Forage Condition Measurement Methods:
Farming for the Future pilot livestock research program

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Contents

Document purpose

This document describes the methods used to calculate the Forage Condition Index used in the *Farming for the Future* Phase 2 pilot livestock research project.

Abstract

Farming for the Future is a research project aimed at demonstrating the relationship between natural capital and farm business performance. Part of this evidence-based research has included the development of a Forage Condition Score and Forage Condition Index. Our scoring system focused on characteristics of pasture species thought to govern the generation of dependable forage for livestock. It used well-accepted characteristics of forage quality including species perenniality, palatability, productivity, persistence/stress tolerance, beneficial gap fillers and species diversity. We used these to generate a quantitative forage score for a range of pastures from sown exotics to naturalised and native systems that can be used as an input to farmer management decision-making and to enable tracking of change over time. Scoring was conducted at up to 30 sites across a farm with scores used to assign a paddock to a forage condition category (A, B, C and D). Non-visited areas were assigned to categories based on vegetation, proximity and management characteristics for estimation and reporting of the total area of the property (excluding non-grazed areas) in each category. The area of each forage condition category was used to calculate a Forage Condition Index (for grazed areas) for the whole property. This was used in the research that sought to understand relationships between the type and quality of the natural capital of a farm and the performance of the farm business. The insights generated from this research are published separately.

Background and project aims

Farming for the Future (FFTF) is a public good agricultural research and change activation program. It is building the first national-scale evidence base of natural capital and its relationship to farm business performance on Australian farms. The recently completed pilot livestock program involved (2022 – 2024) involved the collection of natural capital data across 130 livestock and mixed livestock/cropping enterprises in temperate regions of Tasmania, Victoria, NSW and WA. To do so we developed and tested methods of quantifying natural capital in an objective, repeatable and robust way. Forage condition and pasture quality is thought to be an important contributor to the performance of livestock operations. The pilot project included development of methods to generate a Forage Condition Score (per paddock) and an index of Forage Condition for the farm as a whole to be used in analysis of relationships between the quality of natural capital of a farm and the performance of the farm business.

As a result of the wide spectrum of ecological conditions and farmer management practice over time, forage species composition, condition and abundance can differ significantly from paddock to paddock and farm to farm. Pasture systems across the grazing landscape range from sown annual and perennial systems to self-regenerating naturalised pastures and native grasslands. We required a scoring system that could quantify the relative forage generation capacity of these diverse systems for use in analysis of the contribution of pasture quality to farm business performance. Our aim in developing a forage condition index was to characterise the capacity of the land to dependably produce resilient and high-quality forage for livestock across a range of seasonal conditions. This document explains the methods we developed for this purpose.

Further detail about the other metrics used in FftF can be found in the Natural Capital Methods paper available in the resources section of the FFTF website, in Rainsford et al., 2024. “A state-and-transition model framework to take stock of natural capital on farms”. *Agricultural Systems* 220 (2024) 104104 and in Rainsford et al., 2025. “Natural capital metrics as predictors of farm-scale richness of birds and plants”. *Agriculture, Ecosystems and Environment* 391 (2025) 1097-46 and Radford et al., (in review).

Acknowledgements

Farming for the Future acknowledges the traditional owners of the lands on which we live and of the lands involved in the research. We pay our respect to their Elders past, present and emerging.

We appreciate the support of our philanthropic and industry partners especially the Natural Farmers' Federation, Meat & Livestock Association and Australian Wool Innovation.

We are grateful for the opportunity to collaborate with Rob Hassat and Kevin McCosker of Queensland Department of Primary Industries. We have applied, adapted and extended concepts they have developed in their industry-leading monitoring Landscape Condition Assessment Tool. Their generosity in providing feedback on our approach has been important and we look forward to opportunities for further collaboration.

For our full list of partners see the About Us section of www.fftf.org.au.

We acknowledge the work of La Trobe University in development of the natural capital indices and the underlying protocols for the natural capital data collection. Their support has been invaluable.

We also acknowledge the work of many other scientists whose work we have been able to draw on in the development of these approaches as well as the significant contribution of farmers, farm advisors, farm accountants, our industry partners, and our natural resource management partners. These have been very important in the project, and we have greatly enjoyed working with them.

Photo credit: Imogen Semmler

Disclaimer

1. Principles for design of natural capital indices

The indices of natural capital for use in analysis of relationships between farm natural capital and farm business performance were prepared using the following set of principles.

P1: Natural capital indices should be based on scientifically justified principles that relate measured indicators to a stock of natural capital.

P2: Natural capital indices should not be reliant on social, economic, or farm management actions in order to avoid circularity in measurement. Natural capital indices should represent biophysical properties, not whether a management practice has been applied (or not applied, or poorly applied).

P3: Natural capital indices should represent the capacity of Ecosystem Assets (individually or collectively) to provide ecosystem services or intermediate ecosystem services.

P4: Natural capital indices should be independent of business performance measures (output metrics) used in econometric analysis.

P5: Natural capital indices should measure components of the environment relevant to management decisions (i.e., they should be 'actionable' through management decisions).

P6: Natural capital indices should be generated from data drawn from natural capital accounts of a farm combined with remote sensing data or other publicly available derived datasets.

Further details about the conceptual framing and generation of these indices are available in documents are described in the 'Natural Capital Methods Paper' published on the FFTF website.

2. Characteristics of resilient forage production

Sustainable grazing systems balance socio-economic drivers with the enhancement and protection of on farm natural capital which provide essential ecosystem services[1,2]. Researchers and extension officers across Australia's temperate and rangeland grazing systems have identified key features of both native and exotic pastures that are critical to landscape resilience and long-term viability of livestock production. They recommend that pastures should be dominated by diverse perennial, palatable, productive and persistent grass swards (Box 1), supported by a functionally diverse plant community of gap-fillers and legumes, and should remain above desired thresholds of biomass, groundcover and litter[1,8] (Illustrated in Figure 1). These pastures can provide high levels of palatable forage for livestock while maintaining essential ecosystem functions. This enables long-term pasture productivity through the prevention of landscape degradation and by building ecological resilience to manage risks associated with a variable climate. These eight characteristics that are important attributes of a resilient and productive pasture are outlined below.

