final report

Project code: B.FDP.0040

Prepared by: Lewis Kahn
Agricultural Information & Monitoring Services

Date published: 05 September 2017

PUBLISHED BY
Meat and Livestock Australia Limited
PO Box 1961
NORTH SYDNEY NSW 2059

Real time measurement of pasture quantity

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

The key objective of this project was to establish a calibration curve, using Normalised Difference Vegetation Index (NDVI) values recorded from the Green Seeker active optical sensor, to estimate green pasture biomass for mixed species pastures on the Northern Tablelands of NSW. On their own, NDVI values were not a useful means for estimating green pasture biomass. Pasture height provided a good measure of total pasture biomass and greatly improved the accuracy of predicting green pasture biomass when combined with NDVI values from the Green Seeker active optical sensor. Ultimately, estimates of green and total pasture biomass need to be included in feed budgeting approaches to enable producers to derive value through better management of pastures and livestock.

Executive summary

The key objective of this project was to establish a calibration curve, using Normalised Difference Vegetation Index (NDVI) values recorded from the Green Seeker active optical sensor, to estimate green pasture biomass for mixed species pastures on the Northern Tablelands of NSW. This would provide an advantage over existing subjective measures and be used to develop feed budgets that inform grazing management decisions to control pasture and livestock performance.

The relationship between estimates of NDVI and pasture biomass was developed from the following design. On each of three properties, one mixed species pasture paddock, managed with a single intensive grazing management method, had 12 pasture measures taken on three occasions each year over a two year period. These measures included NDVI and pasture height before pasture was harvested, sorted and dried to allow calculation of green and total pasture biomass. On one of these properties, the effect of grazing method (TechnoGraze® system and rotational grazing) on the relationship between NDVI and pasture mass was evaluated. In the third year of the project, the suitability of calibrations was tested across site and year.

On their own, NDVI values were not a useful means for estimating green pasture biomass with problems arising from wide variation in NDVI values for a particular level of green pasture biomass and high sensitivity of NDVI values to green pasture biomass above 1500 kg DM/ha. Pasture height provided a good measure of total pasture biomass. The combined product of NDVI x pasture height greatly improved the accuracy of predicting green pasture biomass with a predictive accuracy of 80% and a residual error of 342 kg DM/ha.

The results from this project highlight considerable potential for regional equations, based on NDVI and pasture height, to provide accurate estimates of green pasture biomass. However, a process to automate the collection of pasture height will be a critical next step in the commercial application. Such developments will also provide a useful means for estimating total pasture biomass.

Ultimately, estimates of green and total pasture biomass need to be included in feed budgeting approaches to enable producers to derive value through better management of pastures and livestock. This could occur in a number of ways but developing connectivity of this technology with existing applications appears a sensible approach for industry to progress.

Table of contents

1 Background

Estimating pasture biomass is required to develop feed budgets and to inform grazing management decisions to control pasture and livestock performance. Current methods use pasture height (cm) and estimates of pasture density (kg/ha per cm) to calculate total pasture biomass. These methods are prone to variation among operators such that differences in pasture assessment can occur on properties with multiple staff members. These methods are not typically used to provide separate estimates of green pasture biomass —the green component of total biomass— as the subjective estimate of the green content (% of total biomass) of pasture is notoriously difficult to achieve with any accuracy. Producer members were interested to evaluate an Active Optical Sensor, such as the Green Seeker, as a more objective method for measuring green pasture biomass, thus reducing some of the existing errors with pasture estimation and enabling a rapid and more accurate approach for feed budgets and grazing management decisions.

The group consisted of eight producers with grazing properties located on the Northern Tablelands of NSW. They already had skills in pasture assessment and feed budgeting but were looking for an objective method that would increase the accuracy of pasture assessment and provide input into the feed budgeting process. Linkage with scientists investigating the utility of Active Optical Sensors across Australia was enabled through this group providing Participatory Research Sites. Naturalised pastures were the major pasture type on most properties, though sown pastures were also present. The naturalised pastures consisted of a range of native and introduced perennial grasses with a good fertiliser history and white clover the main legume restricted to good seasonal conditions.

