Final Report

P1e Nutritional Value of Kikuyu-based pasture systems

This project was led by Prof. Juan Insua,
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Dairy UP (Phase 1) was a $16 million, five-year industry driven project with a portfolio of 10 research, development and adoption projects collectively aiming to realise three primary objectives:

- Increase Productivity and Profitability by unlocking the potential of milk, the cow and water,
- De-risking the industry and
- Developing new markets.

A key part of Dairy UP was a coordinated network of partner farms across New South Wales (and beyond) providing valuable insights into real world application of new practices, including the challenges and benefits of new innovative technologies.

Dairy UP made a big contribution to dairy research and development rejuvenation, (attracting new researchers, PhD students and Industry investment).

Dairy UP was funded through the Australian and NSW Government's Bushfire Industry Package – Sector Development Grant (BIP-SDG) program, with cash co-contributions from Dairy Australia, The University of Sydney's Dairy Research Foundation, Local Land Services, Norco, Leppington Pastoral Co Ltd and Dairy NSW; and in kind contributions by all the above organisations plus NSW DPI (Biosecurity and Food Safety; Agriculture), Scibus, Australia Fresh Milk Holding Ltd, Dairy Connect and NSW Farmers.

This project was delivered jointly by University of Sydney's Dairy Research Foundation, Scibus, Department of Primary Industries and Regional development.

Proudly funded by

Delivery organisations

Additional program supporters, collaborations or partnerships

Charles Sturt University | DairyBio | DataGene | Eagle Direct | Entegra | Macquarie University | NSW EPA | smaXtec | UC Davis | University of Technology Sydney

Contents

1. Executive Summary....4
2. Project Overview....5
3. Abbreviations....5
4. Project Background and Rationale....6
5. Project Objectives....7
6. Materials and Methods....7
7. Key Findings....8
8. Outputs....11
9. Applications and Impacts....11
10. Future Research Opportunities and Actions....12
11. Project-wide Dissemination....12
12. Conclusions and Recommendations....13
13. Annexes....14
14. References....15

1. Executive Summary

The P1e subproject addressed the rapid decline in Kikuyu pasture nutritive value during regrowth. The project aimed to a) predict, in real-time, rapid, short-term (daily) changes in the nutritive value of kikuyu pastures through modelling of morphophysiological aspects of plant tissue; b) quantify the rate and main drivers of nutritive value decline in Kikuyu pastures during regrowth; and c) generate quantitative benchmarks (e.g. leaf lifespan, rate of fibre digestibility decline) to support improved grazing management decisions. To achieve these goals, the project involved a literature review, a field experiment in summer-autumn repeated across two consecutive years (2023-2024) that included non-destructive and destructive sampling, detailed nutrient analysis at leaf-level and the testing of the Morphogenetic and Digestibility of Pasture (MDP) model to predict quality changes.

The project quantified the main drivers of digestibility decline and calibrated a mechanistic modelling framework to predict short-term changes in pasture nutritive value. Results demonstrated that leaf ageing was the primary determinant of nutritive value decline, with neutral detergent fibre digestibility (NDFD) and dry matter digestibility (DMD) decreasing consistently with thermal time (growing degree days, GDD) of regrowth. Leaf lifespan represents the thermal time of regrowth corresponding to the onset of senescence of the first leaf that appeared after defoliation, and the ageing process explained approximately 70% of the variation in NDFD and more than 60% of the variation in DMD. In this context, changes in neutral detergent fibre (NDF) content were relatively small, indicating that fibre digestibility (NDFD) rather than fibre concentration (NDF) was the main driver of quality decline. leaf lifespan was quantified at approximately 400 GDD, providing a new quantitative reference for this species. The MDP model accurately predicted digestibility dynamics ($R^2 \approx 0.94$), demonstrating strong potential for real-time prediction of Kikuyu pasture nutritive value. The project also identified practical grazing thresholds (~300–350 GDD or 3–4 leaves per tiller) to support improved grazing management and milk production efficiency. In addition, the work establishes a strong foundation for future integration of nutritive value predictions with remote sensing technologies, pasture monitoring systems, and digital agriculture platforms.