Box 1: Note about differences in definition of 3P grasses

Note: preferred perennial grasses are often described as '3P', however depending on the source, region and context these attributes can vary in definition. In some cases, '3P' refers to **p**alatable and **p**roductive sown **p**erennial exotic grasses[4,16], while at other times it describes **p**alatable native **p**erennial grasses with more variable **p**roductivity but increased resilience and reliability in poorer seasons[3,5,6]. '3P' has also described **p**erennial, **p**alatable and **p**ersistent grasses[1], yet across various grazing literature persistence has been defined as tolerance to both drought and grazing[1,12-13,15]. The term persistence is also used within the grazing industry to describe a management goal, i.e. to maintain a desired composition of pasture species through grazing management[4,11] . For the purposes of this project '3P' grasses were defined as **perennial, palatable, productive and/or persistent**, to account for variation in desirable characteristics in both exotic and native grasses.

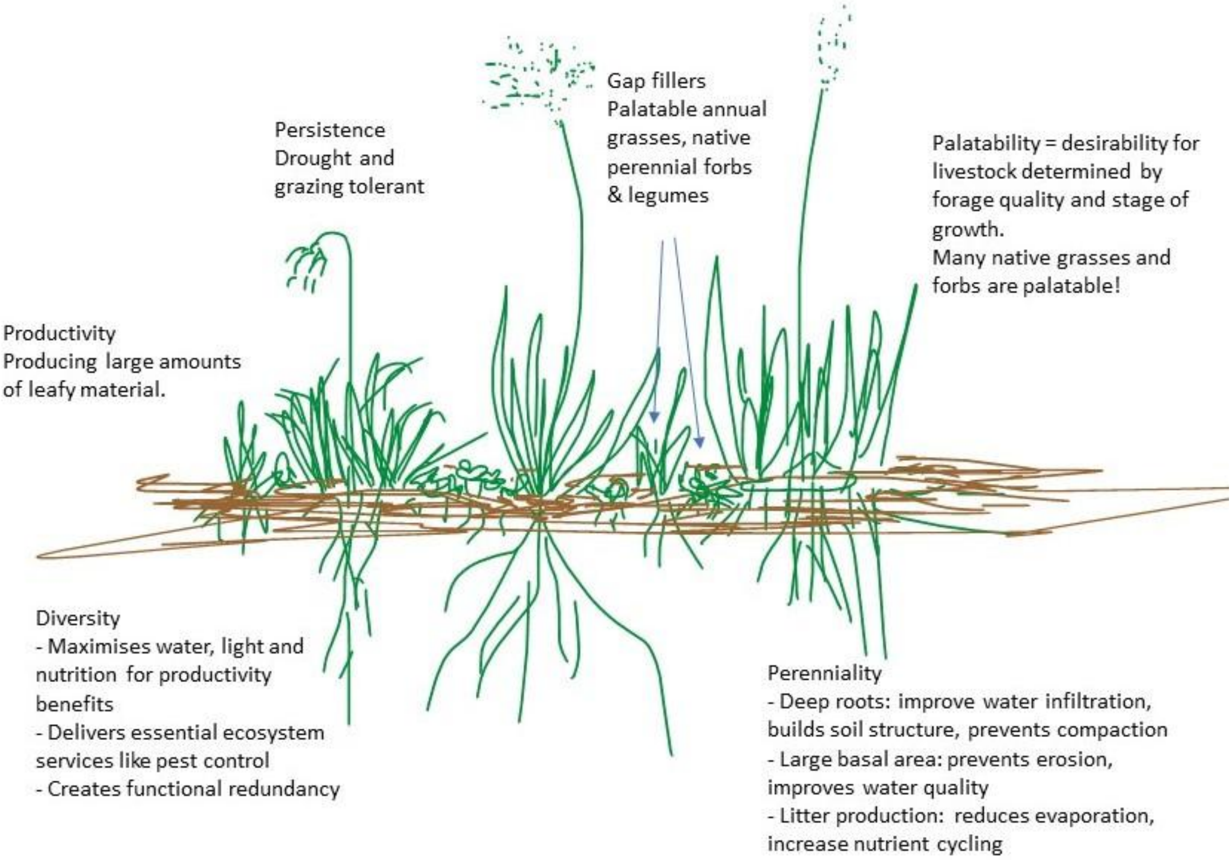

Figure 1: Illustration of pasture characteristics for sustainable livestock production.

2.1. Perenniality

Perennial grasses are grasses that live for more than three years. They are ecologically and economically important to graziers[17]. Their deep, long-lived root systems improve water infiltration and maximise soil water use[19, 20]. Perennials contribute to flow and storage of soil carbon through root exudation, improving soil structure and preventing compaction[21,22]. They also provide year-round groundcover, trapping sediment and reducing runoff and erosion in rain events[22]. Perennial grasses are an important source of litter which reduces evaporation and contributes to nutrient cycling[21]. These processes support a range of ecosystem functions (e.g., water, carbon and nutrient cycling) improving the ecological resilience of landscapes and increasing the capacity for long-term pasture productivity[1]. Research in the high rainfall zone of southern Australia from the 1980s to the early 2000s addressed the decline in desirable and ecologically valuable perennial pastures, which was considered both a cause and effect of productivity loss through increases in soil salinity, acidification, erosion, weed presence and reduced livestock performance[18].

