The Drought and Climate Adaptation Program 2 & Reef Water Quality

‘Inside Edge for graziers to adapt to Queensland’s drought prone climate - Grazing extension tools’ Project

DAF Final Report

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This publication has been compiled by Giselle Whish, Chris Holloway and Gabrielle Penna of Animal Science, Department of Agriculture and Fisheries.

The Department of Agriculture and Fisheries proudly acknowledges all First Nations peoples (Aboriginal peoples and Torres Strait Islanders) and the Traditional Owners and Custodians of the country on which we live and work. We acknowledge their continuing connection to land, waters and culture and commit to ongoing reconciliation. We pay our respect to their Elders past, present and emerging.

Contents

Summary **5**
Land types of Queensland 6
Grazing Land Management land type mapping 6
Benchmark properties 6
SWIFTSYND research sites 7
Develop, validate and improve property-based grazing land management decision support information 7
Integrated engagement, education and communication 8
Recommendations for future work 8
1. Introduction **9**
2. Land types of Queensland **11**
Introduction 11
Enhancing Land types of Queensland 11
Land types of Darling Downs GLM region 11
Land types of Mary and SEQ GLM regions 12
Long-term carrying capacity 12
Regional maps 13
Conclusion and recommendations 14
3. Grazing Land Management land type mapping **16**
Introduction 16
Methods 16
Results 17
Conclusion and recommendation 19
4. Benchmark properties **20**
Introduction 20
Methods 20
Criteria for benchmark 20
Property Visit 20
Data compilation and comparison 21
Results 21
Animal numbers and records 21
Producer learnings 21
Conclusion and recommendations 22
5. SWIFTSYND research sites **24**
Introduction 24
Methods 24
SWIFTSYND methodology 24

Spyglass sites 26
Emerald sites 26
Results 26
Spyglass sites 26
Emerald sites 32
Recommendations for future work 36
6. Develop, validate and improve property-based grazing land management decision support information 37
Introduction 37
Improvement of GRASP land type parameters 37
Validation of FORAGE Long-term carrying capacity report 38
Consistency of information across platforms and extension programs 38
Stocktake GLM App 39
Adult equivalent data 40
Conclusion and recommendations 40
7. Integrated engagement, education and communication 41
Introduction 41
Extension material and information 41
Production of awareness and educational videos 42
FORAGE LTCC video 42
'Practical how to' videos 42
User guides – user-friendly and easily interpreted 43
FutureBeef web pages 43
Publication of data and relevant information 44
Group engagement activities 44
Webinars Production of awareness and educational videos 44
Workshops 45
Presentations 46
DAF Rockhampton presentation 46
Conference presentations 46
Promotional awareness raising activities 47
FutureBeef eBulletin 47
FutureBeef Social media (Facebook and Twitter) 50
Mass media 50
Conference / journal papers 52
8. Conclusion 54
References 55

Summary

Grazing with beef cattle and sheep is the dominant land use in Queensland, occupying nearly 86% of Queensland's 173 million hectares. The gross value of production from beef (cattle herd of 11 million) and sheep (flock of 2.1 million) livestock was estimated to be $8.1 billion and 44% of Queensland's primary industry commodities in 2021-22. The considerable inter-annual and decadal rainfall variability experienced in Queensland and associated major temporal variability in forage supply, leads to significant risks of resource degradation and economic loss in below-average rainfall years. This poses a major challenge for the sustainable and profitable management of grazing businesses. Drought, with its abnormally prolonged dry periods, is one of the many climatic risks that agricultural industries must manage.

The Queensland Government committed to improving drought preparedness and business resilience across Queensland through the Drought and Climate Adaptation Program (DCAP), and to working with industry and the community to improve the quality of water flowing to the Great Barrier Reef as outlined in the 'Reef 2050 Water Quality Improvement Plan 2017-2022. The Department of Science, Information Technology and Innovation (DSITI) led a $4.4 M four-year (2017-2021) '**Inside Edge grazing extension tools for graziers to adapt to Queensland's drought prone climate**' project in collaboration with Department of Agriculture and Fisheries (DAF, $1.4 M). The project was co-funded by the Queensland Drought and Climate Adaptation Program (DCAP) and the Department of Environment and Heritage Protection (EHP) Reef Water Quality (RWQ). The 'Inside Edge - Honing the Edge' project was extended until September 2022.

The purpose of the 'Inside Edge' project was to develop property-based decision support tools and products that promote both sustainable natural resource use in grazing lands and profitable beef and sheep industries in Queensland. FORAGE (www.longpaddock.qld.gov.au/forage/) is an online, web and email-based decision support system that generates and distributes climate and pasture related information in customised reports for a requested location. The information generated through FORAGE can be used to facilitate grazing and environmental land management decisions. The FORAGE system is maintained by the Queensland Government and is a free service.

A fully-automated approach to modelling long-term carrying capacity (LTCC) through the FORAGE online system was developed through the 'Inside Edge Project'. The GRASs Production (GRASP) model is used to simulate pasture growth with parameter sets and safe pasture utilisation rates defined for the grazing land types across Queensland.

Review, refinement and validation of key input data (e.g. land type descriptions, mapping, GRASP parameters), and incorporation of new and existing data and local knowledge, was undertaken by DAF to ensure the FORAGE decision support tool provided consistent and scientifically robust long-term carrying capacity information.

Through the Inside Edge project, DAF achieved the following six key objectives:

- Enhanced Land types of Queensland information
- Improved Grazing Land Management land type mapping
- Expanded the network of benchmark properties in Queensland
- Established SWIFTSYND research sites to calibrate and improve native and buffel pasture GRASP parameters
- Contributed to the development, validation and improvement of land type GRASP parameters and pasture growth estimates for use in the Stocktake GLM App
- Developed and delivered an integrated engagement, education and communication approach to increase awareness, skills and knowledge of the FORAGE system users

This report details the achievements of DAF delivered through the Inside Edge project (2017-2022) and provides recommendations for future work.

Land types of Queensland

Land types of Queensland were revised, improved and updated to reflect user needs, the latest available information and to ensure grazing land descriptions had statewide coverage. More than 240 land types from 16 Grazing Land Management (GLM) regions in Queensland have been described, long-term carrying capacity estimated and their distribution mapped. Land types of Queensland V4.0 are available at FutureBeef (https://futurebeef.com.au/resources/land-types-of-queensland/). The LTCC information is consistent with that provided through FORAGE (https://www.longpaddock.qld.gov.au/forage/report-information/long-term-carrying-capacity-report/), Stocktake GLM App (https://stocktakeglm.com.au/) and EDGE GLM & Grazing Fundamentals packages (https://www.mla.com.au/extension-training-and-tools/edgenetwork/).

Grazing Land Management land type mapping

GLM land type mapping is the spatial representation of 'Land types of Queensland' and both are key input for the FORAGE decision support system and VegMachine online tool. The use of GLM land type mapping, and hence Land types of Queensland, in the online systems enables definition of the grazing landscape and pasture productivity of Queensland. Through a comprehensive initial review, the development of new approaches to redefine almost 50% of the unique regional ecosystems associated with land types, and follow-up systematic review and validation of all GLM regions, the accuracy of land type spatial data has substantially (~80%) improved and as such affords greater confidence in the VegMachine and FORAGE reports which rely upon the land type mapping.

The updated land type spatial data provided by this project, consisting of 12,729 combinations of RE and sub IBRA regions, covering 41% of Queensland's GLM regions, has been published (https://qldspatial.information.qld.gov.au/catalogue/custom/index.page) and is available to a wide range of users. The substantial improvement to land type spatial data, along with its high degree of accuracy, ensures users of FORAGE and VegMachine online systems can be confident in the mapped GLM land type input for these decision support systems.

Benchmark properties

DAF established and expanded the network of benchmarking properties in Queensland to assist in the validation of the FORAGE long-term carrying capacity information. DAF identified eight additional benchmark properties that were located across Queensland's extensive grazing regions and covered a wide range of property sizes, land types and climates. Properties were visited by DAF staff or a consultant to discuss and collate information on the operation, markets, families, grazing management (past and present), pasture and cattle management and goals. During these discussions the accuracy of the property mapping was checked to ensure paddocks, land types and land uses were captured accurately for use in the FORAGE system. Land condition was assessed at sites across the property, and the accuracy of property infrastructure and land type mapping was checked. Animal numbers and weight classes from multiple years were converted to Adult Equivalents (AE) and annual carrying capacities, which were then compared to the modelled FORAGE long-term carrying capacity information for the property.

Benchmarking is a valuable process for validation of the FORAGE system and highlighted the importance of accurate key input data (e.g. land types, sown pastures, tree cover). Benchmarking of the eight properties validated 38 different land types across six GLM regions. Gathering complete property animal data that included paddock movements, weights or animal classes over multiple years and converting these to consistent animal units (AEs) was challenging. However, the capture of accurate animal data is invaluable not only for validation of the FORAGE modelling framework but,

when combined with pasture growth information, it can be used in future modelling investigations to improve knowledge of ‘safe’ pasture utilisation rates.

SWIFTSYND research sites

Five SWIFTSYND sites were established on native pastures over-sown with legumes at Spyglass Research Facility in October 2013 and a sixth site the following year (October 2014). Detailed rainfall, pasture and soil measurements were collected over two years from 2013-2015 and 2016-2018. Four SWIFTSYND sites were also set-up on non-native buffel (*Cenchrus ciliaris*) pastures in good condition, that were established for more than 15 years, and occurred on the geographically dominant Brigalow softwood scrub and Brigalow Blackbutt land types in central Queensland. Detailed rainfall, pasture and soil data measurements were collected between 2019-2022. Total standing dry matter (kg/ha) at the Spyglass native pastures sites was less than 1500 kg/ha at all sites during the below average rainfall years (2014-15). Pasture production of ~1700-2500 kg/ha was measured during the wetter years (2016-2018). Total standing dry matter (kg/ha) at the Emerald buffel grass sites was 2000kg/ha to 3000 kg/ha during the below average rainfall year (2020) and between 3500-3900 kg/ha in the above average rainfall year (2021).

Collation, checking and organisation of all Spyglass and Buffel SWIFTSYND site measurements will be completed prior to the extraction of data into the format appropriate for GRASP model calibration. Once calibrated, the native grass and buffel grass models for each location will be reviewed to determine if and how the models differed, and whether the differences were due to site preparation approach, site-specific characteristics or location. These considerations will then determine the appropriateness for the models to be extended over time and, in consultation with DAF regional experts, spatially to a geographically broader land system. Calibrated GRASP models for the six Spyglass and four Emerald sites will provide improved native pasture +/- stylos and buffel grass pasture growth estimates and long-term carrying capacities for Spyglass property, grazing lands within the Burdekin region, and for the established buffel pastures of central Queensland. Calibrated models will also be incorporated in the FORAGE system to provide improved pasture related information to support grazing and environmental land management decisions and to assist managers of beef enterprises achieve sustainable and profitable animal production.

Develop, validate and improve property-based grazing land management decision support information

Strengthening of collaborations with the DES FORAGE team through the ‘Inside Edge’ project enabled DAF to contribute significantly to the development and improvement of property-based grazing land management information. Key contributions included providing advice, data and information to improve Land type parameter sets; expanding the network of benchmark properties and capturing and responding to feedback to validate FORAGE long-term carrying capacity report; and managing input data (e.g. land type descriptions and mapping, tree cover) and GRASP modelled pasture growth and carrying capacity information to ensure it was current and consistent across platforms (e.g. Long Paddock FORAGE, MyFORAGE, Futurebeef and Stocktake GLM App) and extension programs (e.g EDGE GLM, GLM Fundamentals and Stocktake). Synchronised publication of updated Land types of Queensland, GLM land type mapping and inclusion of new land type GRASP parameters in FORAGE, and updated pasture growth estimates for use in Stocktake GLM App, will ensure current and consistent *property-based grazing land management decision support information* that promotes both sustainable natural resource use in grazing lands and profitable beef and sheep industries.

An opportunity to update the Stocktake App was provided through the Inside Edge project. DAF contracted Viewdale IT to improve the functionality of the Stocktake App and provide on-going maintenance and support of the Stocktake GLM App. The Stocktake GLM app is now able to adequately handle and store all data including land condition photos and determine a forage budget

that will assist graziers to meet ground cover and residual yield targets at the end of the grazing period to maintain and / or improve land condition. GRASP modelled median pasture growth information using climate for 1970-2021 was provided to the Stocktake App developers in May 2022.

The commonly recognised adult equivalent (AE) system, which describes and quantifies the grazing pressure imposed on the pasture by foraging ruminants, was modified and improved in 2020. Through the Inside Edge project, DAF contracted Col Paton and Ian McLean to develop AE and Dry Sheep Equivalents (DSE) rating tables for use in the Stocktake GLM app, deliver four workshops across Queensland, and to deliver a webinar to ensure consistency of understanding, application and delivery of the new AE methodology across decision support systems (e.g FORAGE LTCC report), extension tools and materials, workshops and programs (e.g. Stocktake, EDGE GLM and Fundamentals).

Integrated engagement, education and communication

DAF used an integrated engagement, education and communication approach to increase the awareness, skills, knowledge and capacity of users of FORAGE decision support system (www.longpaddock.qld.gov.au/forage/) and its products. DAF's contributions included the publication of land type descriptions, GLM land type mapping and relevant information (6); group engagement activities such as webinars (5), workshops (4), presentations (5); and awareness raising activities through social media (6), mass media (4), FutureBeef eBulletin (12) and conference / journal publications (9).

Recommendations for future work

Recommendations for future work include improving grazing land type descriptions, mapping and GRASP parameters for additional priority regions that are integral to the FORAGE modelling framework that provides property-based grazing land management decision support information. DAF will continue to revise, improve and update 'Land types of Queensland' and GLM land type spatial data with the inclusion of Mary and SEQ GLM regions. Concurrently, DAF will contribute to development of associated GRASP land type parameters. DAF will also calibrate the SWIFTSYND sites to improve the FORAGE land type modelling and its capacity to simulate grazing systems on improved pasture (buffel grass), introduced Indian couch pastures and native grasses +/- stylos. Additionally, re-interrogating the established Benchmark properties data could improve safe pasture utilisation estimates and validation of FORAGE long-term carrying capacity information.

1. Introduction

Grazing with beef cattle and sheep is the dominant land use in Queensland, occupying nearly 86% of Queensland's 173 million hectares. The Queensland beef cattle herd was approximately 11 million head with 11,600 specialist beef enterprises in 2016-17 (Queensland Government 2019). The State's flock comprised 2.1 million sheep on 1345 sheep farms in Queensland (Queensland Government 2021). The gross value of production from beef and sheep livestock was estimated to be $8.1 billion and 44% of Queensland's primary industry commodities in 2021-22 (Queensland Government 2022).

The considerable inter-annual and decadal rainfall variability experienced in Queensland (Klingaman *et al.* 2013) and the associated major temporal variability in forage supply, leads to significant risks of resource degradation and economic loss in below-average rainfall years (O'Reagain and Scanlan 2013). This poses a major challenge for the sustainable and profitable management of grazing businesses. Drought, with its abnormally prolonged dry periods, is one of the many climatic risks that agricultural industries must manage.

Overstocking during protracted droughts can cause high stock mortality, distress livestock and exhaust producers' financial reserves due to the high cost of supplementary feeding and lower turnoff. Excessive grazing pressure, especially in drought, also leads to the removal of surface-cover, leaving the soil surface bare and subject to erosion. Sediments generated from overgrazed and eroding catchments are a source of pollution in the Great Barrier Reef lagoon (Waterhouse *et al*. 2017). Grazing properties are complex enterprises consisting of heterogeneous assemblages of vegetation types, soil types, tree cover, terrain, and watering point and paddock layouts. Furthermore, grazing properties are run according to different production paradigms, for differing markets, as both family and corporate businesses. Grazing decision support systems that address sustainable grazing practices must incorporate a range of enterprise goals, high climate variability, a diverse natural resource base and variable levels of property infrastructure.

The Queensland Government has committed to improving drought preparedness and business resilience across Queensland through the Drought and Climate Adaptation Program (DCAP), and to working with industry and the community to improve the quality of water flowing to the Great Barrier Reef, as outlined in the 'Reef 2050 Water Quality Improvement Plan 2017-2022 (Queensland Government 2018a). The Department of Science, Information Technology and Innovation (DSITI) led a $4.4 M four-year (2017-2021) '**Inside Edge grazing extension tools for graziers to adapt to Queensland's drought prone climate**' project in collaboration with the Department of Agriculture and Fisheries (DAF, $1.4 M). The project was co-funded by the Queensland Drought and Climate Adaptation Program (DCAP) and the Department of Environment and Heritage Protection (EHP) Reef Water Quality (RWQ). The 'Inside Edge - Honing the Edge' project was extended until September 2022.

The purpose of the 'Inside Edge' project was to develop property-based decision support tools and products that promote both sustainable natural resource use in grazing lands and profitable beef and sheep industries in Queensland. FORAGE (www.longpaddock.qld.gov.au/forage/) is an online, web and email-based decision support system which generates and distributes climate and pasture related information in customised reports for a requested location (State of Queensland 2022a). The FORAGE system interfaces with a range of datasets (e.g. climate, soils, woody vegetation cover and satellite-derived ground cover), performs modelling analyses and data processing, and offers individual reports on property mapping, climate, pasture growth and ground cover (Zhang *et al.* 2021, Figure 1). The information generated through FORAGE can be used to facilitate grazing and environmental land management decisions. The FORAGE system is maintained by the Queensland Government and is a free service.

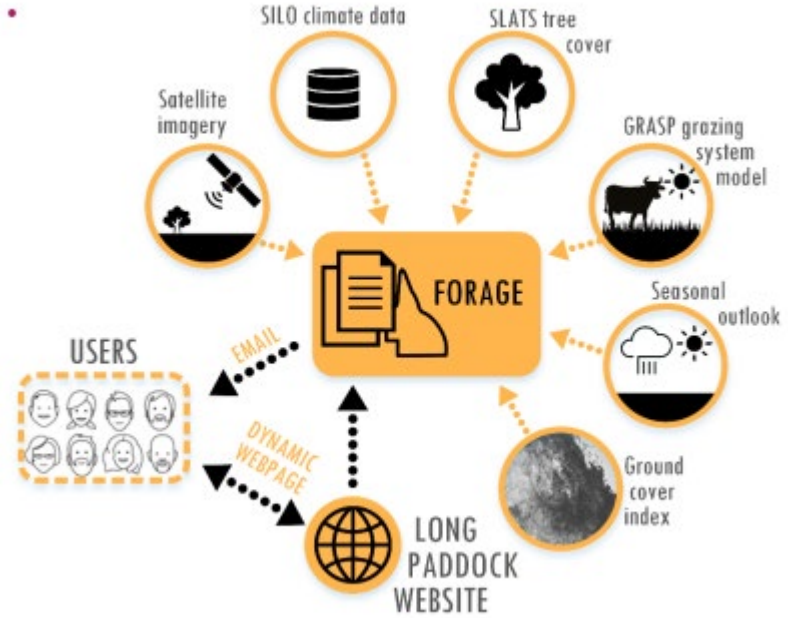


Figure 1. The FORAGE framework that includes a user interface on the Long Paddock website, a background information processing system on government servers, and an email delivery system (State Government 2022a).