2. Project Overview

Item	Description
Project Title	Nutritional Value of Kikuyu-based pasture systems
Funding Body	Dairy UP
Dairy UP Project	P1e
Project Duration	2021-2026
Lead Organisation	The University of Sydney's Dairy Research Foundation
Project Lead	Prof. Juan Insua, The University of Mar del Plata
Key Collaborators	Unidad Integrada Balcarce, The University of Mar del Plata NSW DPIRD Local Land Services (Hunter)

3. Abbreviations

ADSA — American Dairy Science Association
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ANOVA — Analysis of Variance
DMD — Dry Matter Digestibility
DM — Dry Matter
GDD — Growing Degree Days
JDS — Journal of Dairy Science
MDP — Morphogenetic and Digestibility of Pasture
NDF — Neutral Detergent Fibre
NDFD — Neutral Detergent Fibre Digestibility
NDVI — Normalized Difference Vegetation Index
NS — Not Significant
NSW — New South Wales
RMSE — Root Mean Square Error
R^2 — Coefficient of Determination
USYD — The University of Sydney

4. Project Background and Rationale

Kikuyu grass (*Cenchrus clandestinus*; formerly *Pennisetum clandestinum*) is a tropical grass adapted to both tropical and temperate climates. It is a fast-growing species producing dry matter higher than most tropical pastures (Fulkerson et al., 2007), but of moderate nutritive value overall (García et al., 2014; Marais, 2001). Kikuyu's leaves lose digestibility very rapidly if not grazed at the right time (Fulkerson et al., 2010; Reeves et al., 1996), with the window of opportunity being generally smaller than for temperate grasses (Fulkerson et al., 1999), at times making it a somewhat challenging species to manage.

Kikuyu is limited by nutritive value rather than forage yield, with nutritive value being related to leaf:stem ratio (Marais, 2001; Reeves et al., 1996). Previous studies have shown that as regrowth progresses, Kikuyu pastures rapidly accumulate stem and dead material, resulting in declines in crude protein (CP), dry matter digestibility (DMD), and animal intake potential (Fulkerson et al., 1999; Fulkerson et al., 2010). Reeves et al. (1996) reported a significant decline in dry matter digestibility (DMD) after reaching the 4.5 leaf stage during regrowth (i.e. when each tiller had grown 4.5 leaves or more). This was due to a marked change in the proportion of leaf to stem and dead material content when the sward was harvested to ground level.

For temperate species like perennial ryegrass (*Lolium perenne* L.) and tall fescue (*Festuca arundinacea* Schreb.), changes in nutritive value of leaves have been strongly associated with both leaf age and leaf length (Insua et al., 2017; 2020). Leaf ageing progressively reduces fibre digestibility due to cell wall lignification, while longer leaves generally contain a greater proportion of structural tissues with lower digestibility. These relationships allowed changes in nutritive value to be successfully modelled and predicted (Insua et al., 2019c) using the Morphogenetic and Digestibility of Pasture (MDP) model (Insua et al., 2019a). However, for Kikuyu, the effects of leaf age and leaf length on the digestibility of the cell wall (neutral detergent fibre, NDF) component have not been elucidated yet.

5. Project Objectives

- To predict, in real-time, rapid, short-term (daily) changes in the nutritive value of kikuyu pastures through modelling of morphophysiological aspects of plant tissue.
- Quantify the rate and main drivers of nutritive value decline in Kikuyu pastures during regrowth.
- Generate quantitative benchmarks (e.g. leaf lifespan, rate of NDFD decline) to support improved grazing management decisions.

