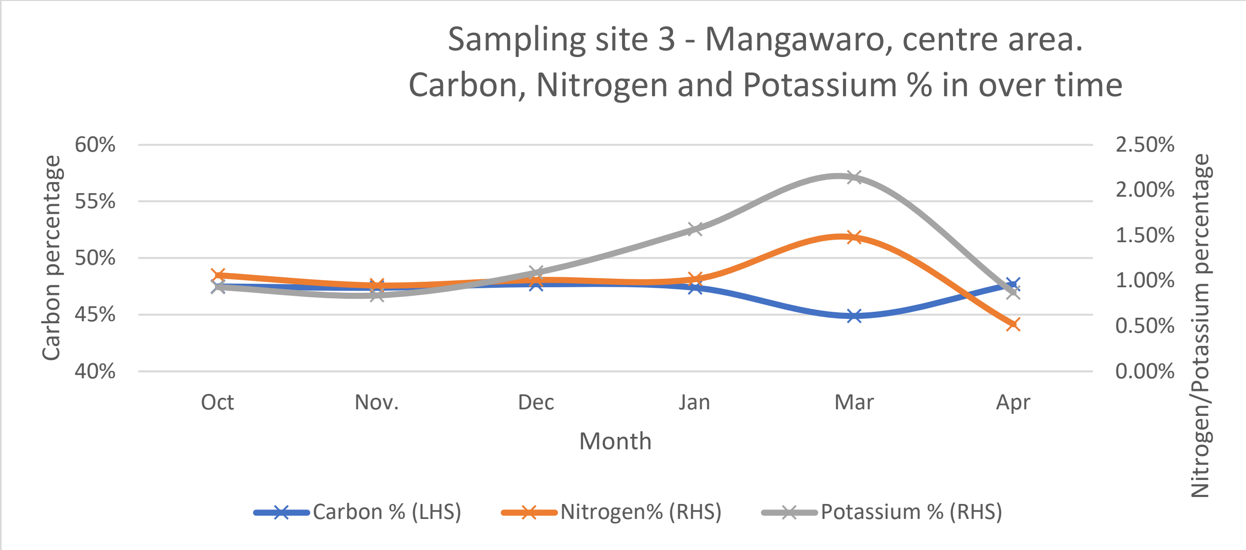

Sampling site 6 - Turkey Creek, centre area.
Nitrogen, Potassium, Phosphorus and Sulphur % over time
1.00%
0.80%
0.60%
0.40%
0.20%
0.00%
Compost nutrient content (%)
Oct
Nov.
Dec
Jan
Mar
Apr
May
Month
Nitrogen
Phopshorus
Sulphur
Potassium