A fully-automated approach to modelling long-term carrying capacity (LTCC) through the FORAGE online system was developed through the 'Inside Edge Project'. The GRASs Production (GRASP) model (Rickert *et al*. 2000, McKeon *et al*. 2000; see Figure 1) is used to simulate pasture growth with parameter sets and safe pasture utilisation rates defined for the grazing land types across Queensland (Zhang *et al*. 2021).

Review, refinement and validation of key input data (e.g. land type descriptions, mapping, GRASP parameters), and incorporation of new and existing data and local knowledge, was undertaken by DAF to ensure the FORAGE decision support tool provided consistent and scientifically robust long-term carrying capacity information.

Through the Inside Edge project, DAF achieved the following six key objectives:

- Enhanced Land types of Queensland information (Section 2)
- Improved Grazing Land Management land type mapping (Section 3)
- Expanded the network of benchmark properties in Queensland (Section 4)
- Established SWIFTSYND research sites to calibrate and improve native and buffel pasture GRASP parameters (Section 5)
- Contributed to the development, validation and improvement of land type GRASP parameters and pasture growth estimates for use in the Stocktake GLM App (Section 6)
- Developed and delivered an integrated engagement, education and communication approach to increase the awareness, skills and knowledge of users of the FORAGE system (Section 7)

This report details the achievements of DAF delivered through the Inside Edge project (2017-2022) and provides recommendations for future work.

2. Land types of Queensland

Introduction

In the early 2000s, the principles and concepts of sustainable 'Grazing Land Management' (GLM) were developed into training packages and delivered through GLM workshops across northern Australia (MLA 2006, Quirk 2006, Stone *et al.* 2021). Decision support and educational tools, including the calculation of the sustainable carrying capacity of land types within a property's paddocks according to land condition, were also developed to aid in the adoption of the GLM principles (Chilcott 2005). A key component of this process was identifying 'land types' for grazing that had characteristic patterns of soil, vegetation and landform and were easily recognised by landholders in a region. Hence, the focus of land type development was at the paddock and property scale to enable producers to identify areas of grazing land that differ in their capabilities to produce forage, and to determine how these differences affect productivity, carrying capacity and influence management options.

The Queensland Department of Agriculture and Fisheries developed and published 'Land types of Queensland' (available at https://futurebeef.com.au/resources/land-types-of-queensland/) in 2009 (v1.2), with updates in 2010 (v1.3), 2011 (v2.0), 2015 (v3.0) and 2019 (v3.1) as new land types, land management guidelines and regional ecosystem information became available.

'Land types of Queensland' are one of three integral components in the FORAGE modelling framework (https://www.longpaddock.qld.gov.au/forage/) that uses satellite imagery, climate data and the GRASP model to provide pasture growth and carrying capacity information for grazing properties in Queensland. The FORAGE decision support system generates indicative land type reports, rainfall and pasture by land type reports, Foliage Projective Cover (FPC) reports, Pasture Growth Alert reports, and long-term carrying capacity reports for Queensland grazing properties.

The GLM Land type mapping (see https://futurebeef.com.au/resources/glm-land-type-mapping/) is the spatial representation of 'Land types of Queensland'. This and the associated GRASP pasture growth model parameters (see Section 6 for further details) have been used extensively by DAF and other extension providers in a suite of extension programs (e.g GLM Edge training packages, Stocktake, Grazing BMP, GRASS) for property mapping, estimating carrying capacity, bio-economic modelling, and to communicate with graziers.

Enhancing Land types of Queensland

Through the Inside Edge project, DAF has continued to revise, improve and update Land types of Queensland to reflect user needs, the latest available information and to ensure descriptions have statewide coverage. DAF consulted widely with key regional staff to ensure 'Land types of Queensland' were useful and meeting the needs of the users of this information. A consensus of feedback indicated that the provision of carrying capacity information and providing clarity on the pasture utilisation value would be the most useful additional information for producers. The review process also identified Darling Downs, Coastal /lower Burdekin, Mary catchment and SEQ as areas where further development of land type descriptions, mapping and GRASP parameters was required.

The major improvements to Land types of Queensland V4.0 (https://futurebeef.com.au/resources/land-types-of-queensland/) are detailed below with recommendations for future work outlined.

Land types of Darling Downs GLM region

The north-east Downs Landcare group provided the impetus for the preliminary development of a subset of land types for 'Darling Downs' in 2007. Ten years on, increasing demand from extension providers for land types and modelled pasture growth estimates resulted in DAF contracting the

services of Jillian Alexander ***Applied Ag*** to describe 17 grazing land types for the Darling Downs GLM region. DAF revised and edited these land type descriptions, compiled a plant index (https://futurebeef.com.au/resources/darling-downs/) and developed GLM land type mapping for the Darling Downs GLM region (see Section 3 for further details). Development of the GRASP parameters for newly described land types was required to incorporate the Darling Downs GLM region in the FORAGE decision support system. DAF developed the draft parameters for the 17 land types and consulted with Grant Fraser (DES) to refine the parameters and validate the GRASP pasture growth estimates for land types of the Darling Downs.

Land types of Mary and SEQ GLM regions

The review of Land types of Queensland indicated that both the Mary River catchment and SEQ were areas that required the development of land type descriptions and associated mapping and GRASP parameters.

DAF contracted Brad Wedlock ***Mary River Catchment Coordinating Committee*** and Bruce Lord ***Health Land and Water*** to develop and describe land types for the Mary and SEQ Grazing Land Management regions respectively. Twenty-two land types were described for the Mary GLM region, with additional dominant pasture, tree cover and stocking rate information provided.

Fifteen draft land type descriptions for the SEQ GLM region have been developed. These include revision and amendments to the original 12 Moreton land types and the addition of three new SEQ specific land types. A further six regional ecosystems (heath, she-oak forests, saltmarsh & wetlands on marine plains and freshwater wetlands, inland sedgelands) that occur predominantly on the coast and support very few livestock, will be developed as supplementary property planning information that highlights their environmental values.

DAF has identified that future work is required to incorporate both the Mary and SEQ regions in the FORAGE decision support system.

Long-term carrying capacity

Extensive consultation with key regional extension staff determined that all land type descriptions would have modelled long-term carrying capacity (LTCC) information that is consistent with that provided through FORAGE, Edge GLM programs and Stocktake GLM App. Consultation and liaising with Grant Fraser (DES) were essential to ensure the GRASP land type parameters were current and validated, and the simulated pasture growth estimates were consistent with FORAGE and formatted for use in Stocktake GLM App (see Section 6).

The LTCC information is based on current GLM land type mapping, Foliage Projective Cover (FPC) spatial data (Queensland Government 2018b) and GRASP modelled outputs for native and, where relevant, buffel grass (*Cenchrus ciliaris*) pastures. The LTCC is dependent not only on the land type but is also strongly influenced by climate, tree cover, land condition and type of pasture. The following approach was used to enable the calculation of the LTCC information for each land type:

- Determine land type spatial distribution within a GLM region
- Determine the median FPC /TBA of land type with woody cover
- For each GLM region, determine the relevant climate stations used in Stocktake GLM App
- For each land type, determine the two climate stations that capture the range of rainfall
- Determine the median annual rainfall for two selected climate stations
- Determine the estimated ‘safe’ annual utilisation pasture growth for native and sown pastures as described in the ‘Land types of Queensland’
- Determine the simulated A condition pasture growth (DM Kg/ha) for each land type at the two identified climate stations with 0 FPC/TBA and median FPC/TBA

- Calculate long-term carrying capacity as hectare/adult equivalents (ha/AE) with an AE being a 450kg cattle consuming 8kg DM/day
- Populate the LTCC table of information and include in land type descriptions

An example of the LTCC information added to all land type descriptions is provided in Table 1.

Table 1. Long-term carrying capacity information (A condition)

Based on fully watered area for 1AE = 450 kg animal consuming 8kg DM/day				
Median annual rainfall 582 – 666 mm				
Pasture type	Median tree cover (TBA m^2/ha) (FPC %)	Median annual pasture growth (DM kg/ha)	Safe annual utilisation pasture growth (%)	LTCC (ha/AE)
Native species	0 TBA/FPC	6730 - 6920	30%	1.4 – 1.4
	13 TBA 31 FPC	4050 - 4750	30%	2.1 – 2.4
Sown			35%	

Regional maps

Regional maps provide a spatial distribution and environmental description of each land type. The maps capture the data used in calculating LTCC and were developed as supplementary information for DAF extension staff. Regional maps were developed for all land types and appended to each land type description. The steps involved in the collation of spatial data and derivation of statistics are indicated below:

- Import various spatial layers into ArcGIS (Qld border, climate stations, GLM regions, GLM Land type mapping, Foliage Projective Cover, TMR.QLD_SC_ROADS)
- Calculate the area of land type within the GLM region, area of land type with woody cover, median FPC/TBA
- Calculate the median and average rainfall range for the land type
- Populate regional map with calculated values

An example of supplementary Regional Map is provided (Figure 2).

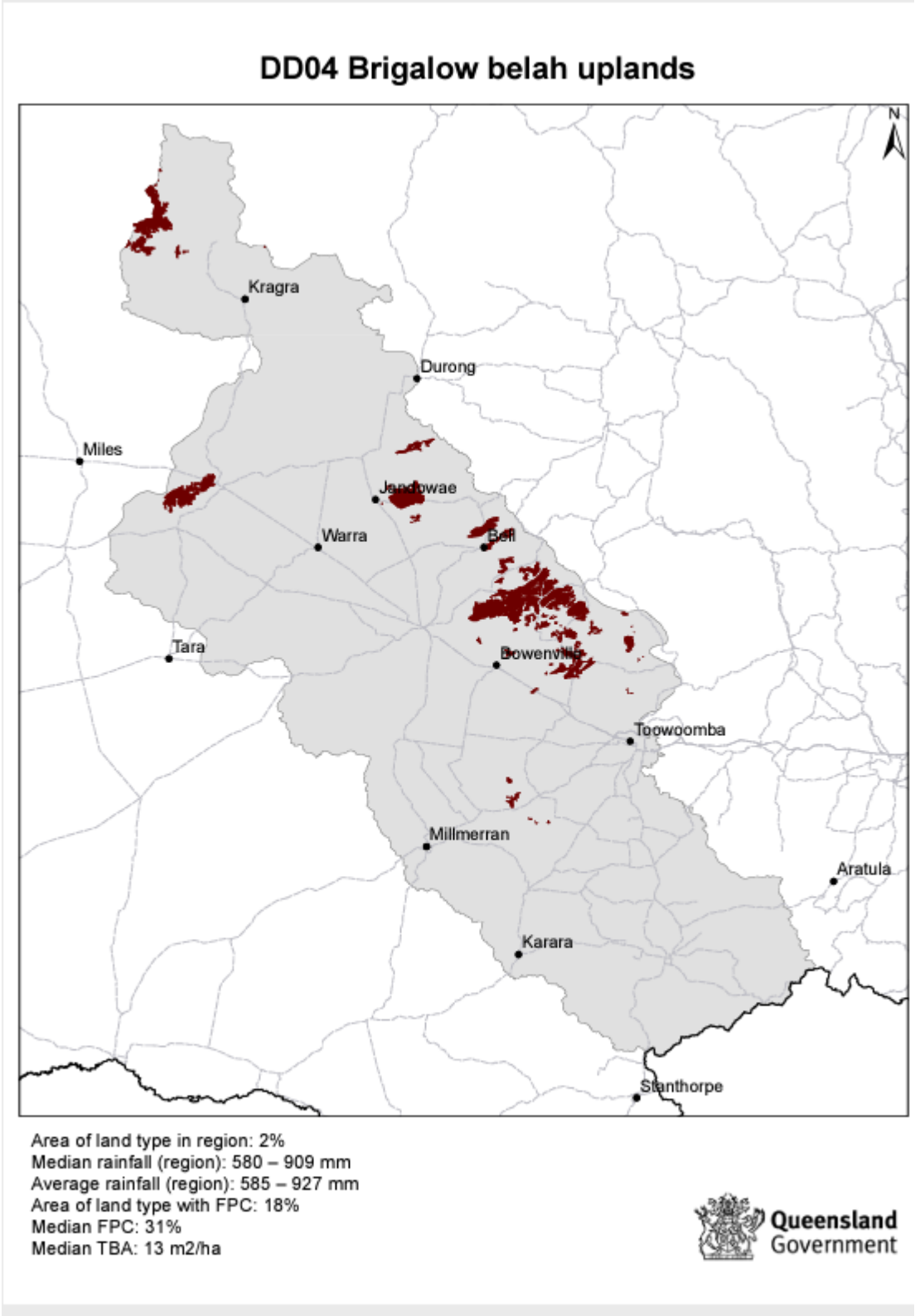


Figure 2. Example of Land types of Queensland supplementary regional map.

Conclusion and recommendations

A substantial review and consensus of feedback have ensured the enhanced ‘Land types of Queensland’ reflect user needs, include the latest available information and have state-wide

coverage. More than 240 land types from 16 Grazing Land Management (GLM) regions in Queensland have been described, long-term carry capacity (LTCC) estimated, and their distribution mapped. Land types of Queensland V4.0 are available at FutureBeef (https://futurebeef.com.au/resources/land-types-of-queensland/). The LTCC information is consistent with that provided through FORAGE (https://www.longpaddock.qld.gov.au/forage/report-information/long-term-carrying-capacity-report/), Stocktake GLM App (https://stocktakeglm.com.au/) and EDGE GLM & Grazing Fundamentals packages (https://www.mla.com.au/extension-training-and-tools/edgenetwork/).

It is recommended that the following work is undertaken to improve and update 'Land types of Queensland' to reflect user needs, the latest available information, and to ensure descriptions have state-wide coverage.

Incorporation of both the Mary and SEQ regions in the FORAGE decision support system:

- revise and edit land type descriptions, compile plant indices and references, add long-term carrying capacity (LTCC) information, and develop regional maps for uploading to Futurebeef website (https://futurebeef.com.au/resources/darling-downs/);
- review and update GLM land type mapping; and
- review and develop the GRASP land type parameters to ensure correlation with new land types.

Ensure land type descriptions are current and that there is consistency across FORAGE and EDGEnetwork and Stocktake GLM App platforms:

- Be proactive in liaising and consulting with DES grazing system modellers to develop, review and refine GRASP land type parameters for:
    - new GLM regions (e.g. Mary, SEQ),
    - new pasture types (e.g. Indian couch *Bothriochloa pertusa*, Buffel *Cenchrus ciliaris*), and,
    - as new data/information becomes available (e.g. benchmark properties informing on pasture growth ranking and safe utilisation rates), and
    - develop the grazing system modelling capacity in DAF.
- Ensure regional ecosystems associated with land types are consistent with GLM Land type mapping.
- Consider the need to automate the derivation of LTCC information to minimise errors and increase efficiency (e,g. extraction of pasture growth estimates and calculation of LTCC).
- Update land type descriptions with revised and new LTCC information.
- Identify new climate stations and collect rainfall statistics as appropriate.
- Liaise with DES to derive the latest pasture growth tables and distribute them for use in Stocktake GLM App.
- Develop a semi-automatic process to extract data for regional maps (e.g. define the distance to rule to identify relevant climate stations, extraction of the land type area, FPC values and rainfall statistics) to minimise data handling errors and increase efficiency.
- Update land type regional maps in synchrony with revised and new land type descriptions.

Continue to revise, seek feedback and update as required to reflect user needs and latest information. For example, the FORAGE Erodible Soils Report are currently available for Burdekin, Fitzroy and Burnett-Mary catchments GLM regions. DAF extension staff have shown initial interest in adding 'Erosion risk' information to land type descriptions that align with the FORAGE reports.

3. Grazing Land Management land type mapping

Introduction

Land types of Queensland (henceforth referred to as GLM land types) were developed by the Department of Agriculture and Fisheries (DAF) to provide information for native pasture and grazing land management across Queensland (see Section 2). Land types of Queensland (State of Queensland 2022b) are publicly available through FutureBeef (https://futurebeef.com.au/resources/land-types-of-queensland/).

The GLM land types have been used extensively by DAF and other extension providers in a suite of extension programs (e.g. GLM Edge training packages, Stocktake, Grazing BMP, GRASS) for property mapping, estimating carrying capacity, bio-economic modelling and to communicate with graziers. The GLM land types are described in terms of their landform, woody vegetation, expected pasture composition and broad soil characteristics. Grazing management recommendations, limitations to the use of the land and, more recently, carrying capacity information, are also provided. In 2022, 241 land types from 16 grazing land management regions in Queensland were described.

GLM land types and their spatial representation are key inputs for the FORAGE decision support system and VegMachine online tool. The spatial representation of GLM land types and its use in the online systems enables the definition of the grazing landscape and pasture productivity of Queensland.

In 2018, Chris Holloway (DAF) and Scott Irvine (DES) completed a major review of the GLM land type spatial data. Several new approaches were developed and implemented, and new data was incorporated into GLM land type mapping Version 5 (V5). Further detailed reviews of the Mitchell Grass Downs, Channel Country, Southern Gulf and Mulga GLM regions were validated by regional experts in 2018 (Irvine and Holloway 2019).

Since 2018, 17 new land types were described for the Darling Downs region and these were incorporated into the latest GLM land type spatial data. Additionally, a systematic and detailed review of all GLM regions has continued with errors and gaps identified, validation by regional experts completed and mapping updated. The methods, results, and conclusions of the work undertaken by DAF to review, improve and update the GLM land type mapping are detailed in this section.

Methods

There were two phases of methodology to improve the spatial representation of the GLM land types. The first phase follows Irvine and Holloway (2019) with the Sub-IBRA bioregions spatial dataset incorporated to ensure that land types were predominantly located within their relevant GLM region. This methodology was completed for the following regions Border Rivers, Burdekin, Coastal Burnett, Darling Downs, Fitzroy, Inland Burnett, Mackay Whitsunday, Maranoa Balonne, Mulga, Northern Gulf, Southern Gulf and Wet Tropics regions.

The second phase involved engaging a regional expert to review these land type associations. Regional experts provide a thorough understanding of the subtle nuances of that region's land types and what combination of tree and grass species and soil types define the land type, and where they are positioned in the landscape. In many cases the regional expert was involved in the initial creation of the land types of that region. The steps used for the regional expert review are described below.