2.2. Palatability

Palatability is commonly defined in the grazing industry as the degree to which livestock find a plant desirable. Forage quality (including crude protein content) and digestibility (e.g., leafiness/stage of growth) are considered key attributes of palatability[6,23]. Palatable pastures are commonly thought to be high quality exotic sown perennial and annual grasses, forbs and legumes[4]. However, many native perennial grasses are also palatable to livestock, some with forage quality and digestibility comparable to exotics[25-28]. Native grasses are often undervalued in grazing systems[6] and quantitative forage quality data is often lacking, forcing reliance on more general terms like low, moderate or high feed quality from industry websites and pasture guide-books[28,29]. Information on the palatability of native forbs is rare, however species such as glycine and native geranium are considered desirable to livestock[6]. In this research, we determined palatability based on pasture resources describing a species as ‘palatable’ (with lower palatability often described as 'moderately palatable', 'less palatable' etc), or where this information was lacking, based on moderate to high feed quality where available.

2.3. Productive Pastures

Productive grass species produce large amounts of leaf material. While this characteristic often refers to introduced sown species, many native species are also described as productive or having variable production, and plant productivity is often dependent on the region, seasonal growth patterns and requirements for fertility[6,27-29].

2.4. Persistence / stress tolerance

Pasture species are often characterised by their persistence or tolerance to abiotic stress such as drought[12,28,31], and many grazing resources highlight the value that native grasses in particular can provide for increased resilience under more variable climate conditions[5,7,10]. Pasture species are also described as persistent in relation to their tolerance of different grazing pressures (ranging from heavy to light)[1,29], including ability to re-establish from seed under grazing[27]. However, this characteristic may vary from farm to farm dependent on grazing management (Box 2).

Box 2: Note about the use of persistence of pastures as an outcome of management.

Persistence as a management outcome

The term persistence is also often used to describe an outcome of farm management in maintaining desired pasture species for long term production benefits[4,15]. Pasture composition may vary from farm to farm depending on grazing strategies, stocking rates, soil nutrition and pest/weed control and is likely to be highly dependent on farmer goals. Historically, farm management that focused solely on livestock needs and short-term financial gains led to excessive clearing, cultivation and declines in pasture productivity[32]. However, grazing management decisions are now often framed within the context of managing for the persistence of 'desired species' which might depend on the farmer's preference for a particular species or for the persistence of the pasture system as a whole. For example, farmers are encouraged to use strategic rest to allow desired plants to set seed[33] or to maintain persistence of sown perennial pastures through management rather than resowing[15]; or to reduce stocking rates to maintain composition of palatable native grasses[5]. This focus on persistence is valuable to farmers in the context of long-term productivity and is the result of decades of research linking preferred pasture characteristics to grazing management[15,32]

2.5. Pasture Diversity

Plant (species) diversity in a grazing system provides a range of benefits to long term resilience and production. With increases in plant species diversity, this is greater variation in micronutrients, macronutrients and dry matter on offer which provides livestock with a nutritionally balanced diet[23].Increases in plant diversity also means more niches for resource capture are occupied, increasing rainfall use efficiency, soil nutrient accumulation and photosynthetic efficiency, thus maximising the productive capacity of a sward[1,9]. Structural diversity is also likely to enhance pest control services by providing a range of habitats for beneficial insects[34]. Diversity in a pasture also ensures functional redundancy, where one species that performs the same essential functions can replace another without impacting on the functioning and productivity of the system[35]. Research conducted under the Sustainable Grazing Systems (SGS) program across southern Australia determined that many more plant niches existed in grazing paddocks than were being exploited by species typically sown in a pasture, leading to invasion of weeds and volunteer species to fill those available niches. This research concluded that primary productivity was maximised in paddocks with 10-20 species[9] and points to the potential benefits provided to production by the increased diversity found in naturalised and native pastures.

Suggestions for maximising resource capture and plant productivity in a pasture system have been developed based on a diversity of functional types. A sward should include palatable perennials constituting >60% cover with a mixture of summer active (C4), winter active (C3) and year-long green (C3) species to provide forage throughout the different seasons. The remainder of the sward should comprise of legumes and gap-filling palatable forbs and annual grasses (such as glycine, clover, chicory and brome). This structural diversity competitively excludes weeds (non-palatable species), while the phenological diversity maximises palatability, and legumes and dynamic accumulators address soil nutrient deficiencies. Woody perennials can also provide gap filling forage as well as improvements in rainfall use efficiency with their deep-rooted systems[1].

2.6. Maintain Herbage Mass

Maintaining perennial pasture biomass (living matter) at intermediate levels (threshold suggestions range from 0.8 – 4.0 t/ha) retains desirable pastures through rapid regrowth, prevents weed invasion, maximises photosynthesis and contributes to landscape resilience by reducing runoff[1,19,36-39].

2.7. Maintain Groundcover

Groundcover (live and dead vegetation) protects the soil surface from rain impact, reduces the size and frequency of runoff events, and leads to higher infiltration rates[22,40]. Very low groundcover leads to soil crusting, moisture loss and lower water use efficiency (and consequently lower net primary productivity), as well as increasing erosion risk across the landscape[41,22]. Maintaining groundcover also regulates soil temperatures for soil fauna and decomposer activity[1]. Most recommendations of minimum groundcover for temperate systems are 70%, and higher in the High Rainfall Zone (HRZ)[1,22,42]. These thresholds are lower in semi-arid areas, for example 50% is recommended for the northern Australian rangelands[43].

2.8. Maintain Litter

Soil surface litter (organic matter) provides groundcover benefits including reduced evaporation, increased water infiltration, and regulation of soil temperature. Decomposing litter is a vital food source for soil organisms driving nutrient cycling and influencing soil structure and organic matter formation[21]. Studies of native pasture systems under different grazing treatments in northern NSW demonstrated that high levels of litter were associated with higher microbial biomass, higher labile carbon and more earthworms compared to lower levels[44]. Thresholds for recommended litter retention in temperate systems vary from 1-3 t/ha[1, 44,45].