6. Materials and Methods

- **Literature review**: A comprehensive review was conducted to identify and quantify the main drivers of nutritive value decline in Kikuyu, supporting model development.
- **Experimental design:** A field experiment was conducted at the University of Sydney's Corstorphine dairy farm (Camden, NSW, Australia) across three independent summer regrowth periods (P1, P2 and P3) during 2022–2024 on a Kikuyu pasture using small (~10 m^2), replicated plots ($n = 2$).
- **Pasture management and sampling:** During regrowth, destructive harvests (pasture cuts) were conducted at successive leaf stages (L1–L6), corresponding to the appearance of new leaves per tiller. At each stage, a randomly selected 1 m^2 area per plot was harvested by cutting the pasture at ground level. Prior to cutting, herbage mass on the randomly selected area was estimated using a calibrated rising plate meter.
- **Morphogenetic measurements:** Leaf appearance, elongation, lifespan, final leaf length, and live leaf number were measured every 2–3 days on permanently marked tillers. Thermal time (GDD) was used to describe regrowth dynamics.
- **Nutritive value analysis:** Leaf blade samples were freeze-dried and analysed for NDF, 24-h NDFD, and DMD.
- **Model parameterisation and evaluation:** The MDP model was parameterised using data from P1 and P2 and independently evaluated using P3 data.
- **Statistical analysis:** Data were analysed using ANOVA and regression approaches to assess relationships between regrowth, morphology, and nutritive value variables. Model performance was evaluated using R^2 and RMSE.

7. Key Findings

- Changes in NDF content were relatively small, indicating that digestibility rather than fibre concentration was the main driver of quality decline (Table 1).
- Kikuyu pastures showed a rapid and consistent decline in NDFD during regrowth (Figure 1, Table 1), primarily driven by leaf tissue ageing (Figure 2).
- The nutritive value changes are better explained by thermal time than by herbage mass.
- The ageing process explained approximately 70% of the variation in NDFD and more than 60% of the variation in DMD.
- Leaf lifespan was quantified at approximately 400 GDD, providing a new quantitative reference for this species (Table 2).
- The MDP model accurately predicted NDFD dynamics ($R^2 \approx 0.94$; RMSE ≈ 1.9%), demonstrating strong capacity to simulate short-term changes (Figure 1).

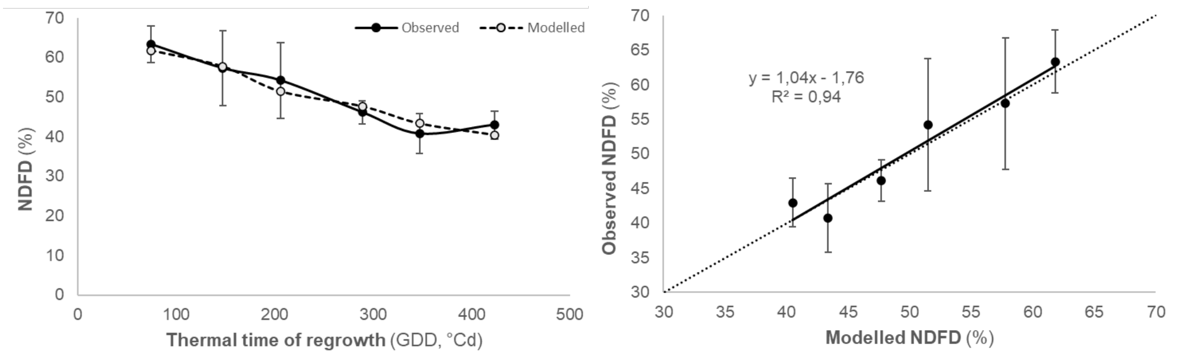

Figure 1. *Evaluation of nutritive value sub-model performance with observed and predicted leaf blade NDFD for Period 3 at leaf stages L1–L6 (left), and the relationship between observed and simulated NDFD compared to the 1:1 line (right) in Kikuyu pastures. Dotted lines show the 1:1 reference (y = x).*