2 Project objectives

By 1st October 2017,

1. Establish a calibration curve for an Active Optical Sensor (AOS) for green herbage mass for fertilised naturalised pastures which includes a mix of introduced species such as cocksfoot, fescue, perennial ryegrass, white clover and native species such as microlaena, paddock love grass, Parramatta grass, and wallaby grass.
2. Establish whether the calibration of the AOS with green herbage mass is affected by differences in sward structure (with the same/similar pasture species) associated with different grazing methods.

3 Methodology

3.1 Experimental design and treatments

The relationship between estimates of Normalised Difference Vegetation Index (NDVI) from the AOS and herbage mass was developed from the following design:
1: On each of two properties, one mixed species pasture paddock, managed with a single intensive grazing management method had 12 pasture replicate estimates/cuts (described later in this section) taken on three occasions (approx. April, October, January) each year over a two year period.
2: On a third property, the same design as for Experiment 1 was implemented across two grazing methods (intensive and less intensive) on the same mixed species pasture type. Intensive grazing was conducted with a TechnoGraze® system where laneways are used to subdivide country and then small paddocks (cells) are created within laneways. Cell area is typically about 1–2 ha and may be

grazed at a stock density of 200-300 DSE/ha or greater. Less intensive grazing was a rotational grazing system using (approx.) 10 ha paddocks at a stock density of 30–60 DSE/ha.
3: In year three of this project, the same design was implemented on two properties (one property different to that used in year 1) for one year to provide evidence of the suitability of calibrations across site and year.

Commercial livestock grazed these paddocks in accordance with normal farmer practise. As per the experimental design, the paddocks on one property were grazed differently (TechnoGraze® versus a less intensive rotational grazing regime). Pastures were managed according to normal farmer practise.
The following measurement protocol was used:

- Twelve pasture replicate sites were chosen to provide a range in green pasture biomass within each paddock at each sampling event (approx. April, October, January).
- At each replicate site, a 30x70cm quadrat formed the basis of the measurement.
- Photographs were taken using the same frame as the mounted AOS and NDVI and pasture height recordings were collected.
- Pasture height (cm) was determined from three estimates using a falling plate.
- Pasture in the quadrat was clipped to ground level and stored in a paper bag and placed in a cool box before transportation to a laboratory.
- The pasture sample was weighed and then thoroughly mixed prior to a representative subsample being sorted into green and dead fractions and each fraction weighed. Fractions were dried (80°C for 3 days) and then reweighed.

The mass of pasture (total, green and dead fractions) was used to calculate total and green pasture biomass (kg dry matter/ha). Associations of pasture biomass with AOS recordings and pasture height were used to establish calibrations.

4 Results

4.1 Associations of NDVI, pasture height, green and total pasture biomass

The results display the following five associations:

- NDVI and green pasture biomass
- Pasture height and total pasture biomass
- NDVI x pasture height and green pasture biomass
- Estimated (from NDVI x pasture height) and measured green pasture biomass
- Testing the accuracy of a composite prediction equation for estimating green pasture biomass

4.1.1 NDVI and green pasture biomass

The relationship between NDVI, recorded from the Green Seeker, and green pasture biomass was curvilinear at all properties indicating an NDVI saturation value of near 0.8. On its own, NDVI did not provide an accurate or precise measure of green pasture biomass in mixed species pastures.