2.9. Pasture Structure

In addition to recommending >60% cover of 3P grasses, experts emphasise the importance of two additional pasture components. First, responsive legumes provide perennial grasses with nitrogen in N-deficient soils (it is often more cost-effective to ensure adequate soil nutrition and an active legume component such as clovers and medics). Second, the space between 3P grass tussocks and legumes (i.e., “interstitial spaces”) should consist of ‘gap-fillers’ (i.e., palatable, productive broad-leaved herbs such as plantains and chicory, and palatable annual grasses such as bromes). Gap-fillers contribute to pasture phenological and nutritional diversity and competitively exclude weeds. Annuals also have a higher radiation-use efficiency (RUE) than perennials[1] . Consideration should also be given about whether the species are summer or winter growing and the degree to which pastures will be productive all year round.

3. Pasture Assessment Tools considered

The FFTF Forage Condition scoring system and Forage Condition Index required a pasture assessment framework that could support the following requirements.

- Incorporation of attributes for resilient forage production.
- Rapid data collection including curation of geolocated photographs.
- Enable consistency among different observers.
- Minimise the effect of seasonality, or timing of grazing or pasture sowing on the assessment of the pasture condition.

We evaluated a number of pasture assessment tools that have been developed to measure key pasture characteristics for long-term productivity of high-quality forage. All were developed as monitoring tools allowing farmers to track progress of pastures, taking seasonal variability into consideration.

Monitoring tools already developed by Meat and Livestock Australia (MLA), Pasture Health Kit[38] and Pasture Paramedic[45], were considered for use. Pasture Paramedic was developed for rapid assessment of sown pastures in the medium to high rainfall zones and designed to guide management decisions towards their long-term persistence and productivity. Pasture Paramedic generates a single quantitative score, but species measured are limited to sown perennial grasses and clovers. This method was deemed unsuitable as the FFTF research question required an approach capable of valuing native and mixed native/naturalised pastures along with entirely exotic sown pastures.

The Pasture Health Kit, also developed by MLA, combines scores of low, medium and high across seven indicators, including proportion of desirable pasture species and the visible resources that contribute to soil and landscape processes (e.g. soil surface condition, groundcover, litter). Difficulties were encountered in turning this method into a single quantitative score due to the confounding effects of combining forage quality and functional indicators. As such, this method was also deemed not suitable for our research.

The rangeland assessment tool PATCHKEY[46] was developed to provide a quantitative measure of land condition and landscape function for grazed landscapes. After discussions with Brett Abbott (PATCHKEY author) it was decided that their monitoring framework was too complex and time-consuming for the rapid assessments required for FFTF.

The Land Condition Assessment Tool (LCAT) was developed by the Queensland Department of Agriculture and Fisheries to assess and monitor the productivity and sustainability of grazing landscapes by evaluating key indicators of long-term land condition[47]. LCAT is an easy-to-use rapid assessment protocol and tool that generates a grazing score using principles and metrics from a range of sources including the Grazing Land Management ABCD land condition framework. LCAT scores species based on their forage characteristics and overall density in the sward. Perennial species (both native and exotic) are scored on a sliding scale based on their desirability (i.e. palatability and productivity). This ensures that associated landscape function benefits provided by perennial cover are valued, while still favouring the more desirable species with higher scores. LCAT also assigned scores for gap-filler species such palatable annuals and forbs. Due to our requirements to score both native and exotic pastures based on their beneficial characteristics to long term pasture production, LCAT was considered the most suitable approach. The FFTF program therefore chose to adapt LCAT methods (in consultation with Robert Hassett) as the basis for the Forage Condition Score.

LCAT has also developed a range of other indicators, including a natural capital indicator and a landscape stability/function indicator (providing additional context to the interacting benefits of landscape processes) to be read alongside the grazing score. Due to timing of the pilot project and resource constraints, FFTF has not used these scoring systems as part of our Forage Condition Score in its pilot livestock program.

4. Methods for data collection and forage condition scoring

We followed (with a slight modification as explained below) Gardiner and Reid's[1] description of the components of a pasture sward that contribute to a sustainable and productive temperate pasture. Gardiner and Reid (2010; p453) describe such a pasture as one that: "maintain(s) pasture composition in terms of palatable, persistent, perennial grasses, responsive legumes and palatable 'gap fillers". No distinction was made between the preferences of sheep and cattle (or other livestock classes). While we acknowledged that shrubs provide valuable forage, they were not included in this phase of the FFTF forage condition score.

We used a ranking system to rank individual forage species in a sward based on their qualities and then ranked a pasture sward with respect to the forage species present, the structure of the pasture and its diversity. Each ground-layer plant observed in the data collected was assigned a category according to its qualities as a forage plant for livestock (Table 1). The quality of the species is combined with its density to provide a score for the sward (Table 2). Scores are calculated by combining these species values with weighted values according to their dominance and density in the sward as well as value assigned to the overall diversity of species recorded (example provided in Table 3). Based on score thresholds, the area is classified into a pasture condition category (Table 4).

4.1. Individual species classifications and ranking

We used information about pasture species quality from published literature (where available) and expert opinion (including from farmers) to rank each species depending on their physiological characteristics such as perenniality, productivity, palatability and persistence (Table 1). We ranked sown or introduced (exotic) species and native species including those found in the grassy understory of grazed woodland areas in temperate regions. The values were scaled according to desirability for dependable forage production. For example a perennial 3P species that exhibits palatability and productivity and persistence will score higher than a perennial 2P (that is lacking a key characteristic of either productivity or palatability). Perennial grasses and forbs were ranked higher than annual grasses and forbs due to the increased landscape resilience and function they impart[36]. Increased value was also assigned to annual pasture and perennial forb species when they are filling gaps in the sward[1]. Species contributing no grazing value or threatening the condition of the land (i.e., recognized weedy species) were given a value of 0. In this phase of research we did not separately classify species for whether they are summer or winter growing but we acknowledge the value of this for assessing the degree to which a pasture will be productive all year. The species list is available via this link.

Table 1: Classification description assigned to individual forage species.