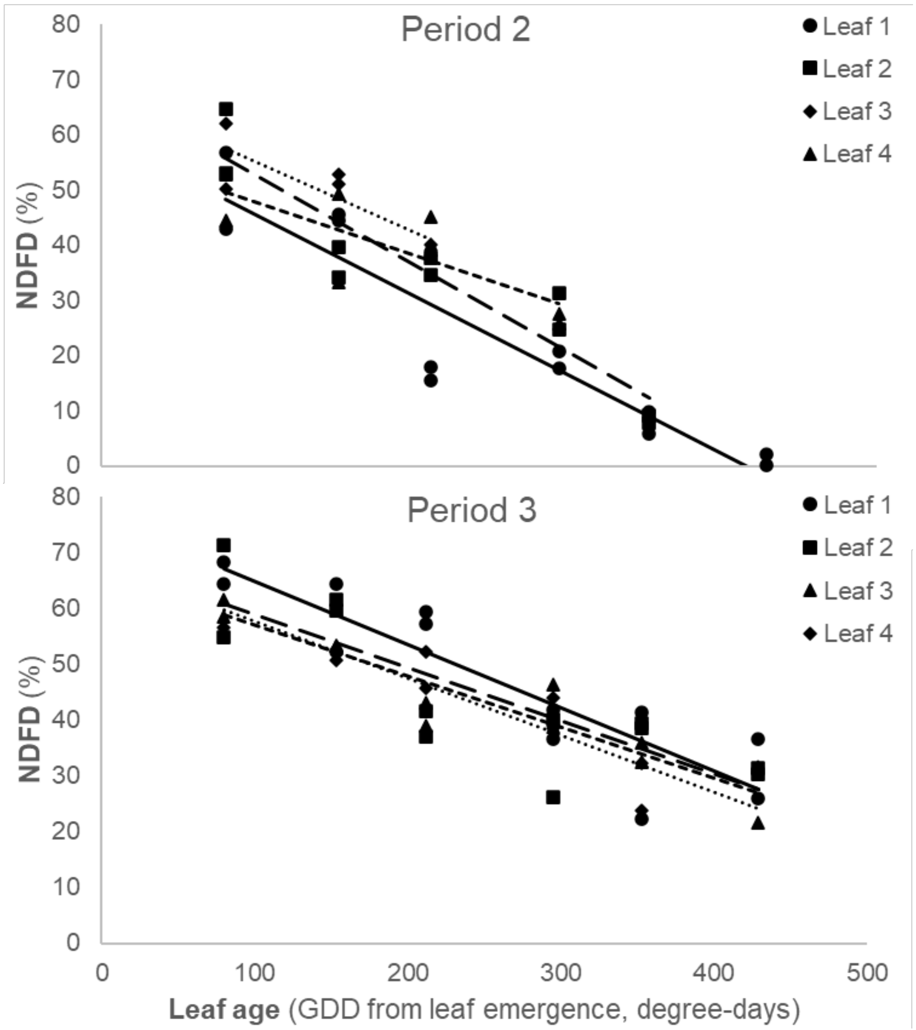

Figure 2. *Relationship between leaf age and digestibility of leaf NDF (NDFD). Leaf age (expressed in growing degree-days, GDD, from emergence) is for the first four leaves produced following cutting of Kikuyu pasture of Period 2 and Period 3. Symbols denote successive leaves: L1 (circles); L2 (squares); L3 (triangles); L4 (diamonds). Lines describe the linear functions for each successive leaf. P1 data are omitted due to no replication.*

Table 1. *Whole-sward nutritive value of leaf blades in different leaf stage of tillers of Kikuyu regrowths of three experimental periods regrowths (P1, P2 and P3). SE: standard error.*

Leaf Stage*	NDF (%)			NDFD (%)			DMD (%)		
	P1	P2	P3	P1	P2	P3	P1	P2	P3
L1	49.8	57.8	60.9	54.8	49.9	66.3	65.6	59.2	60.3
L2	49.5	49.3	57.8	57.9	52.0	60.8	67.2	64.5	62.9
L3	51.3	47.5	61.4	60.2	37.3	59.7	67.7	58.1	61.0
L4	52.6	54.2	63.6	59.1	41.6	45.4	66.6	56.5	48.5
L5	55.1	49.4	64.1	52.6	42.0	40.5	62.0	59.6	45.7
L6	55.7	52.3	63.0	52.2	37.4	45.7	61.4	55.4	49.4
Mean	52.3	51.8	61.8	56.1	43.4	53.1	65.1	58.9	54.6
DS	2.6	3.8	2.3	3.4	6.2	10.5	2.7	3.2	7.6