We first asked the regional expert to nominate several grazing properties and/or areas where they had detailed or were confident in their knowledge of the land types located there. The location of these properties and areas were then supplied to the project team to create maps of the old and changed land types, and of the regional ecosystems (RE hereafter). The regional expert and the

project team then corrected land types associated with each RE where necessary and applied this throughout the GLM region. This was repeated for each area of interest or land type to the RE association noted for review by the regional expert. This process was completed for the Burdekin, Fitzroy, Mackay Whitsunday and Mulga regions.

The Darling downs region was completed in a slightly different way. Before 2018 the Darling Downs grazing land management region did not have any land types described. As part of the Inside Edge project, land type descriptions were developed for the Darling Downs (see Section 2), and, subsequently, were spatially represented in the Statewide GLM land type mapping. For the Darling Downs region, the Sub-IBRA bioregions spatial dataset was used to help identify the RE to land type associations as per the first phase described above. The second phase of mapping the land types involved undertaking a field trip with a regional expert (Jill Alexander) to gain an understanding of the grazing land types; including the woody vegetation species and growth forms in the climax and cleared states, the soil types and fertility, and the landscape position each land type commonly occupied. The RE to land type associations were then revised, and new mapping of the Darling Downs GLM region was produced, reviewed and finalised.

The Moreton and South-east GLM regions have been combined after an assessment by DAF scientists and regional experts and are yet to undergo a review (Phase 3). GLM land type mapping will be developed for Cape York once land type descriptions are developed (Phase 4).

The accuracy of the map was assessed by comparing the identification of land types through data recorded in other projects (Beutel *et.al* 2014). The other projects assessed land types at a location using an on-ground assessment.

Results

Detailed review and a regional expert validation of the GLM land type mapping were completed for all the GLM regions of Queensland bar Moreton/South-east and Mary GLM regions. Currently, there are no land type descriptions for the Cape York GLM region. A total of 12,729 unique RE and sub IBRA region combinations associated with a land type are defined in Queensland. Of these unique associations, 5346 (42%) were changed through the detailed review and regional validation processes (Figure 3, Table 2). The area of the RE and sub IBRA region combinations changed was 65.89 million hectares, which is 41% of the Grazing Land Management regions reviewed (Table 2).

Land types are a unique mapping unit and, therefore, a direct comparison of other land type mapping accuracies is not possible. However, the accuracy of land type spatial data was determined by comparing the land type mapping with on-ground assessment data and with a small number of land use classification mapping projects. The GLM land type mapping correctly identified land types at 79% of on-ground assessment locations and achieved an accuracy between 74% to 95% when compared with land use classification projects.

Updated land type spatial data is published in the Queensland Spatial Catalogue, provided to the FORAGE project team, and published in the Queensland Globe. The updated mapping is then used by the FORAGE online system (e.g. Long-term carrying capacity report) and soon to be released MyFORAGE tool. All version updates are broadcast via the FutureBeef newsletters and emails to key users within DAF and DES.

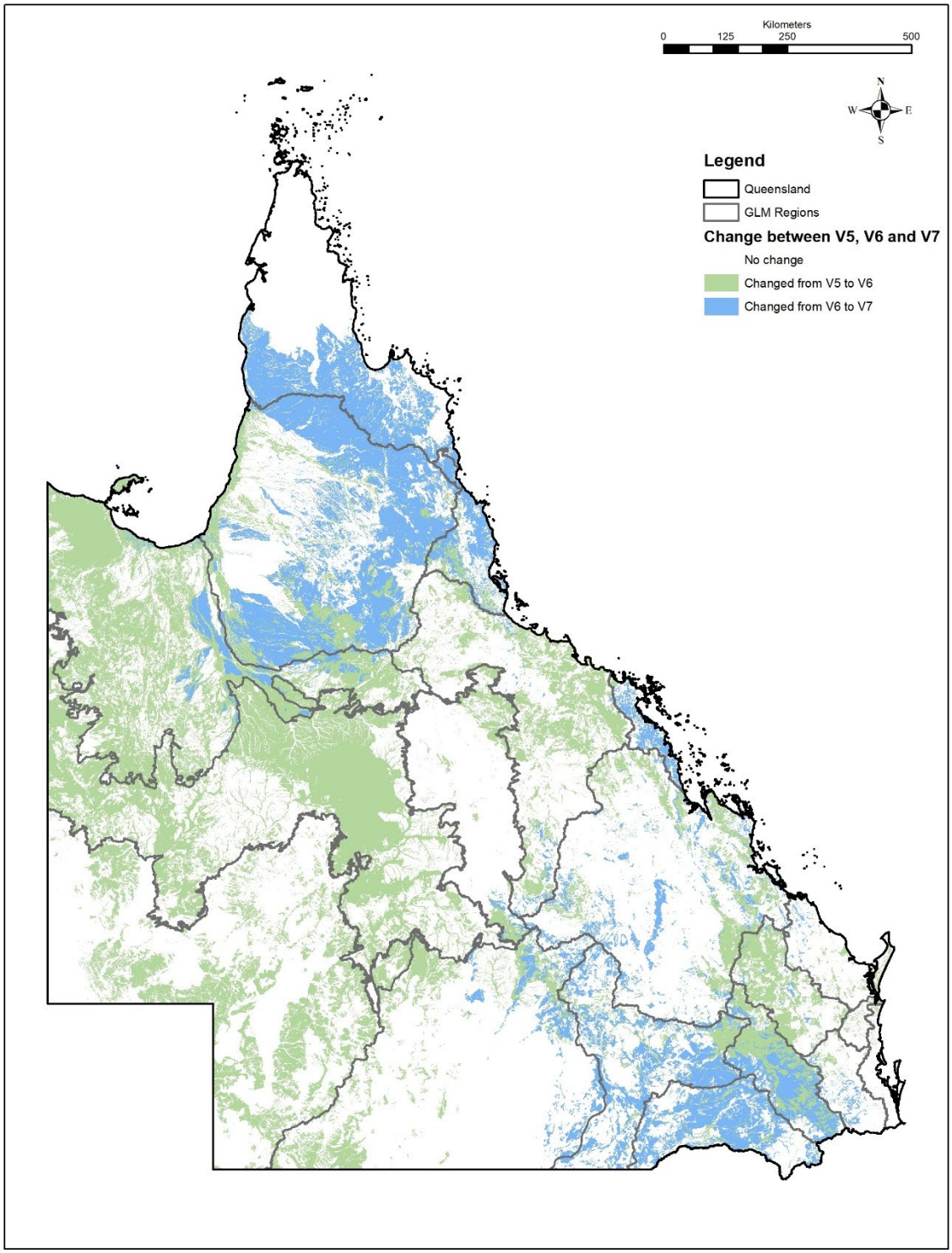


Figure 3. The spatial distribution of RE and Sub-IBRA bioregion combinations that were changed during the land type mapping review and validation phases in this project. Changes from V5 to V6 (green) and V6 to V7 (blue) and no change (white) are displayed. 68 million hectares and 5346 RE and Sub-IBRA combinations were changed.

Table 2. The number and area (millions of hectares) of assessed Regional Ecosystems (RE) by Sub-IBRA bioregion combinations associated with a land type. Assessed RE/Sub-IBRA combinations are categorised to GLM regions, the number and area changed/not changed. Also shown is the status of the regional expert review and mapping review.

Grazing Land Management (GLM) region	Number of combinations	Combinations changed %	Area changed (million) ha	Total Area (million) ha	Area changed %	Regional review status
Phase 1						
Mitchell Grass Downs	629	74.7	13.74	23.54	58.4	Completed
Channel Country	603	32.5	10.71	23.61	45.4	Completed
Southern Gulf	866	97.9	15.38	15.68	98.0	Completed
Phase 2						
Wet Tropics	1802	54.1	1.44	2.41	59.9	No
Northern Gulf	1736	46.8	9.86	20.38	48.4	No
Mulga	739	18.6	1.69	19.86	8.5	Completed
Fitzroy	1644	23.6	2.00	16.48	12.1	Completed
Burdekin + Desert Uplands	2096	33.3	4.41	20.40	21.6	Completed
Inland and Coastal Burnett	807	32.9	1.50	5.44	27.5	No
Mackay Whitsunday	234	33	0.50	1.07	46.5	Completed
Maranoa Balonne	591	43.8	1.65	6.43	25.6	No
Darling Downs	243	45	3.02	3.61	83.6	Completed
Phase 3						
Moreton + SEQ						
Mary						
Phase 4						
Cape	Unknown					
Total	12729	42	65.89	158.90	41	

Conclusion and recommendation

The updated land type spatial data provided by this project, consisting of 12,729 combinations of RE and sub IBRA regions, covering 41% of Queensland's GLM regions, has been published and is available to a wide range of users. The substantial improvement to land type spatial data, along with its high degree of accuracy, ensures users of FORAGE and VegMachine online systems can be confident in the mapped GLM land type input for these decision support systems. The FORAGE decision-support tool is widely used for the management of Queensland's grazing lands.

The Moreton/South-east Queensland and Mary regions need to be reviewed, updated and published to complete the review and improvement of Queensland's grazing land management regions. A preliminary investigation into the land types of Cape York region should be conducted to identify the work required to describe, map and model this region.

4. Benchmark properties

Introduction

FORAGE (www.longpaddock.qld.gov.au/forage) is an automated online system that generates and distributes information for rural Lots on Plan greater than 5 hectares to help grazing and environmental management decisions. It is a modelling framework that assimilates spatial datasets (cadastral, grazing land types, climate data, remotely sensed woody vegetation cover) to provide safe carrying information for grazing properties in Queensland (Stone *et al.* 2021, Zhang *et al.* 2021). The estimates of long-term safe carrying capacity are based on the safe utilisation annual pasture growth generated by the GRASP pasture growth simulation model. The 'FORAGE LTCC' (Long-Term Carrying Capacity) report provides individual property land type, land condition and carrying capacity information that can be used as a starting point for discussion on grazing land management.

Estimates of sustainable or 'safe' stocking rates can also be derived from graziers' experience on their properties over long periods of climate variability. Long-term records of stocking rates in combination with observed land condition can be used to determine, in retrospect, 'safe' long-term stocking rates and the long-term productivity of the property. A verification/validation test of the modelled LTCC information was undertaken by comparing modelled LTCC estimates with grazier-provided information from 'benchmark' properties (Zhang *et al.* 2021).

This section details the approach and outcomes of the work DAF completed to expand the network of benchmark properties used to validate the FORAGE LTCC system.

Methods

Criteria for benchmark

Benchmark properties were identified using a hierarchical system to ensure that properties with the correct attributes were assessed. Potential properties were identified by contacting regional DAF staff who knew of properties that were well-managed, in good condition and had a good density of perennial plants in dry and wet years. The properties also had to be willing to share their animal number data and/or understand the long-term carrying capacity of the land types present on their property.

Potential benchmark properties were then approached initially by regional DAF staff who had rapport with managers and then by the Inside Edge Team. Two potential benchmark properties were identified and assessed by consultants contracted by DAF, and three were identified as collaborators in other DAF projects. Collaborating properties were then visited by the Inside Edge Team.

Property Visit

Preparing for property visits involved collating all information that could be used to create property maps. This included VegMachine reports, ground cover and regional ground cover comparison FORAGE reports and long-term rainfall records. Information on paddocks, water points, land types, tree cover, and areas grazed was collated to develop draft property maps. These draft maps were then updated and improved following discussion with owners during the property visit.

Properties were either visited by one or more DAF staff or a consultant. This commenced with a discussion of a wide range of topics with the owners to understand their operation, markets, families, grazing management (past and present), pasture and cattle management and goals. During these discussions we also checked the accuracy of the draft mapping to ensure paddocks, land types and land uses were captured accurately for use in the FORAGE system.

Cattle numbers and weights or animals age classes are the other primary data source required to accurately benchmark the carrying capacity reports. The level of detail for stock records varied between benchmark properties, but where possible, significant effort was dedicated to identifying animal class, numbers and time spent grazing on a paddock basis.

The remaining time on the property involved undertaking land condition assessments and noting land types, sown pastures, and other areas of interest. A desktop GIS stratification method, that identified areas of the property with similar land condition, was developed to optimise DAF time while accessing and assessing sites on the property. The Stocktake methodology (Aisthorpe *et al*. 2004) was used to assess land condition sites that were randomly selected at the pre-determined areas based on the stratification layer.

Data compilation and comparison

Following the property visit, management notes, land condition data and animal numbers were collated. A Benchmark Property Report that summarised the aims of the Inside Edge project, the purpose of benchmarking, grazing management discussions and land condition assessment data were compiled for each property visited. Land condition assessment data provided to producers included: rationale for assessment sites, methodology used, a summary of property land/pasture types and condition, a property map identifying land types and location of assessment sites, recorded land condition assessment data and site photos. Animal numbers and weight classes from multiple years were converted to adult equivalents (AE) and annual carrying capacities which were then compared to the FORAGE long-term carrying capacity information for the property.

Results

Benchmarking eight properties allowed us to validate 38 different land types across six GLM regions (Table 3). The eight properties covered 164,561 ha of grazing land, ranging in size from 4,616 ha to 43,298 ha. Median annual rainfall ranged from 416 mm to 655 mm. The land condition was a combination of A and B with some areas of C on two properties. Benchmark reports were provided to the owners of three properties not involved with other DAF projects nor visited by consultants.

Animal numbers and records

Animal numbers were highly variable across all properties and most years. Most properties had stock records that covered many years of grazing on their properties. In some instances, properties provided ‘simplified’ carrying capacity estimates for a defined period that was sufficient for validation. Stock records came in a variety of forms, including paper stock charts, excel stock charts, excel notes and accounting charts. Producers used varying methods to calculate grazing pressure such as: Stock days per hectare (SDH), animal numbers by class, animal numbers, adult equivalents (AEs), cow and calf numbers. Collating and checking stock number records required a large amount of work to ensure, as much as possible, accurate capture and conversion of stock records to AEs to allow comparison with the FORAGE estimated long-term carrying capacity.

Producer learnings

The most common theme that was talked about by producers was that they look at their pastures to decide whether to move cattle around paddocks or off the property. A common strategy was selling cattle, with a common decision time being at the end of the wet season when the pasture had finished growing. Most producers had clear plans and were ready to sell cattle at this time. If required to act, these producers did not limit themselves to only selling marketable cattle, they would also sell non-pregnant breeders, young cattle and poorly performing or poor fertility cows if required. Notable quotes included “don’t get attached to breeders be ready to sell”, ”I will always have a dry mob of cattle ready to sell”, “Cows don’t get a second chance.” Another common strategy was the importance of getting their breeders into good condition to maximise their fertility. Here, the producers talked

about matching the country and stocking rate to the breeders age and weaning early to allow the cows to put on condition.

Table 3. Information gathered from the eight benchmark properties which were used in the validation of the FORAGE long-term carrying capacity reports. Area, GLM Region and land types sourced from mapping data. Rainfall sourced from the Bureau of Meteorology, land condition from on ground property assessments, and grazing regime and animal data sourced from the property owners and managers, Abbreviations and units are as follows: ha (hectares), mm (millimetres), GLM (Grazing Land Management), SDH (stock days per hectare), CC (carrying capacity).

Benchmark Property	Area (ha)	GLM Region	Median rainfall (mm)	Land condition	Grazing regime	Animal data	Land types
1	13,829	Burdekin	641	A and B	Rotation short duration, pasture matched	Animal numbers SDH	Narrow-leaved ironbark on deeper soils, Narrow-leaved ironbark on shallower soils
2	43,298	Mitchell Grass Downs /Desert Uplands	416	A and B	Rotation, Pasture matched	CC SDH	Open alluvial plains, Open downs, Scrubs on deep clays, Downs, Wooded downs
3	28,442	Burnett	655	A and B	Rotation medium duration, pasture matched	CC	Brigalow Belah scrub, Narrow-leaved ironbark on granite, Mixed open forests on duplex and loam, Spotted gum ridges
4	37,348	Desert Uplands	498	A, B and C	Rotation, Pasture matched	Animal numbers SDH	Yellowjacket country +/- wattles, Ironbark country, Channels and swamps associated with major streams, Box country, Jump ups
5	12,621	Maranoa Balonne/ Mulga	510	A and B	Set stocking, pasture matched	Animal numbers	Poplar box on alluvial plains, Brigalow with melonholes, Cypress pine on deep sands, Cypress pine on duplex soils, Mitchell grasslands, Bendee ridges, Poplar box and brigalow, Poplar box and silver leaved ironbark, Soft Mulga
6	18,829	Fitzroy	586	A and B	Rotation medium duration	Animal numbers	Brigalow with softwood scrub, Spotted gum ridges, Lancewood-bendee-rosewood, Poplar box / brigalow / bauhinia, Brigalow belah scrub, Box flats, Silver-leaved ironbark on duplex, Softwood scrub
7	4,616	Burnett	627	A and B	Rotation medium duration, planned	Animal numbers SDH	Box on clay, Brigalow and brigalow belah, Gum topped box, Narrow-ironbark on granite, Narrow-leaved ironbark and wattles, Spotted gum ridges
8	5,578	Maranoa Balonne	539	A, B and C	Rotation medium duration	Animal numbers	Poplar box flats, Poplar box and brigalow, Mitchell grasslands, Brigalow Belah scrub, Coolibah floodplains, Softwood vine scrub on clay or loam

Conclusion and recommendations

DAF expanded the network of benchmark properties in Queensland that contribute to the validation of the FORAGE long-term carrying capacity information. The eight additional properties were located across Queensland's extensive grazing regions and covered a wide range of property sizes, land types and climates.

Validation of two benchmark properties with the FORAGE estimated carrying capacity information revealed the FORAGE system underestimated carrying capacity at the Desert Uplands and Burnett benchmark properties. The alignment of producer information and modelled carrying capacity

estimates was improved for the Burnett benchmark property once improved pastures were accounted for in the FORAGE system. Further investigation of the land type parameters for the benchmark property in the Desert Uplands is required to improve the alignment of modelled and producer carrying capacity information.

Gathering complete property animal data that included paddock movements, weights or animal classes over multiple years and converting these to consistent animal units (AEs) was challenging. However, capturing accurate animal data is invaluable, not only for validation of the FORAGE modelling framework, but when combined with pasture growth information, it can be used in future modelling investigations to improve knowledge of 'safe' pasture utilisation rates.

Additionally, validation of the FORAGE system using benchmark properties highlighted the importance of accurate key input data (e.g. land types, sown pastures, tree cover). These insights, coupled with DAF extension staff feedback, led to the development of the MyFORAGE (prototype) tool that allows users to customise FORAGE reports for their property of interest. This tool allows users to set boundaries and paddock configurations, change land types, place water points, set land condition and indicate the proportion of buffel grass in their pastures.