Category	***Description***
3P	Perennial, palatable, productive and/or persistent grasses
2P	Grasses that are perennial with moderate palatability (can have variable productivity)
1P	Perennial grasses with very low palatability
SLP	Short-lived perennials
GFP	Gap Filler Perennials
AV	Valuable annuals – an annual species that is considered valuable as a forage plant
A	Generic annuals
NO	No value for forage (includes high threat weeds)

4.2. Sward structure ranking

We followed LCAT[47] in incorporating capacity of the pasture sward to provide other services such as soil protection and other landscape functions, and used the LCAT approach to assess the density of the observed species. Density was conceptualized as the structure of the plant and the proximity to the other plants in the sward including those of the same species. The categories are shown in Table 2. The risk that density categories will be differently interpreted by different assessors was mitigated to some degree by training and calibration between assessors. Even without specific training or expertise, experience using LCAT in other projects found that it was rare that two people would allocate a density category for a particular plant at the same site more than one category apart[48].

Table 2: Ranking of observed species density.

Plant type density category	***Description***
Closed Dense (CD)	Touching-overlapping canopies. Slightly separated bases.
Moderately Dense (MD)	Touching-slightly separated canopies. Clearly separated bases.
Sparce or Open (SO)	Clearly separated canopies. Well-separated bases.
Very Sparse (VS)	Well separated canopies. Very well separated bases.
Isolated (IS)	Isolated canopies. Isolated bases.
None/absent	NA

In the characterization of resilient forage production, the value of an individual plant in a sward is a function of its individual characteristics, its density in the sward and its relative proportion. For example, species classified as gap fillers (GFP) become more valuable when very sparce (VS) or isolated (IS) than they are when they are dense (CD or MD) and dominate the sward.

To calculate the forage condition score for an observed sward we developed models that combine the quality of the species and the density of them in the sward. An example of the resultant scores is provided in Table 3. The models are provided in Addendum 1.

Table 3: Example of forage condition calculations for an observed sward. The quality of the species is combined with its density to provide a score for the sward.

Farm	**Audit ID**		**Site ID**	**Score**
ABC	Audit_bcc465d8c2266765sec2b		B9.WL-P2	105
	Spp. Name	**Density**	**Species class**	**Score**
Sp1	Festuca arundinacea - Fescue	Mid-dense	3P	53
Sp2	Chloris truncata – Windmill Grass	Very Sparse	2P	16
Sp3	Eragrostis leptostachya – Paddock Lovegrass	Isolated	3P	20
Sp4	Lolium rigidum – Annual Ryegrass	Very Sparse	AV	16
Sp5	Cirsium vulgare – Black/Spear thistle	Isolated	NO	0

4.3. Data collection

Prior to data collection, the farm was stratified based on characteristics of canopy cover, ground cover and the classification of the ecosystem prior to modification for agriculture (for example Woodland, Forest or Grassland). Approximately 30 survey sites were selected across a farm, encompassing these different types of ecosystem characteristics and management types. Further information about the approach is described in the Natural Capital Methods paper available from the FFTF website and in Rainsford et al., 2024[50].

At each survey site, a minimum of three and maximum of five individual points were assessed by a person with capability to identify the pasture species and judge the density by observation. FFTF used experienced ecologists and agro-ecologists. The number of points per site (i.e., 3, 4 or 5) was determined by the observer's judgement of how variable the ground-layer was across the sample area; high variability required more individual points to result in a category assignment that is representative of the paddock.

To ensure traceability of the information for subsequent audit, verification or reanalysis if required, the records contain the Audit ID including date and time of survey, the Site ID of the location of the survey along with the species observations. Geolocated photographs are curated with the Site ID and species observations.

At each of the assessment points, the species and density within a 2m radius circle were observed and recorded and a series of photographs taken to provide artefacts for quality control and to illustrate the sward condition. Data recorded include:

- Sward height (where sward was homogenous)
- Where sward was not homogenous, sward height was estimated as the average height of species present (not including seed heads and stems)
- The five most dominant plant species, with species 1 the most dominant species and species 5 the fifth most dominant species according to dry-weight ranking (DWR) principles. Information recorded per species included:
    - Species name
    - Density category (Table 2).
- Density of all perennial herbaceous plants combined (i.e. overall sward density excluding annual component).
- % Groundcover: percentage of the soil protected by organic cover. This includes plants, plant litter (both attached and unattached), woody litter (<5-cm diameter) and cryptograms.
- Plant litter cover and depth. Litter refers to both attached and detached plant material within 5-cm of the soil surface. (Data not used in sward condition scoring in the FFTF pilot.)

Observations including geolocated photographs at survey points were recorded in iAuditor™ (Safety Culture) and uploaded into a MySQL database for compilation and processing for analysis and reports.

The average of the three to five observation points assessed in each paddock was compiled as the score for the paddock (ecosystem unit). Based on the score thresholds, the sample area was assigned an ABCD score (see next section and Table 4).

To enable all paddocks to be classified for forage condition, the score and category for each surveyed site was assigned ("imputed") to other areas of the farm based on similar vegetation, groundcover, proximity and management characteristics. Refer to the natural capital methods documentation for further information about imputation. Condition classifications of imputed sites have a lower confidence than surveyed sites so reports to farmers included information about which areas (paddocks) were surveyed sites and which areas have imputed scores.

5. Compilation and presentation

Information about the forage condition of the property was compiled in two complementary ways.

Detailed information about the forage condition of each paddock or unit of the farm was collated into a type of natural capital accounting table (Table 5) and also represented spatially in a detailed map (Figure 3).

A Forage Condition index (Figure 2) with a value between 0 and 1 for the whole farm was used to indicate the capacity of the farm to generate reliable forage for livestock.

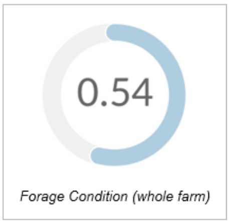

Figure 2: Resilient Forage Condition Index

The Forage Condition index is calculated as the sum of the area weighted average of the forage condition scores for all *k* ecosystem units of the farm, scaled to a maximum of 1 using the following formula:

$$\left(\sum_i^k (FCi \div FCmax) * Ai \right) / \sum_i^k Ai$$

where *FCmax* is the theoretical maximum forage condition score of 200, *FCi* is the average forage condition score for ecosystem unit *i*,, and *Ai* is the area of ecosystem unit *i*.