Table 2. *Morphogenesis characterisation of Kikuyu regrowth for three experimental periods (P1, P2 and P3).*

Variable	**P1**	**P2**	**P3**	**Mean**
Regrowth period (days)	31	35	35	34 ± 2
Regrowth period (GDD, °Cd)	622	601	721	648 ± 64
Mean daily temperature (°C)	23.2	21.0	23.8	23 ± 1
Herbage mass accumulation (kg DM ha^{-1})	NS	3506 ± 133	3472 ± 62	3489 ± 24
Accumulated leaves (leaves tiller^{-1})	7.5 ± 1.3	8.1 ± 0.8	8.5 ± 1.0	8 ± 1
Growing leaves (leaves tiller^{-1})	1.8 ± 0.6	2.5 ± 0.9	1.7 ± 0.6	2.0 ± 0.4
Leaf lifespan (leaves tiller^{-1})	4.4 ± 0.6	3.5 ± 0.6	4.5 ± 0.9	4.1 ± 0.6
Leaf lifespan (days)	20.7 ± 3.1	15.1 ± 3.0	20.3 ± 4.1	19 ± 3
Leaf lifespan (GDD, °Cd)	396 ± 60	342 ± 75	401 ± 80	380 ± 33
Leaf appearance interval (days)	3.9 ± 0.8	3.0 ± 0.7	3.7 ± 0.8	3.5 ± 0.5
Leaf appearance interval (GDD, °Cd)	76 ± 15	63 ± 16	73 ± 16	71 ± 7
Leaf elongation rate (cm leaf^{-1} day^{-1})	1.16 ± 0.4	0.87 ± 0.2	0.53 ± 0.3	0.90 ± 0.30
Senescence rate (cm leaf^{-1} day^{-1})	0.58 ± 0.3	0.63 ± 0.3	0.45 ± 0.3	0.60 ± 0.10

8. Outputs

- A calibrated MDP model that can simulate leaf digestibility dynamic of kikuyu during pasture regrowth.
- Quantification of the main drivers of nutritive value decline in Kikuyu pastures during regrowth, identifying leaf ageing as the primary factor.
- First quantitative estimates for Kikuyu of key morphogenetic parameters, including leaf lifespan (~400 GDD) and rate of decline in NDFD (~0.17% per GDD).
- Development of a mechanistic framework linking leaf morphogenesis with pasture nutritive value dynamics.
- Better understanding of the nutritive value decline of kikuyu during regrowth for the evaluation of elite candidate lines of kikuyu.
- Generation of quantitative thresholds (e.g. 300–350 GDD regrowth) to support improved grazing management decisions.
- Peer-reviewed manuscript submitted to the Journal of Dairy Science.
- Presentation of results at the 2025 American Dairy Science Association (ADSA) annual meeting.

9. Applications and Impacts

At the cow and farm level, this project quantified the rapid decline in Kikuyu nutritive value during regrowth and identified practical grazing thresholds to minimise reductions in dry matter intake and milk production. Results indicated that maintaining grazing intervals shorter than 300–350 GDD (approximately 3–4 leaves per tiller) is critical to avoid major declines in digestibility. Previous studies indicate that a 10-unit reduction in NDFD may reduce milk production by approximately 2.5 kg per cow per day, highlighting the importance of timely grazing management.

At the industry and advisory level, improved management of Kikuyu pasture quality has the potential to enhance feed utilisation efficiency and reduce variability in milk production associated with poor pasture digestibility. The quantitative thresholds and modelling framework developed in this project provide new information that can support advisory services, digital agriculture platforms, and decision-support tools for pasture-based dairy systems.