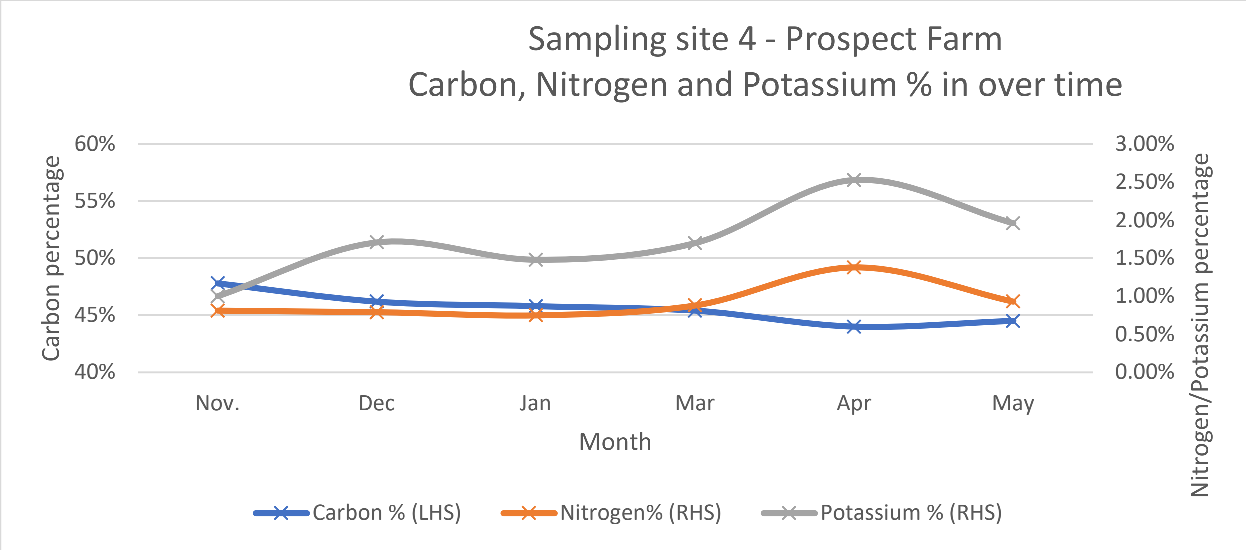
Appendix 8: Compost nutrient content

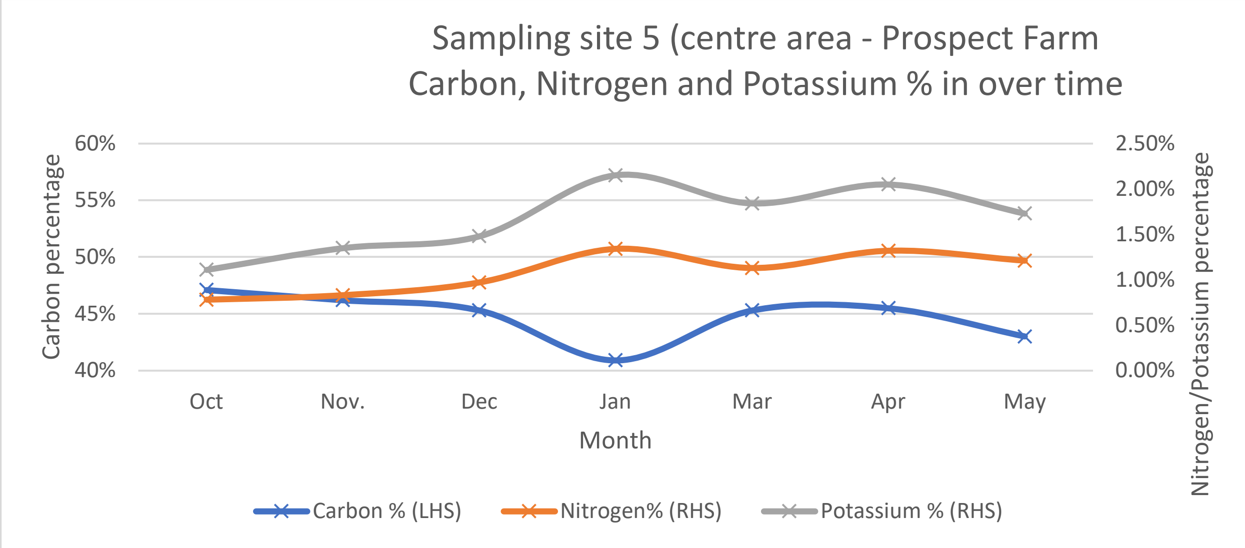
Carbon, Nitrogen and Potassium levels over time, by detailed sampling site