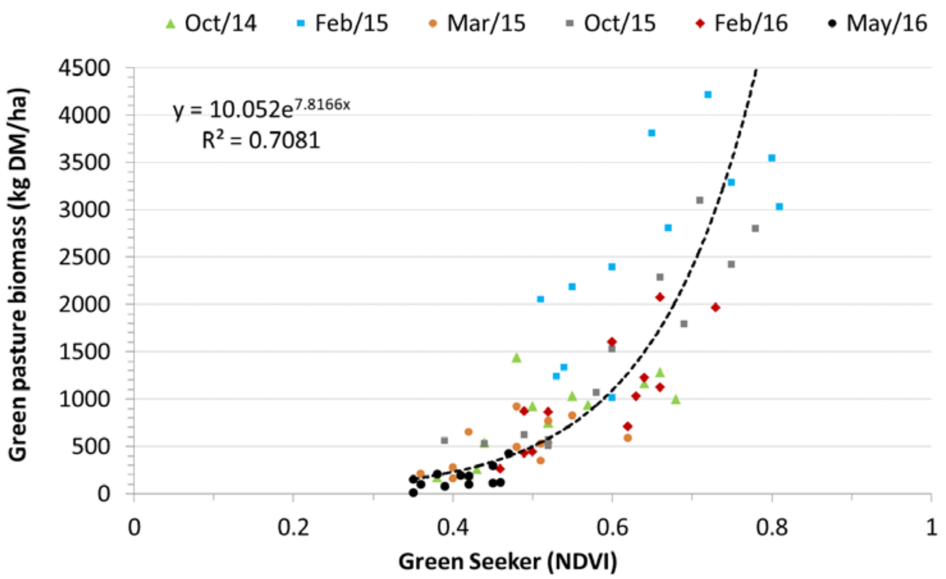

Fig 1. Relationship between Green Seeker NDVI and green pasture biomass at Property 1. The dashed solid line displays the average relationship with the prediction equation and goodness of fit (R^2) displayed.

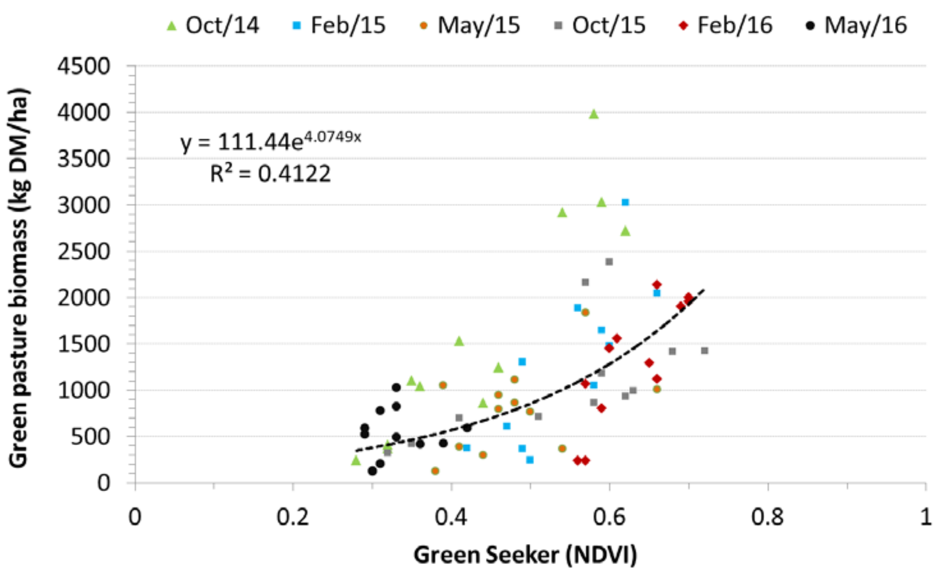

Fig 2. Relationship between Green Seeker NDVI and green pasture biomass at Property 2. The dashed solid line displays the average relationship with the prediction equation and goodness of fit (R^2) displayed.