Benchmarking is a valuable process for the validation of the FORAGE system. Benchmark properties highlight the importance of accurate key input data with the new MyFORAGE tool enabling users to customise for their properties. Key areas for further work include:

- Reviewing the Burdekin land type Yellowjacket with other eucalypts (BD20) and the Desert Uplands land type Yellowjacket country +/- wattles (DU13) GRASP parameters to improve modelled pasture growth estimates, and
- Improving the capacity to model grass growth from improved (sown) pastures.

5. SWIFTSYND research sites

Introduction

Graziers are constantly facing the major challenge of matching stocking rate to pasture growth, this particularly so in northern Australia's variable climate. The GRASP point-based model is used extensively in the rangelands of northern Australia to simulate pasture growth for different land types and climates, and to simulate the different effects of grazing management decisions on the pasture resource. Data collected from native pastures from over 100 sites across Queensland has been used to develop GRASP model parameters that predict the pasture productivity and carrying capacity for our grazing land types. The GRASP model land type parameters are integral to the FORAGE modelling framework that provides property-based grazing land management decision support information.

The establishment of SWIFTSYND research sites and collection of rainfall, pasture and soil measurements provide an opportunity to calibrate the GRASP land type models, improve estimates of pasture production and long-term carrying capacity, and assist in better grazing land management decisions that promote sustainable and profitable beef and sheep industries in Queensland.

This section describes the establishment and collection of data from native pastures over sown with legumes in the Burdekin GLM region and non-native buffel grass (*Cenchrus ciliaris*) pastures in central Queensland. Preliminary results and future work are outlined.

Methods

SWIFTSYND methodology

Data collected from SWIFTSYND plots will help to improve the capacity of GRASP model to simulate pasture productivity. Detailed field information on pasture growth collected at SWIFTSYND plots using methodology of Day and Philp (1997) is used to determine relationships and derive soil and pasture parameters for the GRASP model to simulate pasture growth.

SWIFTSYND sites were located after ensuring they were representative of a particular land type or pasture community, in good condition, and preferably on a mid-slope or where run-on=run-off. At each SWIFTSYND site, fenced small (30m x 30m) plots were established in the paddock and nine cells, walkways and quadrat positions were identified using wooden pegs as markers (see Figure 4 for layout, Day and Philp 1997). Pasture measurements were collected using 1 m^2 quadrats, and in October sites were 'reset' using a whipper snipper to remove material to a height of between 5 and 10cm prior to commencement of the next growing season. Tipping bucket (0.2 mm) rain gauge model TB3 and logger (Mini Log Data Logger ML1-420) were installed inside each SWIFTSYND exclosure and data was downloaded at each harvest, four times a year.

The measurements taken at each site provide the minimum information required to determine pasture and soil parameters for the pasture growth model GRASP. Measurements were undertaken four times a year to capture key pasture growth phases: initial regrowth (usually 6 weeks after start of growing season), peak growth, peak yield and detachment. Pasture species groups included 'buffel grass' 'native 3P – Perennial, productive and palatable,' 'Other grasses,' '*Aristida*,' 'Forbs,' and 'Stylos/legumes.' Measurements obtained four times a year from these sites included: rainfall, gravimetric soil moisture content, ground cover (bare, litter, rock, green and dead plant cover), pasture height, dry matter yield for each pasture species group (kg/ha), pasture species groups composition (% of total yield), total % nitrogen in pasture species groups, grass basal area using a 5-pin bridge (once a year) and soil bulk density (once only) required to convert gravimetric soil moisture to volumetric soil moisture.

Soil profile and bulk density sampling for Spyglass SWIFTSYND sites was undertaken by Ben Harms and Kelly Bryant Soil and Land Resources (DSITI) as part of the 'Soil resources of the Spyglass Beef Research Facility project' 2016. Soil profile reports and bulk density were provided for each SWIFTSYND site.

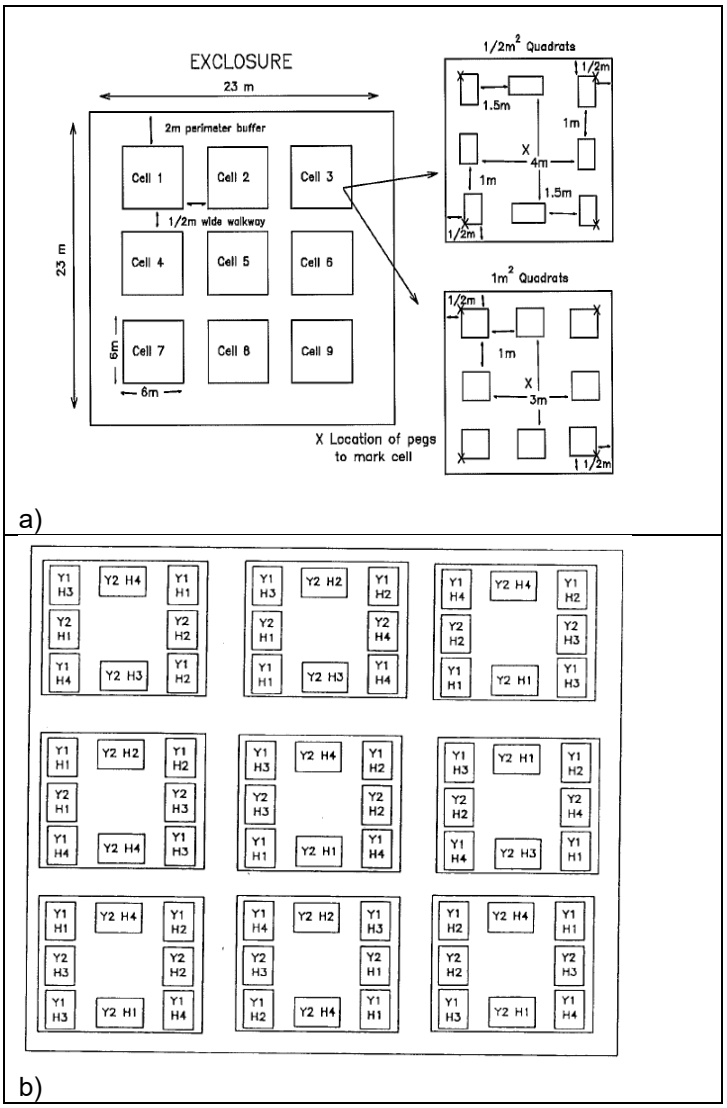


Figure 4. SWIFTSYND exclosure design a) exclosure design for 2-year sampling using 1m^2 quadrats and b) random allocation of quadrat positions for 2-year exclosure design (see Day and Philp 1997).

Soil profile and bulk density sampling at the four buffel SWIFTSYND sites was undertaken by Mark Sugars and Warrick Brown from the Department of Resources in July 2021. The presence of rock fragments in the soil profiles at the two Emerald SWIFTSYND texture contrast sites ('BOBB' & 'TUBB') created some difficulties obtaining intact soil samples. Soil samples were processed and sent to laboratory analysis (for pH, dispersal and slakiness) and bulk density was determined using CSIRO splining tool. This data was entered into the Queensland Government Soil and Land Information (SALI) database and Site Listing Reports were available for DAF to access through the Queensland GLOBE.

The SWIFTSYND methods used at the Spyglass and Emerald sites were as described above with any divergence indicated below.

Spyglass sites

The purchase of the DAF Spyglass Beef Research facility in 2011 provided an opportunity to improve pasture growth estimates for some of the more common grazing land types in the Burdekin GLM region. The land types on Spyglass cover a range of productivity levels and include native pastures over-sown with legumes, and buffel grass pastures.

Five SWIFTSYND sites were established on Spyglass property in October 2013 and a sixth site the following year (October 2014). Manual rain gauges were set-up at each site to complement the tipping bucket rain gauges and logger system, although the manual gauge at the Yellowjacket was only established in the second year of data collection. The sites covered a range of productivity levels from the most productive Loamy alluvials (LOAL), Box country (BOXH) and Narrow-leaved Ironbark on deeper soils (NLIBH) through to lower productivity Yellowjacket with other eucalypts (YJKT) to low productivity Box (BOXL) and Narrow-leaved Ironbark on shallower soils (NLIBL) (see State of Queensland 2022). Detailed rainfall, pasture and soil measurements were collected over two-year periods from 2013-2015 and 2016-2018 as per SWIFTSYND methodology (Day and Philp 1997). Additionally, during 2018-2021 limited pasture measurements were collected from the sites at the end of the growing season and at 'reset' at the end of the dry season.

Emerald sites

Non-native buffel grass (*Cenchrus ciliaris*) pastures cover ~5.1 million ha, occur in almost 15% of grazing land types and are the backbone of the central Queensland beef industry. Measuring pasture growth of buffel pastures in Queensland will improve our understanding of and ability to manage these important pastures.

Broadly, the majority of Queensland's buffel pastures occur from the north of Fitzroy region near Nebo through central Queensland to the southern downs (Roma – Wandoan). Within this region, buffel grass pastures occur on brigalow, softwood scrub and poplar box land types.

SWIFTSYND sites were set-up on buffel grass pastures in good condition, that were established for more than 15 years, and occurred on the geographically dominant Brigalow softwood scrub and Brigalow Blackbutt land types in central Queensland (see State of Queensland 2022). With the help of the local DAF officer, Paul Jones, three properties around Emerald were identified as suitable for the establishment of two Brigalow softwood (TUBS, BUBS) and two Brigalow blackbutt (TUBB, BOBB) buffel pasture SWIFTSYND sites. Data was collected four times a year for two years (2020-2021) as outlined in Day and Philp (1997), and, with the forecast of a 'La Niña' an additional year of data was collected (2022). Due to COVID travel restrictions, there was no second harvest in 2020. At one site (BOBB) inclement weather restricted access to the site in December 2021 and brought a tree down on the fence which allowed herbivores (rabbits) to graze the site.

SWIFTSYND harvest reports detailing rainfall, pasture, soil and N% measurements were compiled and provided to the collaborating producer each year.

Results

Spyglass sites

Summation of the data collected at each of the six native pasture +/- stylos SWIFTSYND sites established on Spyglass Research Facility during October 2013 (5 sites) and October 2014 (1 site) is provided.

Table 4. Soil descriptions for Box high productivity (BOXH), Box low productivity (BOXL), Loamy alluvial (LOAL), Narrowed-leaved ironbark high productivity (NLIBH), Narrowed-leaved ironbark low productivity (NLIBL) and Yellowjacket (YJKT) native pastures +/- stylo SWIFTSYND sites extracted

from Queensland Government Soil resources of the Spyglass Beef Research Facility reports (Bryant and Harms, 2016).

SWIFTSYND site	Project Site	Australian Soil Classification: Soil Association	Surface condition	Runoff	Permeability	Drainage	Depth m : pH
BOXH	Spy Site 8	Grey sodosol: Nosnillor	Firm, hard setting	Slow	Slowly permeable	Imperfectly drained	0.1: 5.9 0.3: 6.7 0.6: 8.2 0.9: 8.9 pH Neutral to alkaline
BOXL	Spy Site 14	Grey sodosol: Bluff	Hard setting		Slowly permeable	Imperfectly drained	0.1: 6.5 0.3: 6.0 0.6: 7.0 0.9: 7.4 1.2: 6.5 1.6: 5.3 pH Neutral to alkaline, subsoil strongly acidic
LOAL	SPY Site 7	Brown sodosol: Cape	Firm, hard setting	Slow	Slowly permeable	Imperfectly drained	0.1: 6.1 0.3: 6.2 0.6: 6.1 0.9: 6.4 1.2: 7.0 1.4: 7.6 pH Neutral to alkaline
NLIBH	Spy Site 6	Yellow kandosol: Boston	Hard setting	Slow	Slowly permeable	Imperfectly drained	0.1: 6.3 0.3: 6.2 0.6: 6.2 0.9: 6.2 1.05: 6.3 pH Neutral to acidic
NLIBL	Spy Site 15	Brown chromosol: Two Creek	Hard setting	Moderately rapid	Moderately permeable	Moderately well drained	0.1: 6.3 0.3: 6.1 0.5: 6.0 pH Neutral to acidic
YJKT	Spy Site 95	Red kandosol: Pentland	Firm, hard setting		Moderately permeable	Moderately well drained	0.1: 6.2 0.3: 6.2 0.6: 6.1 0.9: 5.9 1.2: 5.9 1.4: 5.7 pH Neutral to acidic

The soil profile (Table 4) and bulk density (Table 4) information indicate that the firm to hard setting soil types ranged from brown chromosol, red/yellow kandosol to brown/grey sodosol. Most sites were slowly permeable and imperfectly drained, although the chromosol and red kandosol soils were moderately permeable and well drained. Soil pH ranged from neutral to alkaline +/- acidic subsoils to neutral to acidic (Table 4). Soil bulk densities ranged from 1.5 to 1.9 gm/cm^3 at a depth of 100cm (Table 5). Lower bulk densities at depth (<1.6 gm/cm^3, Table 5) correlated with the occurrence of many (20-50%) small gravel pebbles (2-6 mm) at the BOXH and the common (10-20%) occurrence of small (2-6 mm) and medium (6-20 mm) gravel pebbles at the NLIBL site.

Table 5. Soil Bulk density (gm/cm^3) for Box high productivity (BOXH), Box low productivity (BOXL), Loamy alluvial (LOAL), Narrowed-leaved ironbark high productivity (NLIBH), Narrowed-leaved ironbark low productivity (NLIBL) and Yellowjacket (YJKT) native pastures +/- stylo SWIFTSYND sites.

Soil depth (cm)	**BOXH** Soil bulk density (g/cm3)	**BOXL** Soil bulk density (g/cm3)	**LOAL** Soil bulk density (g/cm3)	**NLIBH** Soil bulk density (g/cm3)	**NLIBL** Soil bulk density (g/cm3)	**YJKT** Soil bulk density (g/cm3)
0-10	1.6	1.65	1.58	1.58	1.58	1.56
10-20	1.66	1.59	1.68	1.65	1.61	1.62
20-30	1.76	1.53	1.77	1.74	1.64	1.68
30-40	1.86	1.58	1.82	1.76	1.38	1.67
40-50	1.96	1.63	1.87	1.78	1.41	1.63
50-60	1.81	1.68	1.92	1.79	1.46	1.62
60-70	1.63	1.69	1.95	1.80	1.5	1.63
70-80	1.58	1.69	1.98	1.81	1.51	1.64
80-90	1.53	1.7	2.01	1.85	1.52	1.65
90-100	1.51	1.67	1.96	1.88	1.52	1.65

Annual rainfall (mm) measured at six Spyglass SWIFTSYND sites during 2014-2019 varied between years and between sites (Figure 5). Across the sites rainfall varied by at least 100mm each year except in 2015 when all sites received only approximately 300 mm (Figure 5). All sites (bar LOAL in 2016 and NLIBH in 2017) received below the long-term (1889-2022) mean (602 mm) and median (570 mm) annual rainfall for Spyglass (SILO 2022) during first four years of measurements (2014-2017). In 2017 the NLIBH site received approximately 950 mm of rainfall almost 300 mm more than any other site. All sites received on or above average rainfall in 2018 and 2019 (Figure 5). Rainfall measurements in 2014 at the YJKT site were inaccurate as the logger failed and there was no manual gauge installed at the site.

Total standing dry matter (TSDM), pasture basal area and nitrogen concentration measurements for plant groups at all six SWIFTSYND sites at Spyglass are shown in Figures 6 & 7 and Tables 6 & 7. Total standing dry matter (kg/ha) was less than 1500 kg/ha at all sites during the below average rainfall years (2014-15), with the highest pasture yield measured at the LOAL site (~1300 kg/ha) (Figure 5). Somewhat surprisingly, pasture yield at the BOXH was consistently the lowest of all sites for all years, with pasture production only improving in the average annual rainfall years (2017-2018). The highest pasture production (~1700-2350 kg/ha) occurred at the sites (LOAL, NLIBL, YJKT) that received near average rainfall in 2016. Pasture production was highest (above 2500kg/ha) at the YJKT in 2017-2018 (Figure 6). During these wetter years, pasture production was also high at NLIBH (2017) and LOAL and NLIBL (2018).

The highest pasture yields are attributed to the dominance of native 3P grasses at YJKT and NLIBH and buffel grass at LOAL (see Figure 7c, d, f). Despite having the lowest pasture yields, the BOXH

site was dominated by native 3Ps (Figure 7a). The high pasture yields at NLIBL are due to 'other grasses' (2016) and stylos (2018) (see Figure 7e). Both 'low productivity' sites (BOXL and NLIBL) had the most amount of *Aristida* spp. and other grasses which included Indian couch (*Bothriochloa pertusa*), and less than 25% of pasture yield was 3P grasses (Figure 7).

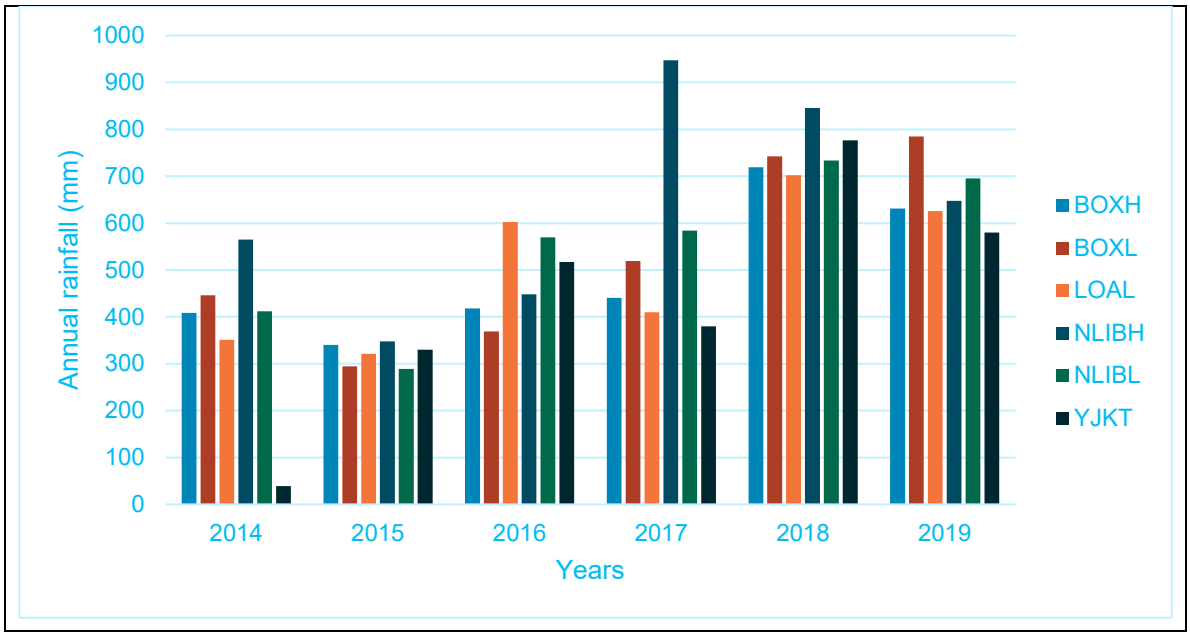


Figure 5. Annual rainfall (mm) measured at Box high productivity (BOXH), Box low productivity (BOXL), Loamy alluvial (LOAL), Narrowed-leaved ironbark high productivity (NLIBH), Narrowed-leaved ironbark low productivity (NLIBL) and Yellowjacket (YJKT) native pastures +/- stylo SWIFTSYND sites during 2014-2019.