5.1. Forage condition categories

To prepare natural capital accounts for the participants in the project, FFTF used a forage condition category approach commonly used in the industry (categories described in Table 4). A condition category provides an easy to interpret set of information about the quality of a paddock from the perspective of its capacity to generate reliable forage for livestock. The area in each forage condition class can be used in forage condition 'asset accounts' in natural capital accounting. Table 5 provides an example of how this information may be presented.

Thresholds for the categories were tested with experienced agri-ecologists and a diverse group of farmers and grazing management experts. Individual rankings for species and rankings for density plus the combined result were used to develop and test thresholds for forage condition categories by comparing sward scores from the dataset with the assessment of photographic evidence of the sward by experienced agri-ecologists and a diverse group of farmers and grazing management experts.

Table 4: Forage condition categories used in FFTF.

Forage condition category	***Description***	***Score range***
A	A high degree of cover of a diverse mix of pasture species (>3 species) that are regarded as 3P species (perennial, palatable productive and/or persistent). Annual grasses and forbs may be present as gap fillers.	135-200
B	A moderate to high cover of perennial grasses with lower diversity of 3P species. Annual grasses and forbs may be present along with perennial grasses of lower palatability or productivity.	80-134
C	Sparse perennial cover. 3P species at low abundance and/or perennials of low palatability. May have a diverse mix of annual pasture species (may be sown species). Some weedy or no value species may be present.	40-79
D	Swards are dominated by annual species, either sown or naturalised. Perennial pasture species isolated or absent. Pastures may include plants with no or very low forage value and may have significant amounts of bare ground.	0-39

5.2. Presentation of forage condition

Table 5 shows an example presentation of the forage condition score for each type of ecosystem present on a farm as per a Natural Capital Account for that farm. The table summarises the number of hectares in each forage quality classification and the overall condition score for that ecosystem type.

Farms participating in the project received very detailed natural capital reports that included this information as well as maps of forage condition for their farms (example in Figure 3). Example reports are available from the FFTF website in the resources section.

Table 5: Example presentation of forage condition information for a farm. The capacity for livestock grazing is summarised by Ecosystem Type and State.

[Farm Name] Grazing classification and extent (ha) by Ecosystem Type and State @ [Date]			Forage Condition Classifications				
Ecosystem Type	Ecosystem State	Ecosystem State long description	A	B	C	D	Forage Condition
Transitioning Woodland	TW1	Some historical clearing - regeneration - ground layer with high native diversity	18	28	109	0	0.05
Transitioning Woodland	TW3	Little regeneration - mostly exotic ground layer	0	0	21	19	0.05
Transitioning Woodland	TW4	No regeneration - exotic ground layer	0	0	43	15	0.05
Modified Grassland	MG5	Modified Grassland 5 - perennial exotic ground layer	0	88	0	0	0.08
Derived Grassland	DG1	Derived Grassland 1 - diverse native ground layer	205	0	135	0	0.07
Planted Native Trees	PNT2	Planted native trees - maturing (10-40 years)	0	0	0	0	0
Exotic Woody Vegetation	EWV3	Perennial Horticulture	0	0	0	0	0
Crops	C1	Non-irrigated crop with scattered trees	0	0	0	0	0.04
Crops	C2	Non-irrigated crop - no trees	0	0	197	0	0.04
Crops	C3	Irrigated crop	0	0	0	0	0.06
Infrastructure	Domestic Infrastructure	Domestic Infrastructure	0	0	0	0	0
Infrastructure	Roads & Laneways	Roads & Laneways	0	0	0	0	0
Infrastructure	Sheds & Yards	Sheds & Yards	0	0	0	0	0
Infrastructure	Water Infrastructure	Water infrastructure (dams, channels)	0	0	0	0	0
Total			223	116	506	35	0.44
Proportion of land used for grazing (baseline)			25%	13%	58%	4%	

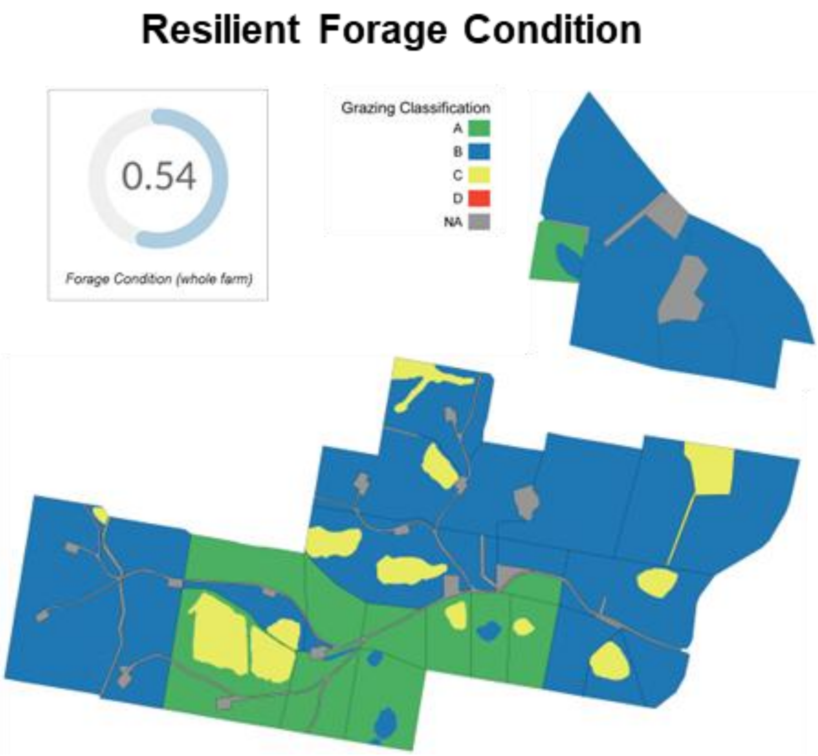

Figure 3: Example of a Forage Condition Index and Forage condition classification map for a different farm.