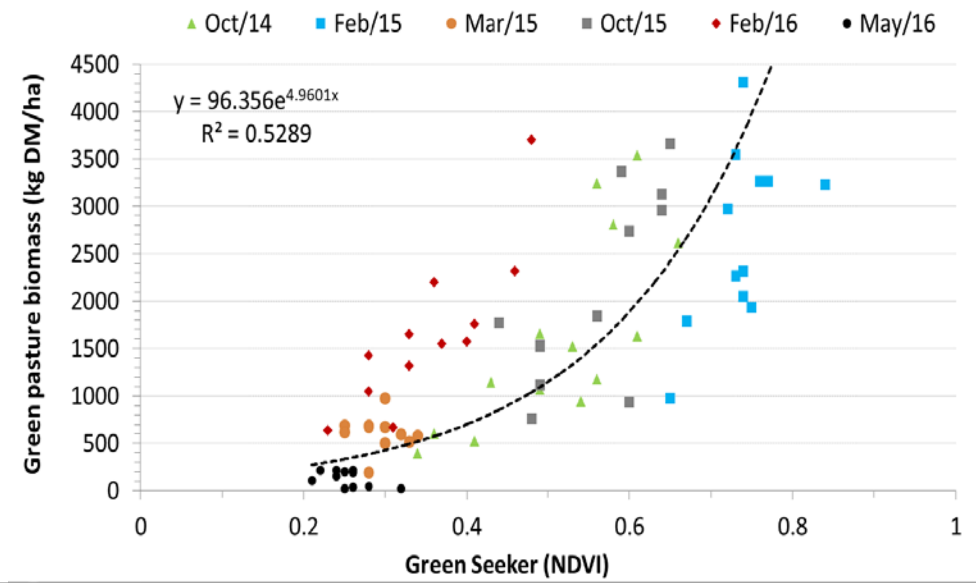

Fig 3. Relationship between Green Seeker NDVI and green pasture biomass at Property 3. The dashed solid line displays the average relationship with the prediction equation and goodness of fit (R^2) displayed.

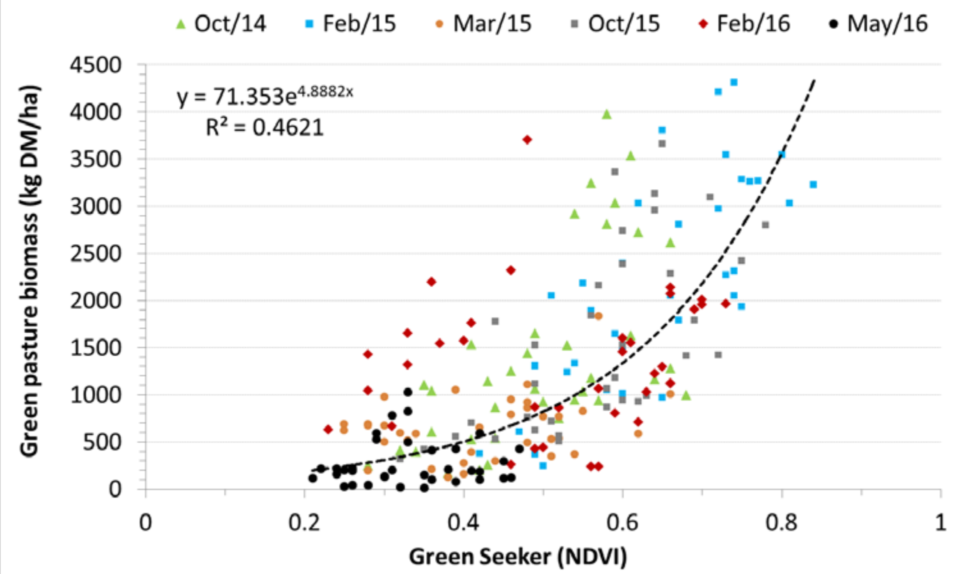

Fig 4. Relationship between Green Seeker NDVI and green pasture biomass at all properties. The dashed solid line displays the average relationship with the prediction equation and goodness of fit (R^2) displayed.

4.1.2 Pasture height and total pasture biomass

Pasture height accounted for approximately 70% of the variation in total pasture biomass. The increase in total biomass with each centimetre of pasture height ranged from 245–357 kg DM/ha with the overall average being 331 kg DM/ha.