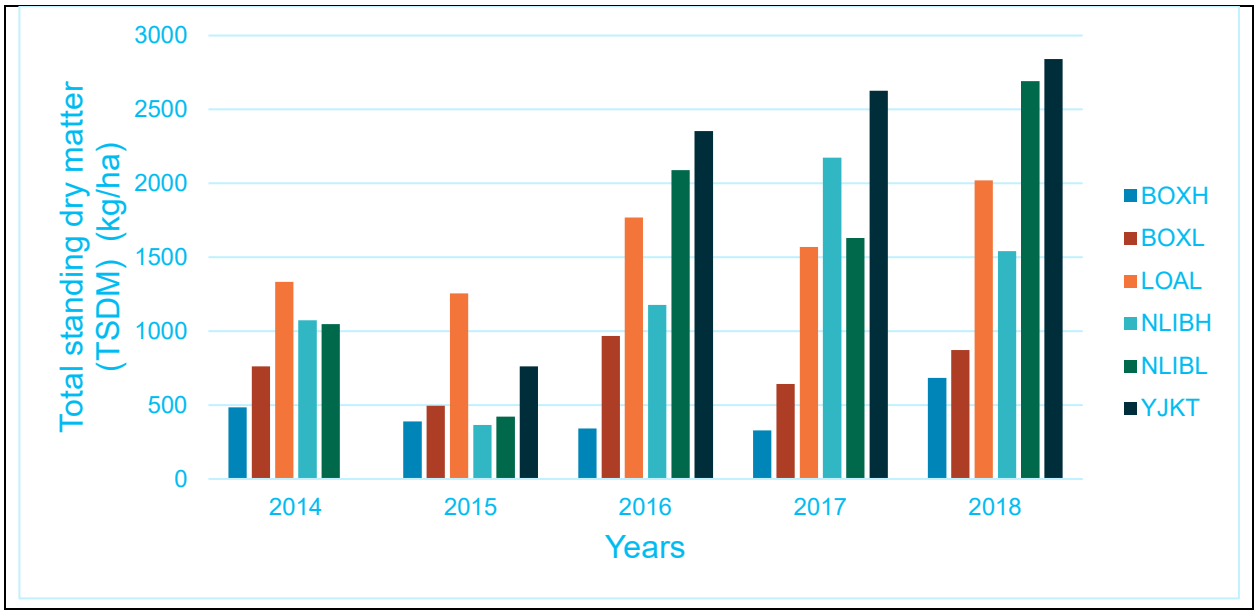


Figure 6. Peak Total standing dry matter (TSDM) (kg/ha) measured at Box high productivity (BOXH), Box low productivity (BOXL), Loamy alluvial (LOAL), Narrowed-leaved ironbark high productivity (NLIBH), Narrowed-leaved ironbark low productivity (NLIBL) and Yellowjacket (YJKT) native pastures +/- stylo SWIFTSYND sites during 2014-2018.

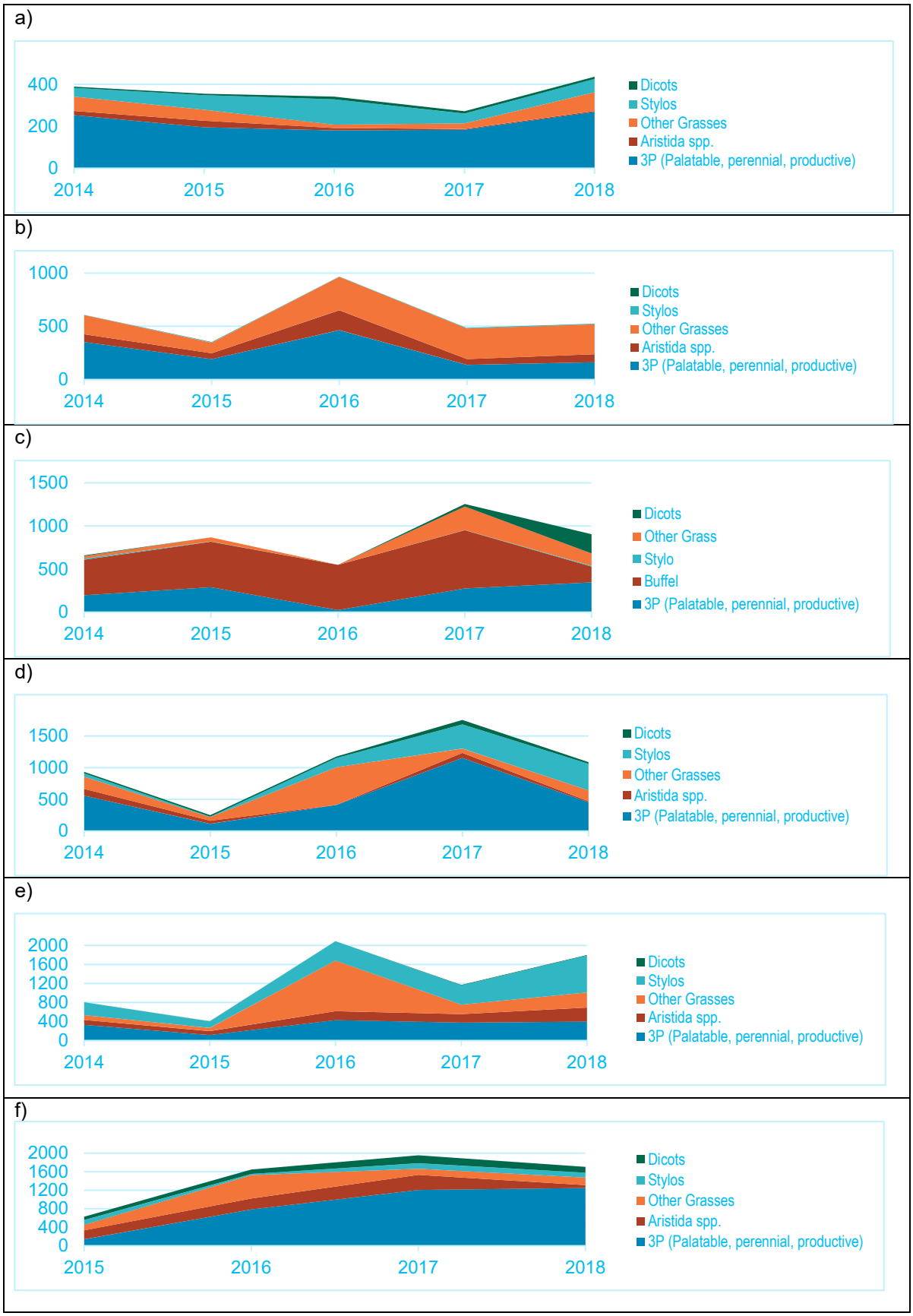


Figure 7. Pasture species group yields (kg/ha) measured at a) Box high productivity (BOXH), b) Box low productivity (BOXL), c) Loamy alluvial (LOAL), d) Narrowed-leaved ironbark high productivity

(NLIBH), e) Narrowed-leaved ironbark low productivity (NLIBL) and f) Yellowjacket (YJKT) native pastures +/- stylo SWIFTSYND sites during 2014-2018.

Table 6. Pasture basal area (GBA%) measured at Box high productivity (BOXH), Box low productivity (BOXL), Loamy alluvial (LOAL), Narrowed-leaved ironbark high productivity (NLIBH), Narrowed-leaved ironbark low productivity (NLIBL) and Yellowjacket (YJKT) native pastures +/- stylo SWIFTSYND sites during 2014-2018.

Site	2014	2015	2017	2018
BOXH	5.56	4.11	2.67	2
BOXL	7.44	3.44	4.44	3.78
LOAL	7.44	4.67	7.89	5.33
NLIBH	6.11	2.89	9.11	8
NLIBL	8.56	8.56	4.44	7.56
YJKT	4.11	2.78	6.22	5.11

Table 7. Plant group (3P grasses – Perennial, Palatable, Productive; Aristida spp.; Other grass species; stylo species; dicots) nitrogen concentration (N%) for Box high productivity (BOXH), Box low productivity (BOXL), Loamy alluvial (LOAL), Narrowed-leaved ironbark high productivity (NLIBH), Narrowed-leaved ironbark low productivity (NLIBL) and Yellowjacket (YJKT) native pastures +/- stylo SWIFTSYND sites.

Site		3P grasses (Perennial, Palatable, Productive) N (%)	Buffel grass N (%)	*Aristida* spp. N (%)	Other grass species N (%)	Stylo species N (%)	Dicots N (%)
BOXH	Max	1.66		0.98	1.26	2.31	2.22
	Min	0.37		0.42	0.39	1.11	0.72
BOXL	Max	1.48		1.16	1.40	2.23	1.99
	Min	0.37		0.41	0.44	0.75	1.03
LOAL	Max	1.33	1.15		1.43	2.82	3.55
	Min	0.40	0.35		0.38	1.11	0.48
NLIBH	Max	1.52		1.10	2.45	1.62	2.25
	Min	0.29		0.48	0.80	0.41	0.50
NLIBL	Max	0.96		0.88	2.16	1.36	1.78
	Min	0.34		0.34	0.88	0.40	0.97
YJKT	Max	1.38		1.35	2.74	1.27	2.48
	Min	0.43		0.49	1.16	0.25	1.41
All sites	Max	1.66		1.35	2.74	2.82	3.55
	Min	0.29		0.34	0.34	0.25	0.50

Pasture grass basal area (%GBA) measurements at each site for each of the four years are shown in Table 6. Across the sites and all years, the grass basal area varied from 2% at the BOXH in 2018 to 9.1% at the NLIBH site in 2017 (Table 6). Over the four years, the variation in grass basal area was ~ 4% at all sites bar NLIBH where grass basal area varied by ~ 6%. Grass basal area was highest (8-9% GBA) at the NLIBH site during the wetter years of 2017-18. Most sites recorded the lowest grass basal area measurement during the driest year 2015. At the BOXH site, where pasture yields were consistently low, the grass basal area declined from an initial value of 5.6% in 2014 to 2% in 2018 (Table 6).

Dicots and stylos had the highest nitrogen content (3.55% N and 2.82% N respectively), with the 'other grasses' plant group that includes Indian couch also recording high nitrogen concentration (2.74% N) (Table 7). In other plant groups, maximum nitrogen concentrations decreased from 1.66% N (3Ps) to 1.35% N (*Aristida* spp.) with buffel grass having the lowest nitrogen concentration of 1.15% N. Minimum nitrogen concentration in all the grass plant groups (3Ps, buffel, other and *Aristida*) was approximately 0.3% N, 0.25% N in stylos with the highest minimum nitrogen concentration of 0.5% N in the dicot plant group (Table 6).

Emerald sites

Summation of the data collected at the buffel pasture SWIFTSYND research sites located on Brigalow blackbutt land type (BOBB & TUBB) and two sites on Brigalow softwood scrub land type (BUBS & TUBS) is provided. All results indicated for 2022 are only for data collected to June, with the last data collected in October to be processed and analysed.

Soil profile (Table 8) and bulk density (Figure 8) indicate similar soil types for both Brigalow softwood scrub sites and both Brigalow blackbutt buffel SWIFTSYND sites. Brigalow softwood scrub sites 'BUBS' and 'TUBS' were black vertosol with periodic cracking soil surfaces (Table 8) and bulk densities ranging from 1.5 to 1.8 gm/cm^3 at depth 150cm (Figure 8). Brigalow blackbutt sites BOBB and TUBB were brown sodosol with hard setting soil surfaces (Table 8) and bulk densities of 1.5 gm/cm^3 at depth <40cm (Figure 8). Collaborating producers were provided with the SALI Site listing reports.

Annual rainfall (mm) measured at Brigalow softwood scrub (BUBS & TUBS) and Brigalow blackbutt (BOBB & TUBB) buffel pasture SWIFTSYND sites during 2020-2022 is shown In Figure 9. For three sites in 2022, the rainfall measured was to June 2022. Due to a logger battery failure no rainfall was measured at the BUBS site until the battery was replaced in July 2022. In 2020, all four sites received below the long-term (1899-2022) mean (543.2 mm) and median (483.6 mm) annual rainfall for Emerald airport (BOM 2022). In 2021, all sites received on or above average rainfall, with one site receiving double the long-term average amount of rain. The highly anticipated 'La Niña' had only produced 'average' rainfall at three sites to June 2022.

Total standing dry matter (kg/ha) measured during the below average rainfall year (2020) was similar (2300kg/ha) at the brigalow softwood scrubs sites (BUBS & TUBS) whilst ranging from 2000kg/ha to 3000 kg/ha at the Brigalow blackbutt sites (Figure 10). In 2021, the above average rainfall resulted in higher pasture growth (3500-3900 kg/ha) on the heavier brigalow softwood soils (BUBS & TUBS) and at BOBB (3700 kg/ha) the site which received 1000 mm of rain. The lowest pasture growth was recorded at the other Brigalow blackbutt site (TUBB) which received ~ 600 mm. Pasture growth to June of 2022 at all sites was less than the previous year.

Table 8. Soil descriptions for the Emerald SWIFTSYND research Brigalow softwood sites ('BUBS' and 'TUBS') and Brigalow blackbutt sites ('TUBB' and 'BOBB') extracted from Queensland Government Soil and Land Information (SALI) site listing reports.

SWIFTSYND site	SALI Site	Australian Soil Classification: Great Soil Group	Surface condition	Runoff	Permeability	Drainage	Depth (m): pH
BUBS	MISCQ Site 62 SALI4320	Black vertosol	Periodic cracking	Moderately rapid	Slowly permeable (5-50 mm/day)	Imperfectly drained	0.05: 7.0 0.3: 8.5 0.6: 9.0 1.2: 9.0 1.5: 7.5
TUBS	MISCQ Site 63 SALI4320	Black vertosol	Periodic cracking	Moderately rapid	Slowly permeable (5-50 mm/day)	Moderately well drained	0.05: 6.0 0.3: 9.0 1.2: 8.0 1.5: 6.0
BOBB	MISCQ Site 60,61 SALI4320	Brown sodosol	Hard setting	Moderately rapid	Slowly permeable (5-50 mm/day)	Imperfectly drained	0.05: 6.0 0.3: 9.0 1.2: 8.0 1.5: 6.0
TUBB	MISCQ Site 64 SALI4320	Brown sodosol	Hard setting	Moderately rapid	Slowly permeable (5-50 mm/day)	Imperfectly drained	0.05: 6.5 0.3: 7.5 0.5: 7.5 1.0: 8.5

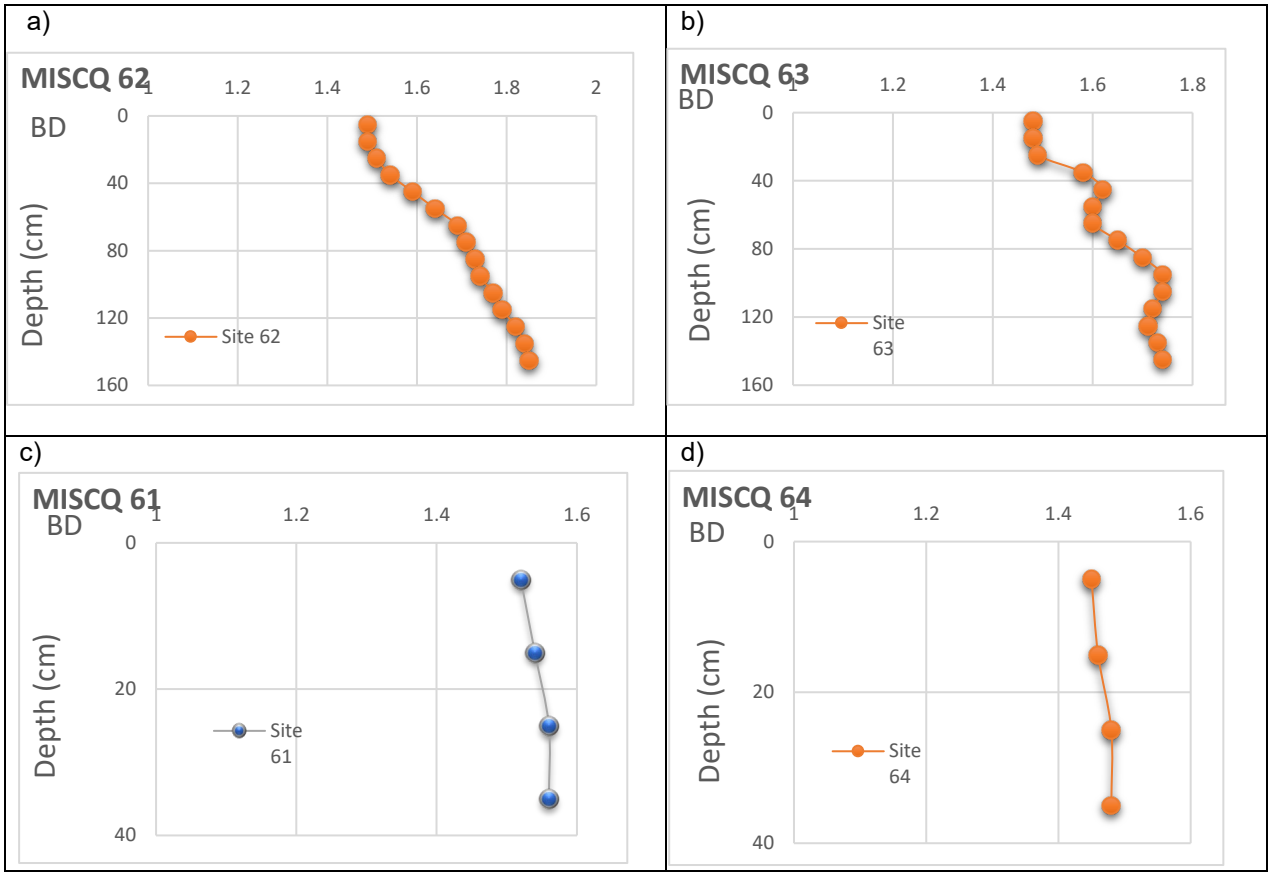


Figure 8. Soil Bulk density (BD) (gm/cm^3) for Brigalow softwood scrub a) BUBS & b) TUBS and Brigalow blackbutt c) BOBB & d) TUBB buffel pasture SWIFTSYND sites.