6. Recommendations for future development

As a result of our experience with this pilot research we propose several recommendations for future development of methods for forage condition.

6.1. Reducing sensitivity of assessment to season quality

The plant types and plant condition in pastures and the ground layer in woodlands and forests can be affected by the timing of observations and the quality of seasons. As far as possible, the forage condition measures used in FFTF have been designed to be relatively robust to these factors and to provide a very similar score independent of whether the assessment was conducted in a favourable or less favourable season or at a time where grazing has been either recent or not. However, assessments of grazing systems are still affected by issues of season. For some grass and forb species, flowers or seeds are needed for their correct identification. Other species can only be reliably detected during their growing season. For example, summer-growing grasses that provide valuable summer forage can be inconspicuous and may not be detected during observations performed in winter. Species observations will also be affected by season quality that might favour certain species and not others.

Since it is not practical for observations to be confined to ideal conditions or to matched seasons, we recommend that further development of forage condition assessments is needed to improve the independence from seasonal conditions.

6.2. Measuring year-round production

It would be valuable to incorporate recognition of the value of having a diversity of C4 (warm season perennials) and C3 (cool season and year-long growing perennials) species. This would be used to assess the degree to which pastures will be productive all year round. This would be relatively easy to incorporate into scoring methods such as were used in this phase of FFTF but would require the issue of non-observability during the non-growing season to be resolved.

6.3. Measuring landscape and soil processes

While the weighting of perennial species and their density implies benefits to soil and landscape processes and resilient long-term production systems, the Forage Condition Score used in the FFTF pilot did not include other vegetation and landscape characteristics desirable in a sustainable grazing system (such as groundcover, litter and biomass retention). These indicators were not included to avoid the confounding effects of functional and production features in a single score. Just as LCAT has developed a Landscape/Stability Index, FFTF is considering the development of a similar Index to be read alongside the Forage Condition Index and provide more context about the function and long-term resilience of the system.

7. Conclusion

The development of the Forage Condition Score and Forage Condition Index during the pilot of the FFTF program enabled the project to analyse whether farms with high scores for dependable forage condition were among the most financially productive and profitable of farms in the program. (Results of the FFTF research are presented separately.) The approach for data collection was found to be robust, practical and efficient, but we recommend development of assessment methods to further reduce the effect of season quality on pasture condition scores.

Addendum 1

Differentiated weightings of pasture species categories and their density depending on their proportion and density in the sward. Species 1 is the most dominant species according to dry-weight ranking principles, Species 2 is the next most dominant and so forth.

SPECIES 1	CD	MD	SO	VS	IS	NN
3P	60	53	45	30	20	0
2P	40	32	24	16	8	0
1P	30	24	18	12	6	0
SLP	35	28	20	14	6	0
GFP	15	15	24	16	8	0
AV	5	5	4	3	2	0
A	3	3	2	1	0	0
NO	0	0	0	0	0	0

SPECIES 2	CD	MD	SO	VS	IS	NN
3P	60	53	45	30	20	0
2P	40	32	24	16	8	0
1P	30	24	18	12	6	0
SLP	35	28	20	14	6	0
GFP	15	15	24	16	8	0
AV	10	8	6	4	2	0
A	3	3	2	1	0	0
NO	0	0	0	0	0	0

SPECIES 3	CD	MD	SO	VS	IS	NN
3P	60	53	45	30	20	0
2P	40	32	24	16	8	0
1P	30	24	18	12	6	0
SLP	30	30	30	24	16	0
GFP	15	15	24	16	8	0
AV	15	12	24	16	8	0
A	15	12	9	6	3	0
NO	0	0	0	0	0	0

SPECIES 4	CD	MD	SO	VS	IS	NN
3P	60	53	45	30	20	0
2P	40	32	24	16	8	0
1P	30	24	18	12	6	0
SLP	30	30	30	24	16	0
GFP	15	15	24	20	16	0
AV	24	24	24	16	8	0
A	15	12	9	6	3	0
NO	0	0	0	0	0	0

SPECIES 5	CD	MD	SO	VS	IS	NN
3P	60	53	45	30	20	0
2P	40	32	24	16	8	0
1P	30	24	18	12	6	0
SLP	30	30	30	24	16	0
GFP	15	15	24	20	16	0
AV	24	24	24	16	8	0
A	15	12	9	6	3	0
NO	0	0	0	0	0	0