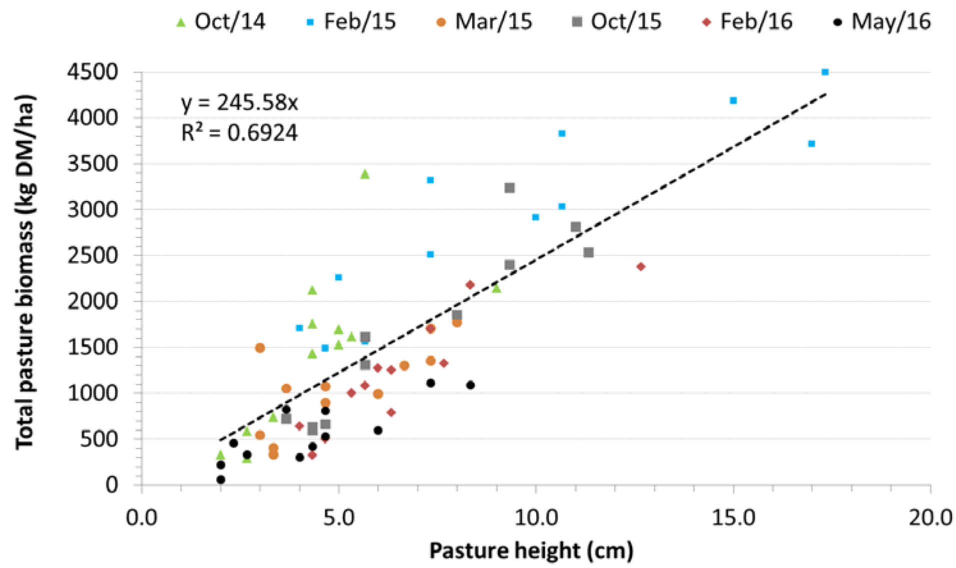

Fig 5. Relationship between pasture height (cm) and total pasture biomass at Property 1. The dashed solid line displays the average relationship with the prediction equation and goodness of fit (R^2) displayed.

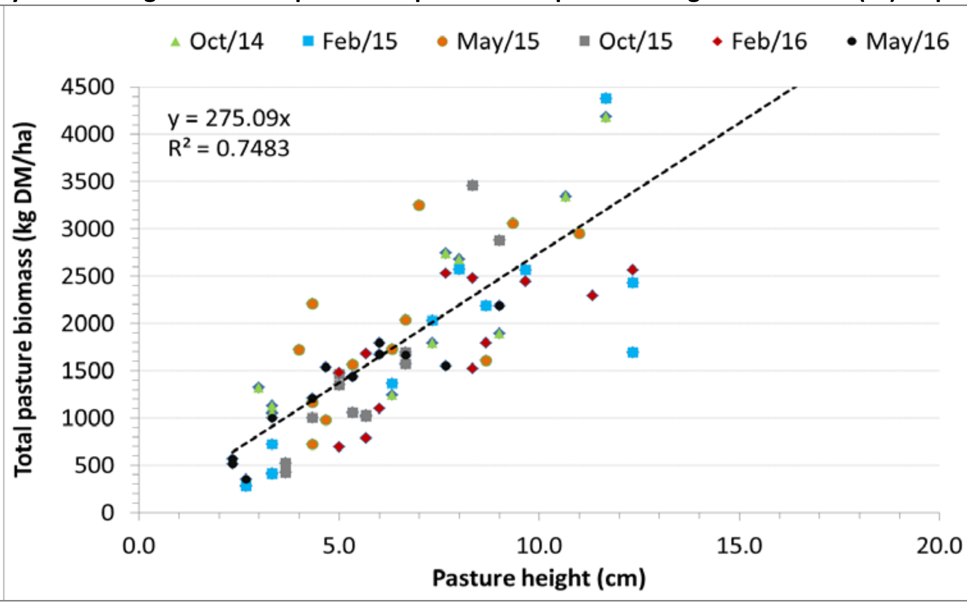

Fig 6. Relationship between pasture height (cm) and total pasture biomass at Property 2. The dashed solid line displays the average relationship with the prediction equation and goodness of fit (R^2) displayed.