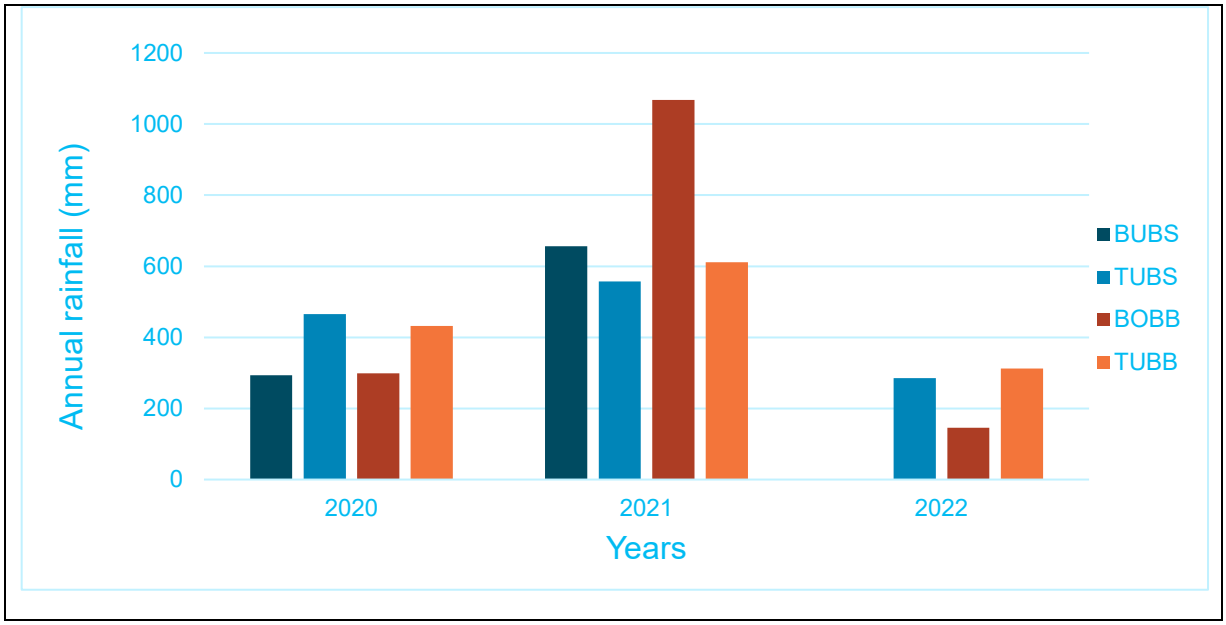


Figure 9. Annual rainfall (mm) measured at Brigalow softwood scrub (BUBS & TUBS) and Brigalow blackbutt (BOBB & TUBB) buffel pasture SWIFTSYND sites during 2020-2022. Note: 2022 Rain measured to June. Due to a logger battery failure no rainfall was measured at the BUBS site until July 2022.

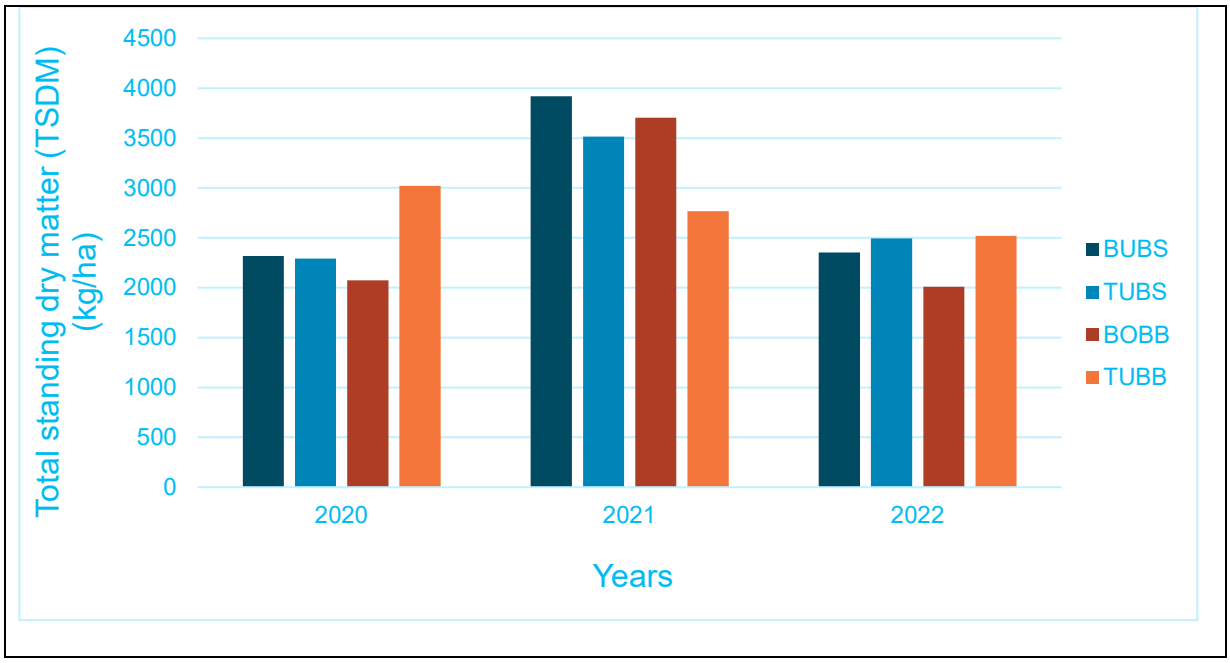


Figure 10. Peak Total standing dry matter (TSDM) (kg/ha) measured at Brigalow softwood scrub (BUBS & TUBS) and Brigalow blackbutt (BOBB & TUBB) buffel pasture SWIFTSYND sites during 2020-2022.

Percent grass basal area (%GBA) was measured in June 2020 and February 2021 & 2022 harvests at each of the four sites (Table 9). Gayndah buffel was the dominant pasture species at all sites, with Biloela buffel grass only present at the heavier textured Brigalow softwood scrub sites (BUBS & TUBS). Total grass basal area ranged from 8.7 (TUBS, 2020) to 23.8 (BUBS, 2020), and peaked in 2021 for all sites bar BUBS which peaked in 2020.

Pasture ill-thrift and potential 'dieback' was observed at the BOBB & BUBS sites in February 2022, with 2.8 & 4.1 %GBA for dead grass tussocks measured at these sites in 2022 respectively (Table 9). Data collection in June suggested the presence of dieback in the pasture at the BOBB site with a decline in buffel grass yield and an increase in forbs such that forbs contributed between quarter to half of pasture yield. Pasture at BUBS showed signs of recovery with an increase in buffel yield and new growth evident on many tussocks with only the odd dead tussock.

Table 9. Percent Grass Basal Area (%GBA) measured at Brigalow softwood scrub (BUBS & TUBS) and Brigalow blackbutt (BOBB & TUBB) buffel pasture SWIFTSYND sites during 2020-2022.

Site	Pasture grass	2020	2021	2022
BUBS				
	Buffel (Gayndah)	20.2	17.6	7.9
	Buffel (Biloela)	3.6	3.2	3.4
	Other grasses			
	Dead tussock	***0.1***		***4.1***
	Total %GBA	23.8	20.8	11.3
TUBS				
	Buffel (Gayndah)	5.4	8.9	6.4
	Buffel (Biloela)	3.1	8.1	4.7
	Other grasses	0.1	0.8	1.2
	Dead tussock			
	Total %GBA	8.7	17.9	12.3
BOBB				
	Buffel (Gayndah)	12.3	22.0	9.6
	Buffel (Biloela)			
	Other grasses	0.2	0.4	1.3
	Dead tussock			***2.8***
	Total %GBA	12.6	22.4	10.9
TUBB				
	Buffel (Gayndah)	10.1	18.1	10.7
	Buffel (Biloela)	0.2	0.6	
	Other grasses			
	Dead tussock			
	Total %GBA	10.3	18.7	10.7

Peak nitrogen in buffel grass was the least in 2021 (Table 10) with average or above average rain received at the four sites. The apparent recovery of the BUBS site on the black vertosol soils may be due to 'stored' soil nitrogen becoming available for plant growth which is reflected in the relatively high peak N% in buffel grass (1.5 %N, see Table 10). Across all sites and years peak nitrogen of buffel grass was similar between the varieties with 1.5 % N for Gayndah buffel compared to 1.46 % N for Biloela buffel. Generally, rates of pasture growth per mm of rainfall were higher at the Brigalow softwood scrub sites compared to Brigalow blackbutt sites (Table 10). Soil phosphorus (0-10cm depth) measurements across the four sites varied between 7 and 9 mg/kg except at TUBS in 2021 where soil P was measured as 11.5 mg/kg (Table 10).

Table 10. Peak pasture growth (kg/ha), % of grass in pasture, total ground cover %, peak N% in buffel grass, pasture growth (kg/ha) per mm of rain, soil Colwell P (mg/kg) measured at Brigalow softwood scrub (BUBS & TUBS) and Brigalow blackbutt (BOBB & TUBB) buffel pasture SWIFTSYND sites during 2020-2022**.**

Year	Site	Peak pasture growth kg/ha	Grass %	Total ground cover %	Peak Nitrogen % in buffel grass	Pasture growth (kg/ha) per mm of rain	Soil Colwell P mg/kg
2020	BUBS	2319	100	84	1.18	11.2	9
	TUBS	2289	99	75	1.19	6.2	9
	BOBB	2074	100	68	1.18	5.2	7
	TUBB	3017	100	63	1.12	8.5	8
2021	BUBS	3920	100	95	0.94	6.1	7
	TUBS	3516	99	81	0.91	7.3	11.5
	BOBB	3704	100	87	0.93	5.0	7
	TUBB	2766	100	74	0.93	5.5	8.5
2022	BUBS	2352	90	91	1.5		
	TUBS	2495	97	86	1.14		
	BOBB	***1962***	***61***	***61***	***0.98***		
	TUBB	2521	100	82	0.97		

Recommendations for future work

Data measurements collected (2013-2021) from six Spyglass and four Emerald SWIFTSYND sites will be used to calibrate and improve existing GRASP models for land types in the Burdekin GLM region and buffel pastures in central Queensland.

Collation, checking and organisation of all Spyglass and Buffel SWIFTSYND site measurements will be completed prior to the extraction of data into the format appropriate for GRASP model calibration. A systematic approach for model calibration (Scanlan *et al*. 2008) will be employed to ensure key biological and physical pasture processes are well represented in the GRASP model. Calibration of the Spyglass and Buffel SWIFTSYND sites will be undertaken using CEDAR GRASP (version 2.1.02 2021) and GRASP Calibrator (version 1.33 Build 7177) software.

As GRASP is an empirical model there are many calibrated parameter values. A few of these parameters relate to the location and characteristics of the site, a number of them can be estimated initially from field data, and some parameters can only be adjusted by comparing the model output with field observations.

Once calibrated, the native grass and buffel grass models for each location will be reviewed to determine if and how the models differed, and whether the differences were due to site preparation approach, site-specific characteristics or location. These considerations will then determine the appropriateness for the models to be extended over time and, in consultation with DAF regional experts, spatially to a geographically broader land system.

The calibration of GRASP models for the six Spyglass and four Emerald sites will provide improved native pasture +/- stylos and buffel grass pasture growth estimates and long-term carrying capacities for Spyglass property, grazing lands within the Burdekin region, and for the established buffel pastures of central Queensland. Calibrated models will also be incorporated in the FORAGE system to provide improved pasture related information to support grazing and environmental land management decisions and to assist managers of beef enterprises achieve sustainable and profitable animal production.

6. Develop, validate and improve property-based grazing land management decision support information

Introduction

Review, refinement and validation of key input data (e.g. land type descriptions, mapping, GRASP parameters), and incorporation of new and existing data and local knowledge, was undertaken by DAF to ensure the FORAGE decision support tool provided consistent and scientifically robust long-term carrying capacity information. This section details DAF's contribution to the development, validation and improvement of land type GRASP parameters and the pasture growth estimates for use in the Stocktake GLM App to ensure the provision of consistent and scientifically robust long-term carrying capacity information. Through the Inside Edge project, a strong collaboration with the lead GRASP modeller Grant Fraser (DES) enabled productive consultation, efficient modelling analyses and timely achievement of project objectives.

Improvement of GRASP land type parameters

DAF specifically contributed to the development and improvement of the Land types of Queensland GRASP parameters through the following activities:

1. Consulted, collaborated and liaised with Grant Fraser (DES) to review the pasture growth rankings, estimated safe carrying capacities and pasture growth utilisation information for all land types of Queensland.
2. Developed/refined GRASP land type parameters to correlate with current grazing land descriptions through the:
    a) Collation of pasture productivity rankings and estimated long-term stocking rates for 'new' Darling Downs grazing land type descriptions
    b) Identification of land types in Maranoa-Balonne, Fitzroy, Inland Burnett, Moreton and Border Rivers GLM regions that were equivalent or similar to the newly described (see Section 2) land types of the Darling Downs GLM region
    c) Development of draft GRASP parameters for each of the land types of the Darling Downs GLM region, and collation of associated pasture productivity rankings and estimated 'safe' long-term stocking rates
    d) Provision of the draft land type parameters for Darling Downs GLM region and supplementary information to Grant Fraser (DES) for further refinement and validation.
3. Consulted, liaised and provided advice for the inclusion of buffel pastures in the FORAGE modelling framework through the following activities:
    a) Provided DES with rainfall and calibrated parameters for a buffel pasture (*Cenchrus ciliaris cv.* Biloela and Gayndah) near Moura that was established in early 1997
    b) Provided rainfall use efficiency (RUE) and multiplier information for sandy red earths and gidgee/brigalow/softwood scrub derived from Eastwood grazing trial in SW Queensland
    c) Provided some 'back of the envelope' estimates for estimating productivity gains from buffel grass pastures compared to native grass pastures i.e. 1.2 x UR%, 1.2 x pasture growth
    d) Ensured the use of 'safe' pasture utilisation rates used in FORAGE were consistent with best available information including estimates provided by literature, producers and regional experts.
4. DAF established and collected detailed rainfall, soil and pasture measurements at Spyglass Research Facility (6) and buffel pastures around Emerald (4) SWIFTSYND sites between 2013-2022 (see Section 5). This data will be used to calibrate and improve existing GRASP parameters for land types in the Burdekin GLM region and buffel pastures in central Queensland.

Validation of FORAGE Long-term carrying capacity report

DAF specifically contributed to the review, validation and improvement of the FORAGE Long-term carrying capacity Report through the following activities:

1. Collated and reviewed land type carrying capacity information for 18 extensive grazing properties in Queensland that were part of the NRM Spatial Hub project (Whish *et al*. 2016) and provided information to the DES project team to compare with FORAGE estimates of carrying capacity.
2. Property mapping (ArcGIS shapefile), annual animal numbers and land condition assessment information that DAF collated for the eight established benchmark properties (see Section 4) was provided to DES to assist in the validation of the FORAGE Long-term carrying capacity Report
3. Consulted and liaised with DES on land type mapping and tree cover issues identified through feedback on FORAGE reports. Land type mapping was reviewed and updated to address identified issues (see Section 3), and the FPC data was updated when the new layer was made available in 2019.

Consistency of information across platforms and extension programs

DAF proactively ensured input data (e.g. land type mapping, tree cover) and GRASP modelled pasture growth and carrying capacity information was current and consistent across platforms (e.g. Long Paddock FORAGE, MyFORAGE, Futurebeef and Stocktake GLM App) and extension programs (e.g EDGE GLM, GLM Fundamentals and Stocktake) by:

1. Developing a system to ensure version control of CEDAR GRASP and the use of the most current land type parameters is consistent between DES and DAF, across all platforms and extension programs and for use in specific modelling activities by:
    a. Consulting with Grant Fraser and Anthony Chun (DES) to enable the most current version of CEDAR GRASP be available at:
    https://data.longpaddock.qld.gov.au/static/grasp/cedar.zip
    b. Making the most current GLM land type parameters available at:
    \\lands\data\dsiti\grazinglandsystems\nas\grazinglandsystems\projects\forage_land_type_mrx_files\
2. Providing advice to DES that ‘long-term carrying capacity’ terminology was preferred for use in the FORAGE reports
3. Identifying the need to align with the latest Adult Equivalent (AE) methodology (McLennan *et al.* 2020) and to change the animal intake value for calculation of the FORAGE LTCC report from 9kgDM/day/AE to 8kgDM/day/AE (see below for further details)
4. Identifying the need for consistency in the version of GLM land type mapping used in the FORAGE modelling framework and MyFORAGE tool. DAF developed a system to notify all key users of GLM land type mapping when a new version is published to ensure all platforms have access to current spatial data (see Section 3)
5. Tested ‘MyFORAGE’ functionality to provide user-enhanced property carrying capacity report and provided advice to DES project team including:
    a) Ensured that the title of the user-enhanced report indicated the information had been changed from the FORAGE LTCC report
    b) Identified errors in MyFORAGE calculation of watered areas and the need for ‘Fully watered’ and ‘Actually watered’ labels on MyFORAGE LTCC reports
    c) Suggested that a ‘tour’ be run to explain how to add water points to ensure model correctly simulates ‘distance to water’ impacts on carrying capacity
    d) Tested user-friendliness of importing property information from zipped shapefile, rename paddock, split paddock, change land condition, land type and edit features
    e) DAF is also liaising with DES to ensure GRASP-derived median pasture growth information for the Stocktake App is consistent with the modelling approach used in FORAGE (see below for further details). In particular, changing the 100 years historical

climate used in Stocktake to align with the 50 years (1970-2021) historical climate used in FORAGE. Additionally, the revised Stocktake data needs to include recent changes to Ashy Downs parameters made by DES following feedback from property owner near Hughenden, new Darling Downs land types and buffel grass pasture information.