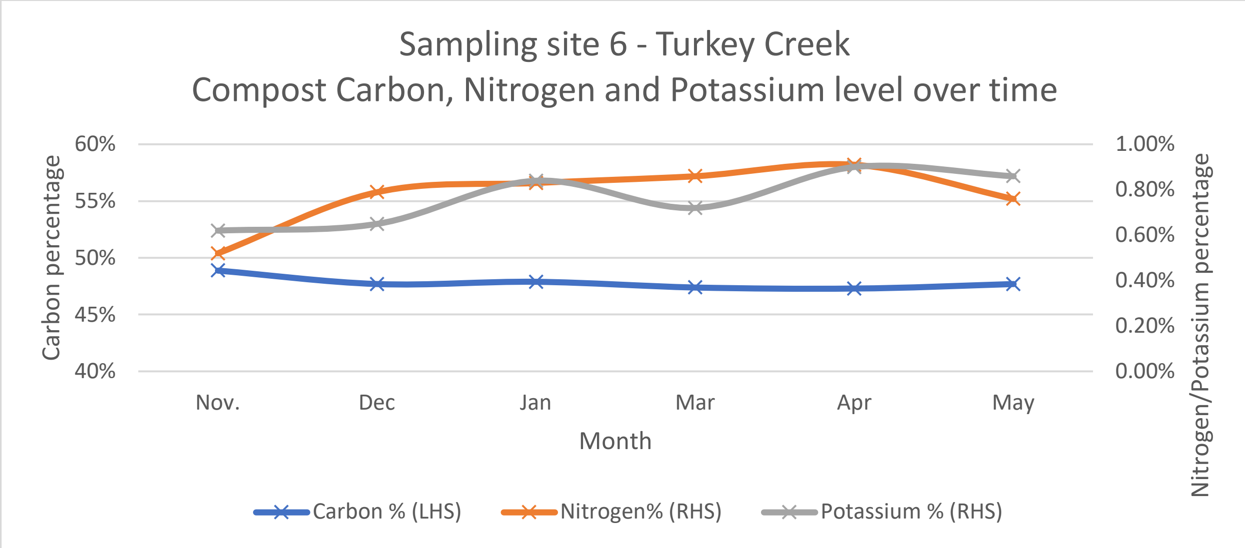





Sampling site 3 - Mangawaro, centre area.
Carbon, Nitrogen and Potassium % in over time
Carbon percentage
60%
55%
50%
45%
40%
2.50%
2.00%
1.50%
1.00%
0.50%
0.00%
Nitrogen/Potassium percentage
Oct
Nov.
Dec
Jan
Mar
Apr
Month
Carbon % (LHS)
Nitrogen% (RHS)
Potassium % (RHS)


Sampling site 4 - Prospect Farm
Carbon, Nitrogen and Potassium % in over time
Carbon percentage
60%
55%
50%
45%
40%
3.00%
2.50%
2.00%
1.50%
1.00%
0.50%
0.00%
Nitrogen/Potassium percentage
Nov.
Dec
Jan
Mar
Apr
May
Month
Carbon % (LHS)
Nitrogen% (RHS)
Potassium % (RHS)


Sampling site 5 (centre area - Prospect Farm
Carbon, Nitrogen and Potassium % in over time
Carbon percentage
60%
55%
50%
45%
40%
2.50%
2.00%
1.50%
1.00%
0.50%
0.00%
Nitrogen/Potassium percentage
Oct
Nov.
Dec
Jan
Mar
Apr
May
Month
Carbon % (LHS)
Nitrogen% (RHS)
Potassium % (RHS)


Sampling site 6 - Turkey Creek
Compost Carbon, Nitrogen and Potassium level over time
Carbon percentage
60%
55%
50%
45%
40%
1.00%
0.80%
0.60%
0.40%
0.20%
0.00%
Nitrogen/Potassium percentage
Nov.
Dec
Jan
Mar
Apr
May
Month
Carbon % (LHS)
Nitrogen% (RHS)
Potassium % (RHS)

Appendix 9: Bedding Expenses

Estimated annual bedding costs by case study farm across a range of prices and longevity												
	Prospect				Mangawaro				Turkey Creek			
	Longevity (years)				Longevity (years)				Longevity (years)			
Bedding cost ($/M^3)	0.5	1.0	1.5	2.0	0.5	1.0	1.5	2.0	0.5	1.0	1.5	2.0
$ 24	174,048	87,024	58,016	43,512	153,216	76,608	51,072	38,304	124,416	62,208	41,472	31,104
$ 26	188,552	94,276	62,851	47,138	165,984	82,992	55,328	41,496	134,784	67,392	44,928	33,696
$ 28	203,056	101,528	67,685	50,764	178,752	89,376	59,584	44,688	145,152	72,576	48,384	36,288
$ 30	217,560	108,780	72,520	54,390	191,520	95,760	63,840	47,880	155,520	77,760	51,840	38,880
$ 32	232,064	116,032	77,355	58,016	204,288	102,144	68,096	51,072	165,888	82,944	55,296	41,472
$ 34	246,568	123,284	82,189	61,642	217,056	108,528	72,352	54,264	176,256	88,128	58,752	44,064
$ 36	261,072	130,536	87,024	65,268	229,824	114,912	76,608	57,456	186,624	93,312	62,208	46,656
$ 38	275,576	137,788	91,859	68,894	242,592	121,296	80,864	60,648	196,992	98,496	65,664	49,248
$ 40	290,080	145,040	96,693	72,520	255,360	127,680	85,120	63,840	207,360	103,680	69,120	51,840