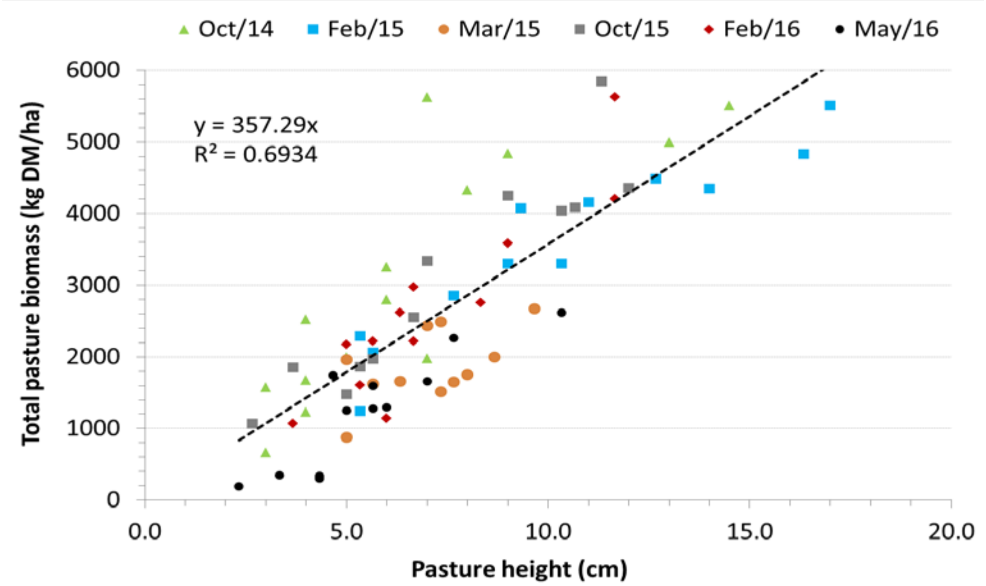

Fig 7. Relationship between pasture height (cm) and total pasture biomass at Property 3. The dashed solid line displays the average relationship with the prediction equation and goodness of fit (R^2) displayed.

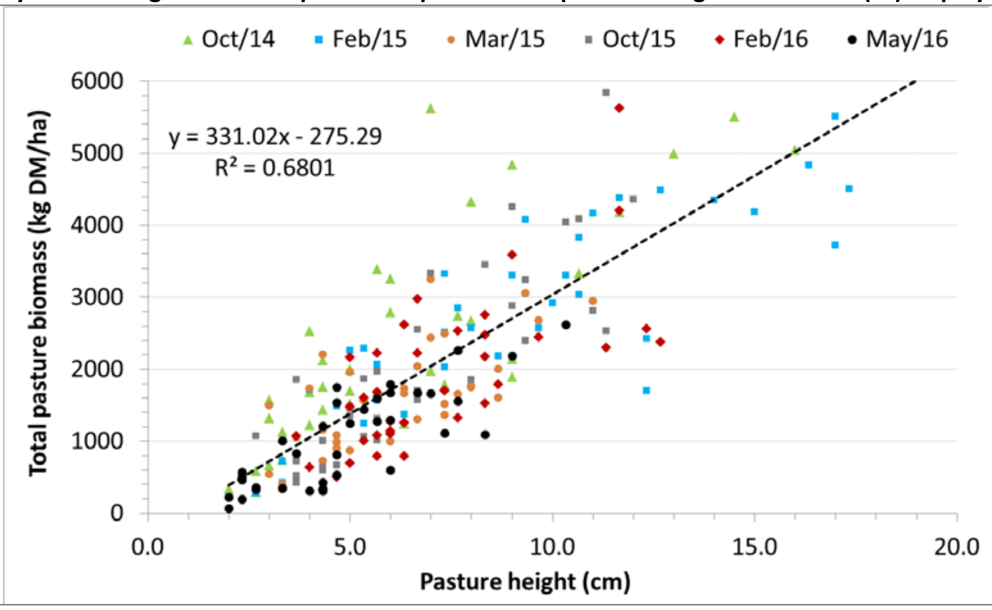

Fig 8. Relationship between pasture height (cm) and total pasture biomass at all properties. The dashed solid line displays the average relationship with the prediction equation and goodness of fit (R^2) displayed.

4.1.3 NDVI x pasture height and green pasture biomass

The product of NDVI and pasture height provided a better predictor of green pasture biomass than NDVI alone. When considered across all properties (Fig. 12), NDVI x pasture height accounted for 76% of the variation in green pasture biomass whereas NDVI alone (Fig. 4) accounted for 46% of the variation.