6. DAF consulted with DES to ensure GRASP-derived median pasture growth information for Stocktake GLM App was consistent with the modelling approach used in FORAGE to provide long-term carrying capacity information (see below for further details) by:
    a. Changing the original 100 years of historical climate data to match the 50 years (1970-2021) used in FORAGE.
    b. Using same animal intake of 8kg/AE/year as that used in FORAGE to match current methodology.
    c. Ensuring Stocktake data includes recent changes to climate locations and land type parameters (e.g. changes to Ashy Downs parameters following feedback from property owner near Hughenden)
    d. Ensuring Stocktake data includes recently added Darling Downs land type parameters
    e. Deriving buffel pasture growth estimates for the 15 land types identified by DES to have the potential for the establishment of buffel grass pastures.
    f. Facilitating the inclusion of current pasture growth data in Stocktake GLM App.
7. Following extensive consultation with key regional extension staff, ~240 GLM Land type descriptions were revised and updated to include modelled long-term carrying capacity (LTCC) information that is consistent with that provided through FORAGE, Edge GLM programs and Stocktake GLM App (see Section 2 for further details).
8. DAF consulted with Grant Fraser to ensure buffel grass modelled estimates, where relevant, were included in the updated Land types of Queensland V4.0, and were also available through the Stocktake GLM App.
9. Consistency of information across all platforms was ensured with synchronised publication of key information (GLM Land types mapping V7, Land types of Queensland descriptions V4.0 that included newly described land types of Darling Downs) with recently developed Darling Downs GRASP parameters for use in FORAGE, and updated pasture growth estimates for use in Stocktake GLM App.

Stocktake GLM App

The Stocktake App was developed as a grazing land management decision support tool for northern Australian graziers, natural resource management groups and public and private extension service providers. The tool can improve knowledge and understanding and enable land condition monitoring and forage budgeting with a focus on making better land resource management decisions. The App has been embedded in relevant FutureBeef extension activities and training packages (Stocktake workshops, Edge GLM and Fundamentals workshops, Grazing BMP project) since its initial launch in 2013.

The original App included a range of inbuilt support tools, land type descriptions, pasture yield and ground cover standards, and modelled pasture growth estimates for a range of land types, tree cover and locations across northern Australia.

An opportunity to update the Stocktake App was provided through the Inside Edge project. DAF contracted Viewdale IT to improve the functionality of the Stocktake App and provide on-going Maintenance and Support of Stocktake GLM.

The new ***Stocktake GLM*** app reflects a substantial re-development, update of code, and new user interface that provides improved functionality. Additionally, all calculations have been revised, data updated, and adult equivalent rating tables that align with the new AE methodology (McLennan *et al*. 2020) included to provide a faster, more robust practical tool.

Stocktake GLM app is now able to adequately handle and store all data including land condition photos and determine a forage budget that will assist graziers meet ground cover and residual yield targets at the end of the grazing period to maintain and/or improve land condition. GRASP modelled

median pasture growth information using climate for 1970-2021 was provided to the Stocktake App developers in May 2022.

Adult equivalent data

The commonly recognised adult equivalent (AE) system describes and quantifies the grazing pressure imposed on the pasture by foraging ruminants. The AE rank assigned to an animal is determined as the ratio of its (metabolisable) energy (ME) requirements relative to that of a 'standard animal', where ME requirements are usually determined using the feeding standards. Previous research indicated that the Australian feeding standards (NRDR 2007) considerably over-estimated the energy requirements of cattle consuming tropical forages in northern Australia (McLennan *et al*. 2020). McLennan *et al*. (2020) modified the equations of the feeding standards, which improved predictions of ME, thus also forage dry matter (DM) intake by cattle. Recommendations specific to application of the revised animal unit system to the Meat & Livestock Australia (MLA) EDGE products were outlined in the authors' Final Report to MLA. MLA is currently revising the EDGE products and is responsible for broader industry understanding of these changes.

To ensure consistency of understanding, application and delivery of the new AE methodology across decision support system (e.g FORAGE LTCC report), extension tools and materials, workshops and programs (e.g. Stocktake, EDGE GLM and Fundamentals) Col Paton and Ian McLean were contracted to develop AE and DSE (goats and sheep) rating tables for use in the Stocktake GLM app, deliver four workshops across Queensland to Animal Science staff and Natural Resource Management officers working with the grazing industry, and deliver a webinar to DAF staff (see also Section 7).

Conclusion and recommendations

Strengthening of collaborations with the DES FORAGE team through the 'Inside Edge' project enabled DAF to contribute significantly to the development and improvement of property-based grazing land management information. Key contributions included:

- providing advice, data and information to improve Land type parameter sets;
- expanding the network of benchmark properties and capturing and responding to feedback to validate FORAGE long-term carrying capacity report; and
- managing input data (e.g. land type mapping, tree cover) and GRASP modelled pasture growth and carrying capacity information to ensure it was current and consistent across platforms (e.g. Long Paddock FORAGE, MyFORAGE, Futurebeef and Stocktake GLM App) and extension programs (e.g. EDGE GLM, GLM Fundamentals and Stocktake).

Collation, review and finalisation of the 'new' land type descriptions and associated information from both Mary and SEQ GLM regions is required to allow for the development of associated land type parameters for inclusion of these GLM regions in the FORAGE modelling framework. This will also require an update of GLM land type mapping. Synchronised publication of updated Land types of Queensland, GLM land type mapping and inclusion of new land type GRASP parameters in FORAGE, and updated pasture growth estimates for use in Stocktake GLM App, will ensure current and consistent *property-based grazing land management decision support information* that promotes both sustainable natural resource use in grazing lands and profitable beef and sheep industries.

7. Integrated engagement, education and communication

Introduction

The purpose of the 'Inside Edge' project was to develop property-based decision support tools and products that promote both sustainable natural resource use and profitable beef and sheep industries in the grazing lands of Queensland. An integrated engagement, education and communication approach was used to increase the awareness, skills, knowledge and capacity of users of the FORAGE decision support system (www.longpaddock.qld.gov.au/forage/) and its products. The integrated engagement, education and communication approach undertaken by DAF had three components: extension material and information; group engagement activities; and promotional activities.

The DAF project team's main objectives were to develop an 'extension training package' for the FORAGE ***Pasture Growth Alert*** and ***Long-term Carrying Capacity*** Reports, and to promote these through the Long Paddock and Futurebeef websites. In consultation with Grant Stone from the DES project team, DAF developed an 'extension training package' that included the following engagement, education and communication activities:

- Webinars
- Production of awareness and educational videos
- User guides – user-friendly and easily interpreted
- Promotion

DAF developed the following extension materials and information, and group engagement and promotional activities to increase awareness, skills, knowledge and capacity of users of FORAGE decision support system and its products:

- Extension material and information
  - Production of awareness and educational videos (4)
  - User guides – user-friendly and easily interpreted information (4)
  - FutureBeef web pages (3)
  - Publication of data and relevant information (6)

- Group engagement activities
  - Presentations for specific user groups and conferences (5)
  - Webinars and workshops (9)

- Awareness raising activities
  - Social media (6)
  - Mass media (4)
  - FutureBeef ebulletin (12)
  - Conferences/journal publications (9)

The extension materials and information, and group engagement and promotional activities developed by DAF are detailed below.

Extension material and information

DAF contributed to the development of a wide range of user-friendly and easily interpreted information and extension products to increase awareness, skills, knowledge and capacity of users of the

FORAGE decision support system and its products. The professional videos, user guides, FutureBeef web pages and published data and information developed by DAF through Inside Edge project are described below.

Production of awareness and educational videos

Through the Inside Edge project DAF contributed to the development of an awareness FORAGE LTCC video, and three 'practical how to' videos to enable on-farm practice change.

FORAGE LTCC video

DAF liaised with Grant Stone of DES to develop and produce a professional video to raise awareness of the FORAGE Long-term carrying capacity (LTCC) report. The target audience for the video included extension providers (government and private), consultants, valuers and agents, banks, land owners and managers. Advice from a select group of extension providers (DAF extension officers and consultants) was sought to understand who, how and why this group used long-term carrying capacity information. This information helped frame the content of video to ensure the information was relevant and met the needs of potential users of LTCC reports. DAF assisted in the compilation of draft scripts for video production, provided feedback and advice for amendments to scripts and video footage, and directed the company RedSuit to undertake additional work to achieve a high quality and informative awareness raising FORAGE LTCC report video.

DAF ensured the synchronised release of awareness raising elements including the development of the FutureBeef FORAGE LTCC report web page, assisted with the presentation of the FORAGE LTCC webinar and eBulletin article.

'Practical how to' videos

FutureBeef (led by Kate Brown DAF) with the company Sound Images produced 15 short (4-5 minute) professional videos on a variety of topics for the 'anything but average' beef producer. The videos aimed to provide a practical 'how to' approach to enable on-farm practice change. The Inside Edge project funded the production of 'wet season spelling', 'key decision dates' and 'land condition assessment' videos to promote sustainable natural resource use in grazing lands. These videos will be integrated with and promote existing extension programs (e.g. GLM Edge, Grazing Fundamentals, the Stocktake package) and tools (FORAGE, VegMachine, Stocktake GLM App) to encourage greater understanding and uptake. The video themes are outlined below:

- Wet season spelling - removing cattle during the pasture growing season and allowing 3P (perennial, palatable and productive) grasses to set seed can help restore degraded paddocks and increase long-term animal productivity. This video explains how long to spell for and getting stocking rates right, and how to find out more information
- Key decision dates –the use of decision dates, such as mid-way through the growing season, at the end of the growing season and mid-way through the dry season, to review paddock and animal conditions and make early decisions on stocking rates and numbers can conserve pasture and minimise land degradation. The video also indicates how to find out more information.
- Land condition assessment – highlighting producers' views on why land condition is important, how to assess land condition (pastures, soils, tree cover and ground cover) and why better land condition is important (i.e. able to produce more pasture with the same amount of rainfall). The video also indicates how to find out more information.

The following suite of videos were uploaded to FutureBeef in March 2022.

1) Ageing cattle by their teeth https://youtu.be/4Df7p6GQXmQ

2) Stylos to boost beef production (1 of 2) https://youtu.be/mgyOnh3SuyQ
3) Managing land condition https://youtu.be/Iu0jj9h29xo
4) Using decision dates for grazing management https://youtu.be/rTB1DPQJ9o0
5) Pregnancy testing for forward planning https://youtu.be/9rsXjqEVNhM
6) Vaccination for healthy herds https://youtu.be/-akDTXl0d6k
7) Wet Season Spelling https://youtu.be/0NAavPAZ0hc
8) How to make informed conditions in changing conditions https://youtu.be/4KFUttiQ1xM
9) Foetal ageing for targeted breeder management https://youtu.be/cm_nXoyQ9uc
10) Transporting Cattle Safely https://youtu.be/x_4DAOHzvnQ
11) Using fire as a management tool in grazing lands https://youtu.be/E56rE6lzTu4
12) Bull Breeding Soundness Evaluation https://youtu.be/QKV96kvjEfs
13) Phosphorus Supplementation in Northern Australia https://youtu.be/qHPT0LCD9J8
14) Signs of overgrazing https://youtu.be/0kRRqjTPHr8
15) Getting the best out of your weaners https://youtu.be/UHCTyM4ABuk

User guides – user-friendly and easily interpreted

During the development of the Awareness FORAGE LTCC video, DAF also provided advice on:

1. The email template accompanying requested FORAGE LTCC report to highlight for the user:

- the pasture and watered area information considered in the report (e.g. native pastures and fully rundown following clearing; fully watered)
- the development of a dynamic property mapping tool (MyFORAGE)
- regions and land types where LTCC estimates maybe inaccurate

2. The Long-term carrying capacity report (prototype) 'side-bar' on the Long Paddock FORAGE website (https://www.longpaddock.qld.gov.au/forage/) which has:

- content describing what information the Long-term carrying capacity report provides, key data inputs such as land type models and mapping, SILO climate, how LTCC calculated using AEs and pasture utilisation
- link to the LTCC awareness video
- links to LTCC report sample and 2-page "quick guide"

3. User guide – 2-page "quick guide" which describes:

- what is the LTCC report
- why would you want this
- what information is in the report
- what you receive in a requested report
- how to get a LTCC report

4. Rainfall poster maps

- DAF contributed to printing rainfall posters (400 x 4) that were distributed during Jan – June 2021.

FutureBeef web pages

DAF developed, revised and updated the following three FutureBeef web pages to raise awareness and increase understanding of the FORAGE system and its products:

- FutureBeef Grazing Land Management land type mapping landing page was developed in 2019 and continues to be revised as data is updated https://futurebeef.com.au/resources/glm-land-type-mapping/

- FutureBeef Land types of Queensland was revised and updated in 2019 (v3.1) and 2022 (v4.0) https://futurebeef.com.au/resources/land-types-of-queensland/
- FutureBeef FORAGE Long-Term Carrying Capacity report landing page was developed in 2020 and updated in 2022 https://futurebeef.com.au/forage-ltcc/

Publication of data and relevant information

Updated and improved versions of GLM Land type mapping are published by DAF on the publicly - accessible QSpatial website (https://qldspatial.information.qld.gov.au/catalogue/custom/index.page). The version publication history of GLM land type mapping (https://futurebeef.com.au/resources/glm-land-type-mapping/) includes:

- GLM land type mapping V3 2010
- GLM land type mapping V5.4 2020 (General, Mitchell Grass Downs, Southern Gulf, Mulga)
- GLM land type mapping V6.1 2021 (Inland and Coastal Burnett, Mary, Burdekin, Desert Uplands)
- GLM land type mapping V7 2022 (Darling Downs, Maranoa Balonne, Border Rivers, Mackay Whitsunday, Wet Tropics)

Updated and improved versions of Land types of Queensland are published on the publicly-accessible FutureBeef website (https://futurebeef.com.au/resources/land-types-of-queensland/). The version publication history of Land types of Queensland (https://futurebeef.com.au/resources/land-types-of-queensland-conditions-of-use/) includes:

- Land types of Queensland Version 1.2 – February 2009
- Land types of Queensland Version 1.3 – March 2010
- Land types of Queensland Version 2.0 – August 2011
- Land types of Queensland Version 3.0 – June 2015
- Land types of Queensland Version 3.1 – May 2019
- Land types of Queensland Version 4.0 – June 2022

Additional published information includes:

The GLM Land type mapping technical report:

Irvine, S. and Holloway, C.T. (2020) *Spatial Grazing Land Management Land Types of Queensland: Review and amendments.* Technical Report. Department of Agriculture and Fisheries, Queensland. http://era.daf.qld.gov.au/id/eprint/7588/

Group engagement activities

DAF contributed to the following group engagement activities (webinars, presentations, workshops) targeting and promoting the FORAGE decision support system:

Webinars Production of awareness and educational videos

DAF liaised and consulted with Grant Stone (DES) to develop a short webinar series '***Getting the "Inside Edge" in grazing land management***' to raise awareness of the revamped Long Paddock website and FORAGE products. Four webinars in this series were promoted by Greg Bath (DAF) through FutureBeef/Beef Central and delivered by Grant Stone over two months in 2018. The delivery of the webinar series included:

1. The Long Paddock website: what's new, and it's all free! (9 & 17 October 2018)
2. Our rainfall and pasture growth – comparing current seasons with the past (25 October 2018)
3. FORAGE – free property information to assist with grazing land management decisions: Part 1 – currently available information (15 November 2018)
4. FORAGE – free property information to assist with grazing land management decisions: Part 2 – new and soon to be released information (29 November 2018)

Greg Bath (DAF) collated registered and attendee data for the '***Getting the "Inside Edge" in grazing land management***' webinar series (Table 11) for project reporting. The number of registrations was highest for the FORAGE webinars (no.3 - 108, no. 4 – 92) and least for Long Paddock (no. 1 – 62) and Rainfall Poster (no. 2 – 45) webinars. Attendees of all four webinars were approximately between 30 and 50% of registrations. Attendee responses indicated high ratings of 8/10 or above for 'improvement in knowledge' and 'satisfaction with webinar' for all four webinars. Attendee responses for Long Paddock and Rainfall Poster webinars indicated that they were highly likely to make a practice change, whilst attendee responses for both FORAGE webinars indicated more uncertainty about making a practice change.

Col Paton and Ian McLean delivered the 'New AE methodology' **webinar on 12/2/21**. 36 DAF staff registered and there were 18 live attendees. There have been a further 89 YouTube views.

Workshops

Col Paton in conjunction with the Stocktake GLM App development team **delivered four workshops** in 2021 to both Animal Science staff and NRM officers working with the grazing industry. The goal of the workshops was to increase understanding of the application of the new Adult Equivalent tables and how these tables have been applied in the Stocktake GLM app.

Presentations were also given demonstrating a basic introduction to Stocktake GLM.

- Charters Towers had a total of 23 participants, with 16 from NRM organisations including NQ Dry Tropics, Terrain and CHRRUP, and 7 from DAF. This was presented by Col Paton and Megan Willis.
- Charleville had a day-long Stocktake workshop attended by 13 people, with 8 DAF staff members and 5 others. This was presented by Col Paton, Greg Bath and Megan Gurnett.
- Warwick had a total of 18 people from DAF. This was presented by Col Paton, Greg Bath and Kate Brown.
- Mareeba workshop was attended by 12 DAF and 4 NRM staff.

Table 11. Registrations, satisfaction and likelihood of practice change results from 'Getting the "Inside Edge" in grazing land management' webinar series delivered in 2018.

Webinar Name and (no.)	Registered	Attended	Improve knowledge	Satisfaction with webinar	Intend to make a practice change	Very likely to make this change (an indicator of actual change)	Average likelihood of making this change
Long Paddock (1)	62	31	8/10	8/10	100%	100%	7/7
Rainfall pasture growth posters (2)	45	15	8/10	8/10	100%	100%	7/7
FORAGE 1 (3)	108	43	8/10	8.8/10	50%	0	5.5/7
FORAGE 2 (4)	92	28	8.1/10	8.5/10	67%	25%	5.7/7

Presentations

DAF Rockhampton presentation

Giselle Whish (DAF) and Grant Stone (DES) presented the FORAGE LTCC report to the central west region DAF Beef and Sheep staff at Rockhampton in December 2020.

Conference presentations

Northern Beef Research Update Conference – Brisbane 19-22 August 2019

> Penna, G., Whish, G. and Holloway, C. (2019). Benchmarking to improve long-term carrying capacity estimates for extensive grazing properties in Queensland. *Northern Beef Research Update Conference* – Brisbane 19-22 August 2019.