Appendix 10: Breakdown of detailed farm working expenses analysis.

Detailed farm working expenses analysis		Prospect				Mangawaro				Turkey Creek			
		2021/22	Change	modelled	Comments	2021/22	Change	modelled		2021/22	Change	modelled	
	Increase	$/kgMS	$/kgMS			$/kgMS	$/kgMS			$/kgMS	$/kgMS		
Wages and Salaries	Neutral	0.91			Removed l	0.91			benchmark	0.71			Benchmark
Animal health	Neutral	0.22				0.20				0.23			
Breeding & Herd improvement	Neutral	0.23				0.24				0.08			
Farm dairy expenses	Neutral	0.01				0.14				0.08			Benchmark
Electricity	Neutral	0.07				0.00			BM elect.	0.07			
Feed expenses		2.38				0.00				1.48			
Winter/summer feed crops	Decrease		-0.20		Reduced w	0.05	-0.05		no swedes or turnip		-0.06		
Supplements imported	Increase				Offset by s	0.72							
Supplements made on farm (or SB)	Increase		0.10		Additonal	0.71					0.06		
Grazing & support block expenses						0.00							
Young stock grazing	Neutral				on SB - no	0.00							
Winter cow grazing	Decrease				SB Feed gr	0.04	-0.04						
Support block expenses					SB adjustm	0.00							removed S
Fertiliser	Neutral	1.08			May decre	1.64				1.05			
Nitrogen	Neutral	0				0.00				0			
Regrassing	Decrease	0.05	-0.01			0.09	-0.01			0.01			
Weed & Pest	Neutral	0.02				0.10				0.08			
Vehicles	Increase	0.13	0.03			0.17	0.03			0.07	0.02		
Fuel	Increase	0.17	0.02			0.23	0.02		removed 5	0.19	0.02		
R & M – Land & buildings	Increase	0.27				0.41				0.35			Adjusted d
R & M – Plant & equipment	Increase	0.17				0.12	0.05		132k on flo	0.22			
Freight & General	Neutral	0.03				0.04				0.03			
Administration	Neutral	0.13				0.08				0.06			
Insurance	Increase	0.11	0.01			0.25	0.01			0.12	0.01		
Rates	Neutral	0.03				0.10				0.09			
Additional mootel costs													
- Annual woodchip @ 3m^3/cow			0.17			0.00	0.18				0.17		
Farm working expenses (cash)		6.01	0.12	6.13	2.0%	6.24	0.19	6.43		4.92	0.22	5.14	
Depreciation	Increase	0.81				0.25				0.41			
Mootel			0.14		Assumed $	0	0.15				0.15		
Plant & equip			0.08		IRD rate of	0	0.12				0.00		
Total depreciation		0.81	0.22	1.03	27%	0.25	0.27	0.52		0.41	0.15	0.56	
Total operating costs		6.82	0.34	7.16		6.49	0.46	6.95		5.33	0.37	5.70	
KgMS:		334388				186064				162738			
total farm working exps.:		2,009,672	40,127	2,049,798	2.0%	1,160,811	35,352	1,196,163	3.0%	800,671	35,802	836,473	4.5%
total depreciation		270,854	73,673	344,527	27.2%	46,516	50,791	97,307	109.2%	66,723	23,984	90,707	35.9%
Total $:		2,280,526	113,799	2,394,325		1,207,327	86,143	1,293,471		867,394	59,787	927,180	