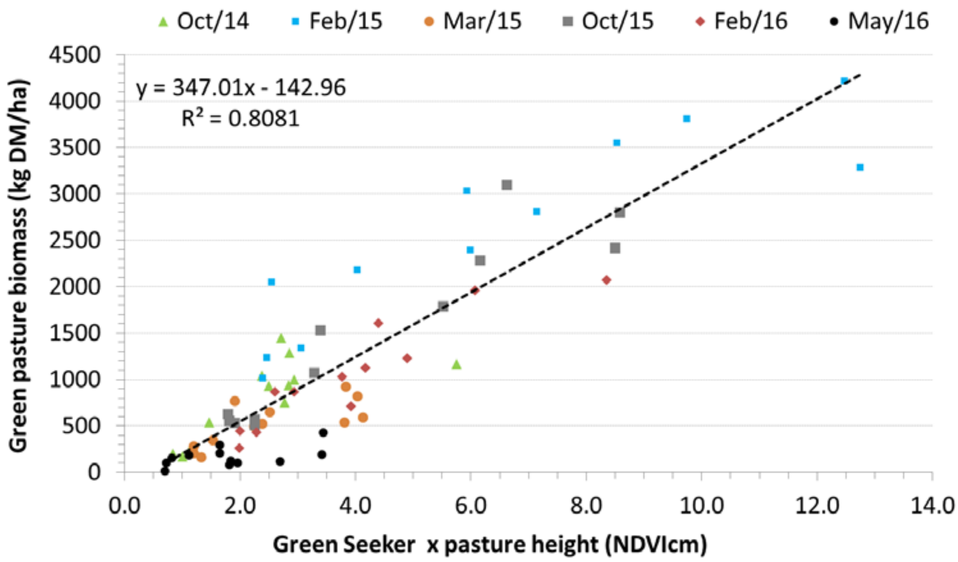

Fig 9. Relationship between NDVI x pasture height (cm) and green pasture biomass at Property 1. The dashed solid line displays the average relationship with the prediction equation and goodness of fit (R^2) displayed.

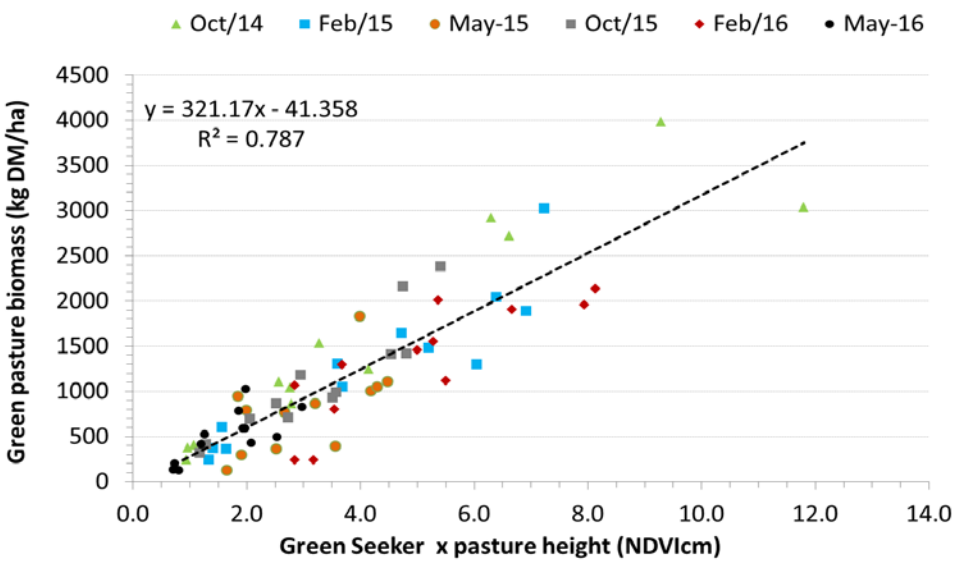

Fig 10. Relationship between NDVI x pasture height (cm) and green pasture biomass at Property 2. The dashed solid line displays the average relationship with the prediction equation and goodness of fit (R^2) displayed.