References

1. Gardiner, B. & Reid, N. (2010). Sustainable Livestock Production. In D. Cottle (Ed.), *International Sheep and Wool Handbook* (pp.445-471). Nottingham University Press.
2. Mason, W.K., Lamb, K., & Russell, B. (2003). The Sustainable Grazing Systems Program: new solutions for livestock producers. *Australian Journal of Experimental Agriculture, 43*(8), 663-672.
3. Ash, A., Corfield, J. & KsiKsi, T. (2001). *The Ecograze Project – Developing Guidelines to Better Manage Grazing Country*, CSIRO Sustainable Ecosystems, Davies Laboratory, Townsville.
4. *Persistent Pastures*, MLA
5. *Lighter stocking maintains 3P grasses*, Future Beef
6. O'Sullivan, D & Lord, B (2nd Ed, 2022) *Pasture management for South East Queensland catchments*, Dept Agriculture & Fisheries, QLD
7. *Pasture sustainability and management in drought* (2017), Department of Primary Industries, NSW
8. Land, D. & McDonald, W. (2005). *Maintaining groundcover to reduce erosion and sustain production.* Agfact P2.1.14, NSW Department of Primary Industries.
9. Kemp, D. et al. (2003). SGS Biodiversity Theme: impact of plant biodiversity on the productivity and stability of grazing systems across southern Australia, *Australian Journal of Experimental Agriculture,* 43, pp 961-975.
10. Pasture recovery after drought and fire | Land and pasture management | Farm management | Agriculture Victoria
11. Harbison, D. (2015). Persistent perennials? An advisor's perspective. *Proceedings of the 29th Annual Conference of The Grassland Society of NSW Inc.*
12. Culvenor, R. & Simpson, R. (2014). Persistence traits in perennial pasture grasses: the case of Phalaris (*Phalaris aquatica L.*), *Crop and Pasture Science,* 65, 1165-1176
13. DEDJTR_Native_Pasture_Management_brochure_final.pdf (wgcma.vic.gov.au)
14. Watson, R.W., McDonald, W.J. & Bourke, C.A. (2000) Phalaris Pastures, Agfact P2.5.1
15. Selecting Pastures for Place and Purpose | EverGraze More livestock from perennials
16. Improved perennial pastures | Meat & Livestock Australia (mla.com.au)
17. Mason, W.K., & Kay, G. (2000) Temperate Pasture Sustainability Key Program: an overview. *Journal of Experimental Agriculture*, 40, 121-123
18. Kemp, D.R. & Dowling, P.M. (2000) Towards sustainable temperate perennial pastures. *Australian Journal of Experimental Agriculture*, 2000, 40, 125-132.
19. Hughes, J.D., Packer, I.J., Michalk, D.L, et al (2006) Sustainable grazing systems for the Central Tablelands of NSW. 4. Soil water dynamics and runoff events for differently managed pasture types. *Australian Journal of Experimental Agriculture*, 46, 483-494
20. DuPont, S.T., Beniston, J.D., Glover, J.D. et al (2014) Root traits and soil properties in harvested perennial grassland, annual wheat and never-tilled annual wheat. *Plant Soil,* 381, 405-420
21. Lavelle, P. & Spain, A.V. (2001) *Soil Ecology.* Kluwer Academic Publishers.
22. Lang, D. (2005) *Maintaining groundcover to reduce erosion and sustain production.*
23. *Understanding livestock nutrition requirements*, MLA
24. *Rangelands glossary*, Department of Primary Industries and Regional Development, WA
25. Lodge, G.M. & Whalley, R.D.B. (1983) Seasonal variations in the herbage mass, crude protein and in-vitro digestibility of native perennial grasses on the north-west slopes of NSW. *The Australian*

Rangeland Journal 5(1), 20-27

26. Archer, K.A. & Robinson, G.G. (1988) Agronomic potential of native grass species on the Northern Tablelands of NSW. II. Nutritive value. *Australian Journal of Agricultural Research,* 39(9), 425-436
27. Jones, C.E. (1996) Pastoral value and production from native pastures. *New Zealand Journal of Agricultural Research,* 39(4), 449-456
28. Lodge, G.M., Robinson, G.G. & Simpson, P.C. (1990) *Grasses - native and naturalised: recognition, value, distribution.* Agfact P.2.5.32, NSW Agriculture & Fisheries
29. Rose, H., Kidson, J., Rose, C. & Edwards, C. (2013) *Grasses of the NSW tablelands*, Department of Primary Industries, NSW.
30. *Pasture species and varieties,* Department of Primary Industries, NSW
31. Lodge, G.M. & Orchard, B.A. (2000) Effects of grazing management on Sirosa phalaris herbage mass and persistence in a predominantly summer rainfall environment. *Australian Journal of Experimental Agriculture,* 2000 (40), 155-169.
32. Kemp, D.R., Michalk, D.L. & Virgona, J.M. (2000) Towards more sustainable pastures: lessons learnt, *Australian Journal of Experimental Agriculture.* 40, 343-356
33. How do I optimise seedling recruitment to avoid resowing? MLA
34. Woodcock, B.A., Potts, S.G., Westbury, D.B. et al. (2007) The importance of sward architectural complexity in structuring predatory and phytophagous invertebrate assemblages. *Ecological Entomology,* 32, 302-311
35. Lawton JH & Brown VK (1993) Redundancy in ecosystems. In E.D. Schulze & H.A.Mooney (Eds) *Biodiversity and ecosystem function*, Springer New York.
36. McIntyre, S. & Tongway, D. (2005) Grassland structure in native pastures: links to soil surface condition. *Ecological Management and Restoration,* 6(1), 43-50
37. Kahn, L. & Earl, J. (2009) *Pasture Management checklist for the Northern Tablelands of NSW.*
38. Meat & Livestock Australia (2013) Pasture Health Kit
39. Bell, A. (2006) Pasture assessment and livestock production, PrimeFact 323, Department of Primary Industries, NSW
40. Murphy, S.R., Lodge, G.M. & Harden, S. (2004) Surface soil water dynamics in pastures in northern NSW. 2. Surface runoff. *Australian Journal of Experimental Agriculture,* 44, 283-298
41. Lodge, G.M., Murphy, S.R. & Johnson, I.R. (2001). *Soil water balance modelling highlights limitations for pasture production in northern NSW.* Proceedings of the 10th Australian Agronomy Conference, Hobart.
42. Managing ground cover to reduce run-off and water loss, MLA
43. Land Condition, Future Beef
44. Lodge, G.M., Murphy, S.R., Harden, S. (2003) Effects of grazing and management on herbage mass, persistence, animal production and soil water content of native pastures. 2. A mixed native pasture, Manilla, North West Slopes, NSW.
45. Meat & Livestock Australia (2019) Pasture Paramedic: technical manual to support the use of the rapid assessment tool.
46. Abbott, B.N & Corfield, J.P. (2012) PATCHKEY – A patch based land condition framework for rangeland assessment and monitoring, CSIRO
47. Hassett, R. C. (2020) Land Condition Assessment Reference Guide Version 1.0., Rural Economic Development, Department of Agriculture and Fisheries, Brisbane, Queensland.

48. R. Hassett (personal communication, 2023).
49. Rainsford et al., 2025. Natural capital metrics as predictors of farm-scale richness of birds and plants. Agriculture, Ecosystems and Environment 391 (2025) 1097-46
50. Rainsford et al., 2024. A state-and-transition model framework to take stock of natural capital on farms. Agricultural Systems 220 (2024) 104104.

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