Australian Rangelands Conference – Canberra 2019

> 'A benchmark for stocking rate management in a highly variable climate.'
> Giselle Whish[a], Gabrielle Penna[a] and Christopher Holloway[a]

Australian Rangelands Conference – Longreach 2021

NRM in the Rangelands Conference – shaping our future, 2021

> DAF submitted 5 min Lightning talk and Poster for presentation in the Virtual library to accompany the abstracts submitted previously.
>
> Buffel (*Cenchrus ciliaris*) pasture productivity in Central Queensland
> Gabrielle Penna, Giselle Whish, Chris Holloway
>
> Potential impacts of Indian couch invasion on production and enterprise profitability
> Giselle Whish[a], Lester Pahl[b] and Nicole Spiegel[c]

Promotional awareness raising activities

Promotional activities targeting FORAGE decision support system included:

- FutureBeef eBulletin
- Social media
- Mass media
- Conferences/journal publications

FutureBeef eBulletin

- FutureBeef Events calendar - 'Getting the "Inside Edge" in grazing land management' webinar series - 4 web pages

- 'Getting the "Inside Edge" in grazing land management' webinar series promoted as 'Upcoming event' in the in October 2018 edition of FutureBeef Update eBulletin https://mailchi.mp/futurebeef/futurebeef-october-update-out-now-ydh3rklzk6

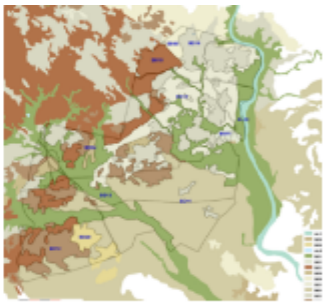
- Email sent out on 12 November 2018 to 4177 eBulletin subscribers promoting last two webinars in the series.

- 'Fire Scars, a new FORAGE report' to 4160 subscribers in October 2018 edition of FutureBeef Update eBulletin https://mailchi.mp/futurebeef/futurebeef-october-update-out-now-ydh3rklzk6

- 'New rainfall' and "Map App" visualisation' to 4177 subscribers in November 2018 edition of FutureBeef Update eBulletin https://mailchi.mp/futurebeef/futurebeef-october-update-out-now-ydh3rklzk6-907593

- FORAGE LTCC Report – with 226 4th most read eBulletin article of 2020 https://futurebeef.com.au/top-15-ebulletin-articles-of-2020/

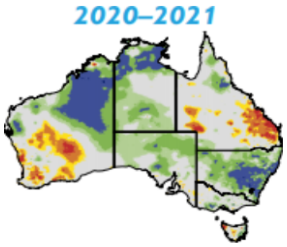
4. FORAGE Long-term carrying capacity report



FORAGE can now provide Queensland graziers an objective long-term carrying capacity report. The report estimates the average number of stock a property can carry over a long period of time, including through good and poor seasons, extended periods of dry conditions and drought, with no decline in land condition. It could also be used to assist property purchasing decisions. Find out more, here.

- eBulletin article by MLA Redefining the AE – with 225 5th most read eBulletin article of 2020 https://futurebeef.com.au/top-15-ebulletin-articles-of-2020/
- Promotion of the update to Long paddocks Rainfall poster map through FutureBeef eBulletin May 2021, where the article received 66 unique clicks

2020-2021 Rainfall poster map update!



The Long Paddock's well known series of rainfall and pasture growth posters have been updated for 2021.

Visit the rainfall poster page on the Long Paddock site for new poster PDF files, play with the poster Map App, download the poster update page or watch the instructive webinar.

- Awareness raising FutureBeef ebulletin article June 2021 for the 'practical how to' videos on a variety of topics for the 'anything but average' beef producer that were uploaded to FutureBeef in March 2022

  'New videos coming to FutureBeef' FutureBeef eBulletin June 1 2021

FutureBeef ▸ News ▸ New videos coming to FutureBeef

In this section
News

New videos coming to FutureBeef

1 June 2021

Featured articles

FutureBeef will soon launch online 15 new 'how-to' videos on a variety of topics for the '*anything but average*' beef producer. With topics ranging from foetal aging and vaccination through to using fire and wet season spelling, these videos include something for every beef producer.

With filming across three states (Queensland, Northern Territory and Western Australia) these videos feature prominent beef producers, veterinarians, beef advisors and scientists from across northern Australia. These short videos cover the practical implementation of specific management options across a number of locations and country types on commercial scale properties.

Topics featured include:

1. Foetal aging for management
2. Pregnancy testing for management
3. Establishing stylo in northern forest country
4. Making informed economic decisions
5. How to age cattle by their teeth
6. Bull Breeding Soundness Evaluation
7. Transporting cattle safely
8. Wet season spelling
9. Land condition assessment
10. Weaner management
11. Vaccination techniques
12. Feeding phosphorus
13. Recognising signs of overgrazing
14. Using fire within management
15. Setting and using decision dates in grazing land management.

Joe Rolfe, Senior Principal Beef Extension Officer with the Department of Agriculture and Fisheries, stars alongside Kevin 'Hooter' Young at 'Dels Hole' in Georgetown and Darcy O'Brien from 'The Brook' north of Charters Towers to provide insights on successful stylo establishment in forest country. Joe emphasises "many producers are time-poor and these videos are an easy way to see and hear about some handy management options." As Joe states: "There's nothing better than hearing practical tips from producers and seeing how different practices can improve a beef operation."

Kate Brown, Department of Agriculture and Fisheries (DAF) beef extension officer, who was leading the video production for FutureBeef said 'We had a few extra challenges thrown our way with COVID19 and traveling interstate but I am very pleased to say we managed to get to most places as planned. It has been extremely rewarding working with such a variety of great contributors'.

The videos are just one of many resources you can find on the FutureBeef website. If you haven't yet, you should jump on the website (futurebeef.com.au) and subscribe to our monthly eBulletin, and like and follow us on Facebook, Twitter and Linked In.

- New and improved Stocktake GLM for graziers 1 June 2021 eBulletin

FutureBeef ▸ News ▸ New and improved! Stocktake GLM for graziers

In this section
News

Featured articles

New and improved! Stocktake GLM for graziers

1 June 2021

Stocktake GLM is an updated smart device application that assists beef and sheep producers with their grazing land management.

Based on the popular Stocktake workshop, the app provides graziers, consultants and other land managers with a simple tool to monitor land condition and undertake forage budgeting on their property.

Available in the AppStore or via Google Play Stocktake GLM is free to download and use with no subscription fees. The app works in remote areas without the need of mobile reception, backing up securely once a connection is restored. Data may also be easily synced to another device should anything happen to yours.

Setting up a property is simple as it contains the latest spatial mapping where users can quickly locate and pin their grazing property. Using updated pasture growth modelling data, land type mapping and adult equivalent data, the app can calculate long term carrying capacity using grazier on-ground monitoring inputs. Stocktake GLM also guides you through a basic or detailed forage budget to determine short-term stocking rates by balancing pasture supply with stock demand.

Capable of storing rainfall records and cattle numbers, Stocktake GLM produces a variety of reports that can be exported as a PDF, or alternatively a CSV, for those wishing to import their data into spreadsheet format. During land condition assessment GPS coordinates are collected along with photos and site information to be revisited when monitored in future, allowing for easy land condition change assessment over time.

Stocktake workshops are run on demand across Queensland. If you are interested in holding one in your local area, contact your local beef extension officer. Likewise, if you require assistance with downloading and setting up your property. Alternatively, learn more about Stocktake GLM on our website https://stocktakeglm.com.au/.

- Land types of Queensland V4.0 June FutureBeef eBulletin 2022

Land types of Queensland have been updated

Without fail, every year, the land type descriptions for Queensland pages rank within the top 50 pages visited on the FutureBeef website.

Users will now benefit from updated land type descriptions that feature modelled long-term carrying capacity information and complimentary regional land type maps. The maps also include a summary of the distribution, rainfall and tree cover for each of the 240+ land types. Additionally, there are 17 new land type descriptions for the Darling Downs region.

Click here to find out more.

- GLM land type mapping V7 FutureBeef eBulletin September 2022

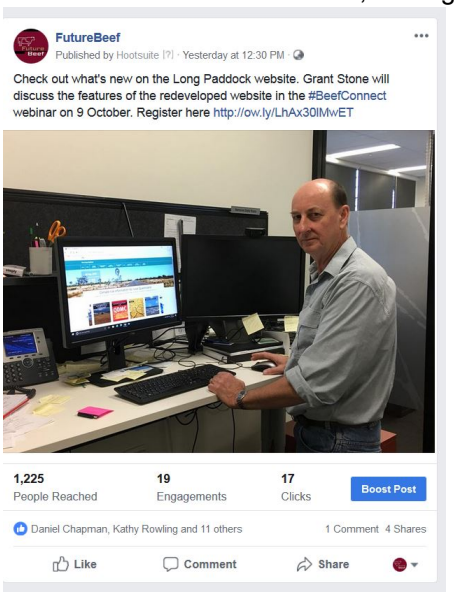
Updated Queensland land type mapping available now

Users of the Grazing Land Management (GLM) land type mapping can now access version 7 of the digital mapping product. The new version added in the Darling Downs GLM regions land types and updated the Maranoa Balonne, Border Rivers, Mackay Whitsunday and Wet Tropics regions. This follows on from V6 (January 2021) which updated the Inland & Coastal Burnett, Mary, Burdekin and Desert Uplands regions. Around 1.58 million km^2 have been assessed (91% of Queensland) and 650 000 million km^2 have been altered through the project.

Access all the GLM land type mapping page here.

FutureBeef Social media (Facebook and Twitter)

- Sam McGee DAF (DCAP) Corp Coms was notified regarding all Inside Edge promotional materials
- 'Getting the "Inside Edge" in grazing land management' webinar series – 25/9/2018 linked shared with Sam McGee (DAF DCAP media) with Queensland Agriculture tagged
- Posted 25/9/18: reached 1225, 19 engagements (like, comments, share), 17 clicks



- Re-Posted four FORAGE videos developed for 'Accelerating the use of FORAGE and other complementary tools to support sustainable grazing land practices' (Whish 2016)
    i. 'Awareness' posted 11/9/18: reached 681, 11 engagements (like, comments, share), 18 clicks
    ii. 'Land condition' posted 18/9/18: reached 1742, 20 engagements (like, comments, share), 29 clicks

- GLM land type mapping was promoted through FutureBeef *e*bulletin June 2019 with **96** total clicks, **69** unique clicks. Clicks from June's eBulletin article through to the Land Types landing page: **43 t**otal clicks, **29** unique clicks https://mailchi.mp/futurebeef/in-this-edition-strategic-cost-effective-p-supplementation-pulpy-kidney-and-toxic-plants-improved-land-type-mapping-tropical-legumes-more?e=e5af85059f

- Grazing Land Management land type mapping post scheduled for 6:15pm Saturday 29 June

Mass media

- FORAGE: a new tool to help you manage grazing pastures – Beeftalk Issue 45 – Autumn 2016 which featured in Queensland Country Life futurebeef.com.au/wp-content/uploads/Beeftalk-Issue-45-Autumn-2016.pdf

- Submitted an article for the Northern Muster April 2022 featured in QCL

Long-term pasture measures at Spyglass aid carrying capacity decisions for the north

A research project that has been running at Spyglass Beef Research Facility since 2014 will help producers make better-informed grazing land management decisions.
Producers managing grazing systems face complex decisions that require a detailed understanding of their livestock, land, pastures and the environment.
The amount of pasture that grows annually dictates stock numbers and long-term carrying capacity.
Detailed rainfall, soil and pasture measurements collected from six sites, which have been fenced to exclude all grazing, allow us to use modelling to extend that knowledge over decades and across regions.
The inclusion of site-specific data in the GRASP model, which is designed for northern Australia rangelands, improves the quality of pasture production and carrying capacity estimations.
Further analysis and modelling will improve our understanding of pasture production of more common land types, plus or minus stylos, in the Burdekin rangelands.
Long-term carrying capacity information, together with regular land condition monitoring and pasture budgeting, will assist land management decisions that contribute to sustainable natural resource use in grazing lands and profitable beef industries in north Queensland.

Giselle Whish, principal scientist, Department of Agriculture and Fisheries, 3708 8455.

- DAF Agri-Science Queensland quarterly report **ASQ 2020-21 Q1**

Summary of DAF contributions to the Inside Edge Grazing Extension tools project

Inside edge grazier extension tools (AS10797)

The 'Inside edge grazing extension tools' 4-year collaborative DES/DAF project has developed and improved property-based decision support tools that promote profitable beef and sheep industries and sustainable natural resource use in grazing lands. Through the FORAGE decision support system (www.longpaddock.qld.gov.au/forage/) a modelling framework that uses land type mapping, satellite imagery (e.g. tree cover), climate data and the GRASP pasture growth model has been developed to provide long-term carrying capacity information for grazing properties in Queensland.

DAF has led the review and development of new approaches, and validation of the Grazing Land Management land type mapping (https://futurebeef.com.au/knowledge-centre/glm-land-type-mapping/) that is a key input in the FORAGE decision support tool. Land type mapping provides the spatial representation of Land types of Queensland (https://futurebeef.com.au/knowledge-centre/land-types-of-queensland/) and is used extensively by DAF in a suite of extension projects (Reef Grazing, GrazingFutures, GLM EDGE and Stocktake), property mapping, assessing land condition information (VegMachine) and bio-economic modelling.

The Inside Edge project has established benchmark properties in Burdekin, Mitchell Grass and Inland Burnett GLM regions to validate long-term carrying capacity modelled estimates. Mapping data (land type, tree cover, property infrastructure), grazing land management practices/strategies, long-term stocking rate records and observed land condition are used to validate the FORAGE modelling framework and long-term carrying capacity estimates. DAF will extend the network of benchmark properties in Burdekin (2), Fitzroy (1), Inland Burnett (1), Maranoa Balonne (1) and Mulga regions.

DAF is contributing to the validation and improvement of land type GRASP models by providing comprehensive feedback to DES; establishing four swiftsynd sites in buffel pastures around Emerald to collect rainfall, soil and pasture measurements to calibrate and improve GRASP

buffel models; commencing development of GRASP land type models for recently described and mapped Darling Downs grazing land types; and through the GRASP calibration of six swiftsynd sites at Spyglass Research property.

DAF has also collaborated closely with DES in awareness raising activities for long-term carrying capacity FORAGE report such as video production, webinars, Futurebeef web pages, eBulletin and social media posts. Contact: Giselle Whish

Photo: DAF Inside edge project team gaining valuable insights from producers during property visits in Burdekin, Fitzroy and Inland Burnett regions.

The new and improved Stocktake GLM app was launched at Beef 2021 with awareness-raising articles in Queensland Agriculture news April 2021.

Stocktake app is back!

Stocktake app for graziers is back and better than ever before. The new and improved smart device application is free to download and assists beef and sheep producers with their grazing land management.

The app is designed to be used in the paddock, even without connectivity, and features everything a grazier or land manager needs to balance livestock numbers with pasture supplies (forage budgets), monitor land condition, store monitoring information and produce paddock reports.

Find StocktakeGLM in the AppStore or via Google Play.

Conference / journal papers

Northern Beef Research Update Conference – Brisbane 19-22 August 2019

Holloway, C. and Irvine, S. (2019). Out with the old and in with the new: new methods for more accurate grazing land management (GLM) land type mapping. In: Proceedings of the Northern Beef Research Update Conference, 19-22 August 2019, Brisbane, Queensland, Australia.

Penna, G., Whish, G. and Holloway, C. (2019). Benchmarking to improve long-term carrying capacity estimates for extensive grazing properties in Queensland. In: Proceedings of the Northern Beef Research Update Conference, 19-22 August 2019, Brisbane, Queensland, Australia. https://era.daf.qld.gov.au/id/eprint/7338/

Australian Rangelands Conference – Canberra 2019

Whish, G., Penna, G. and Holloway, C. (2019). A benchmark for stocking rate management in a highly variable climate. In: 20th Biennial Australian Rangeland Society (ARS2019) Resilient future rangelands: integrating environment and livelihoods, 2-5 September 2019, Canberra. https://era.daf.qld.gov.au/id/eprint/7333/

Whish, G., Phelps, D., Bowen, M. and Chudleigh, F. (2019). Bio-economic modelled outcomes of stocking rate and drought recovery strategies in the Mitchell grass region. In: 20th Biennial Australian Rangeland Society (ARS2019) Resilient future rangelands: integrating environment and livelihoods, 2-5 September 2019, Canberra.

Australian Rangelands Conference – Longreach 2021
NRM in the Rangelands Conference – shaping our future, 2021

DAF submitted 5 min Lightning talk and Poster for presentation in the Virtual library to accompany the abstracts submitted previously.

Buffel (*Cenchrus ciliaris*) pasture productivity in Central Queensland
Gabrielle Penna, Giselle Whish, Chris Holloway

Potential impacts of Indian couch invasion on production and enterprise profitability
Giselle Whish[a], Lester Pahl[b] and Nicole Spiegel[c]

The Rangeland Journal
Special Issue: Managing drought and improving business resilience in Australian rangelands
October 2021
Guest Editors: Fiona McCartney, Lindsey Perry, Giselle Whish, Jacqui Willcocks, Andrew Ash.

Managing drought in Australian rangelands through collaborative research and industry adoption
J. Willcocks, A. Ash, G. Whish and N. Cliffe

An online system for calculating and delivering long-term carrying capacity information for Queensland grazing properties. Part 1: background and development
G. Stone, B. Zhang, J. Carter, G. Fraser, G. Whish, C. Paton and G. McKeon

An online system for calculating and delivering long-term carrying capacity information for Queensland grazing properties. Part 2: modelling and outputs
B. Zhang, G. Fraser, J. Carter, G. Stone, S. Irvine, G. Whish, J. Willcocks and G. McKeon

8. Conclusion

DAF has made significant contributions to the development and improvement of property-based decision support tools and products that promote both sustainable natural resource use and profitable beef and sheep industries in the grazing lands of Queensland.

DAF has revised, developed, improved and updated ‘Land types of Queensland’ that describe a grazing management area and the GLM land type mapping that are integral to the FORAGE decision support system and the provision of rainfall, pasture and carrying capacity information for Queensland’s grazing lands.

DAF contributed to the review, validation and improvement of the FORAGE Long-term carrying capacity report through the provision of pasture growth and productivity rankings, and land type carrying capacity information for grazing properties in Queensland. Additionally, DAF ensured input data (e.g. land type mapping, tree cover), animal intake approach, and GRASP modelled pasture growth and carrying capacity information was current and consistent across platforms (e.g. Long Paddock FORAGE, MyFORAGE, Futurebeef and Stocktake GLM App) and extension programs (e.g EDGE GLM, GLM Fundamentals and Stocktake).

DAF successfully used an integrated engagement, education and communication approach involving publication, presentation and promotional activities across a range of platforms to increase awareness, skills, knowledge and capacity of users of FORAGE decision support system and its products.

Recommendation for future work includes improving grazing land type descriptions, mapping and GRASP parameters that are integral to the FORAGE modelling framework that provides property-based grazing land management decision support information. DAF will continue to revise, improve and update ‘Land types of Queensland’ and GLM land type spatial data with the inclusion of Mary and SEQ GLM regions. Concurrently, DAF will contribute to development of associated GRASP land type parameters. DAF will also calibrate the SWIFTSYND sites to improve the FORAGE land type modelling and its capacity to simulate grazing systems on improved pasture (buffel grass), introduced Indian couch pastures and native grasses +/- stylos.

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