In addition, the relationships identified between leaf morphology and digestibility provide a useful framework for future breeding and selection of Kikuyu genotypes with improved nutritive value characteristics.

10. Future Research Opportunities and Actions

Future research should validate these findings under commercial dairy farm conditions across a wider range of environments, management strategies, and seasonal conditions. Additional work is also needed to incorporate other drivers of pasture growth and nutritive value, such as nitrogen status and water availability, into the modelling framework to improve predictive capacity.

There is strong potential to integrate the model with real-time weather, remote sensing, NDVI, and on-farm pasture monitoring technologies to support the development of practical decision-support tools for grazing management. Current work is also focused on transitioning the model from an Excel platform to Python-based applications to facilitate scalability and future integration into digital agriculture systems.

Further opportunities include evaluating whether this modelling approach can support improved management of Kikuyu silage systems and exploring the integration of pasture biomass accumulation with predicted changes in nutritive value to better guide grazing and harvest decisions.

11. Project-wide Dissemination

Findings from the project were presented at the 2025 American Dairy Science Association (ADSA) Annual Meeting in the USA, reaching an international audience of researchers and dairy industry professionals. Results were also communicated internally through Dairy UP presentations and updates to project collaborators and stakeholders.

The project generated one peer-reviewed manuscript submitted to the *Journal of Dairy Science* (JDS), contributing to the dissemination of new knowledge on the nutritive value dynamics of Kikuyu pastures and pasture quality modelling.

In addition, project outcomes were disseminated through Dairy UP newsletter articles and webinars, supporting engagement with industry advisors, farmers, and the broader Dairy UP network.

Table 2. *Scientific publications from this project*

Author	Title	Journal	Year Published
Insua et al.	Understanding and predicting changes in nutritional value of Kikuyu	JDS	Submitted

12. Conclusions and Recommendations

The P1e project successfully quantified the short-term dynamics of nutritive value decline in Kikuyu pastures and demonstrated that these changes can be accurately predicted using a morphogenetic–digestibility modelling approach. Across experimental periods, consistent declines in NDFD and DMD during regrowth confirmed that leaf ageing is the primary driver of nutritive value loss, while leaf morphology influenced the rate and extent of this decline.

The project also demonstrated that thermal time is a more robust predictor of nutritive value dynamics than herbage mass alone, highlighting the importance of considering growth conditions and leaf developmental stage when interpreting pasture nutritive value. The MDP model accurately reproduced observed patterns of digestibility decline, providing a mechanistic framework capable of predicting short-term changes in Kikuyu nutritive value from temperature-driven leaf development processes.

These findings have direct implications for grazing management, as they provide quantitative thresholds and predictive tools to support better timing of grazing and improved utilization of Kikuyu pastures. In addition, the work establishes a strong foundation for future integration of nutritive value predictions with remote sensing technologies, pasture monitoring systems, and digital agriculture platforms.

Across the project, results were disseminated through international scientific conferences, Dairy UP activities, newsletter articles, and a peer-reviewed manuscript submitted to the *Journal of Dairy Science*, contributing to industry and scientific engagement.

13. Annexes

Table 3. *Conference presentations, abstracts and other meetings*

Authors	Title	Presentation Type	Conference/ Event	Location	Year	Audience
Insua et al.	Understanding and predicting changes in nutritional value of Kikuyu	Refereed abstract/Oral presentation	ADSA Annual Meeting	Louisville, USA	**2025**	40

Table 4. Technical reports, pamphlets, published material and other media engagements

Authors	Title	Place Published	Year
Insua, J., García S.	Kikuyu nutritional value	Dairy UP Website	2024
Insua, J., Correa-Luna, M.	P1e – Understanding and predicting changes in nutritional value of Kikuyu	Dairy UP Webinar	2024
Insua, J.	P1e Nutritional Value of Kikuyu-based pasture systems	Dairy UP Webinar	2022

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