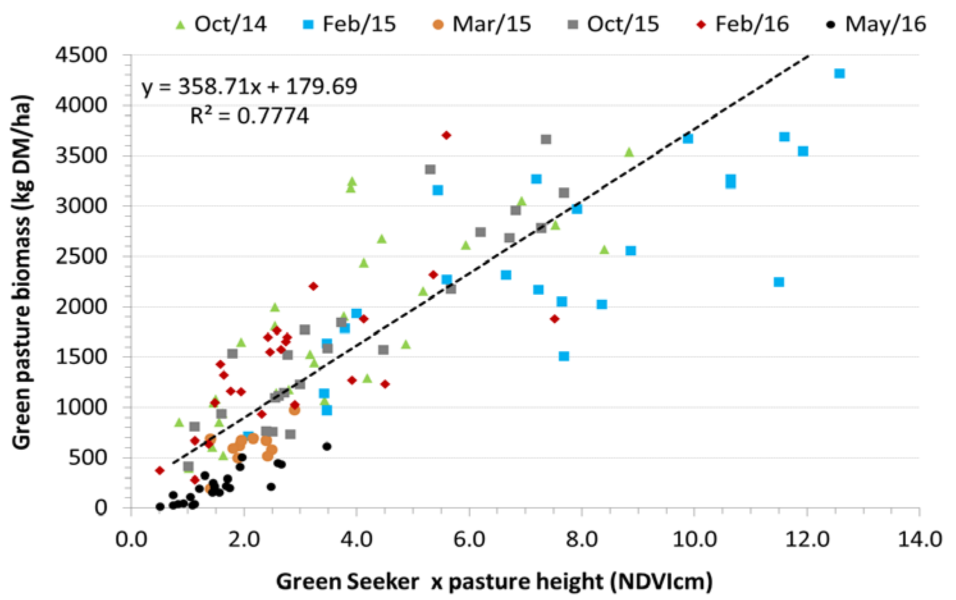

Fig 11. Relationship between NDVI x pasture height (cm) and green pasture biomass at Property 3. The dashed solid line displays the average relationship with the prediction equation and goodness of fit (R^2) displayed.

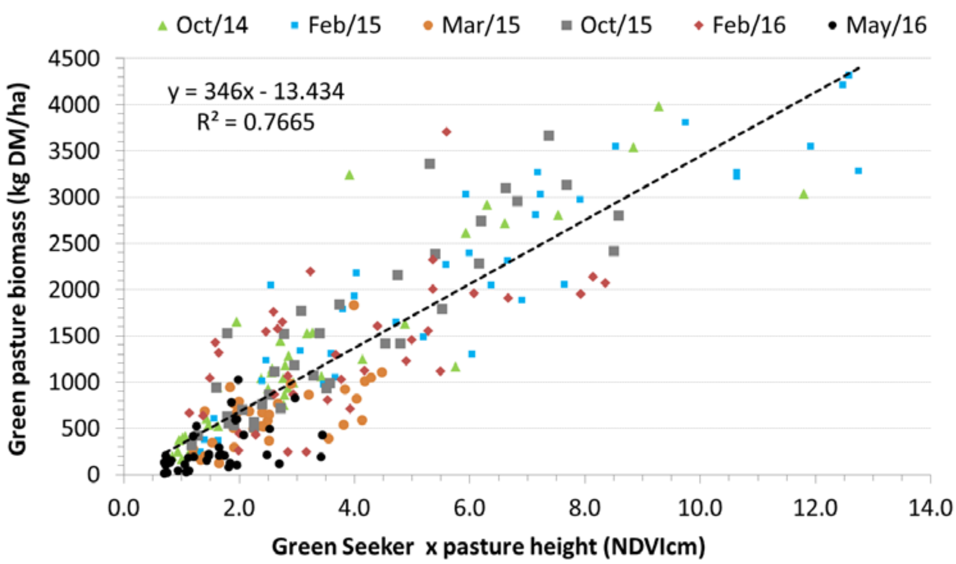

Fig 12. Relationship between NDVI x pasture height (cm) and green pasture biomass at all properties. The dashed solid line displays the average relationship with the prediction equation and goodness of fit (R^2) displayed.

4.1.4 Estimated (from NDVI x pasture height) and measured green pasture biomass

An estimate of green pasture biomass on each Property was calculated using the within Property relationships between NDVI x pasture height and green pasture biomass. Averaged across all Properties (Fig. 16), estimated green pasture biomass accounted for nearly 80% of the variation in measured values. There was no evidence of bias across the range of recorded values and the line of best fit typically sat closely aligned to the ‘perfect’ 1:1 relationship.

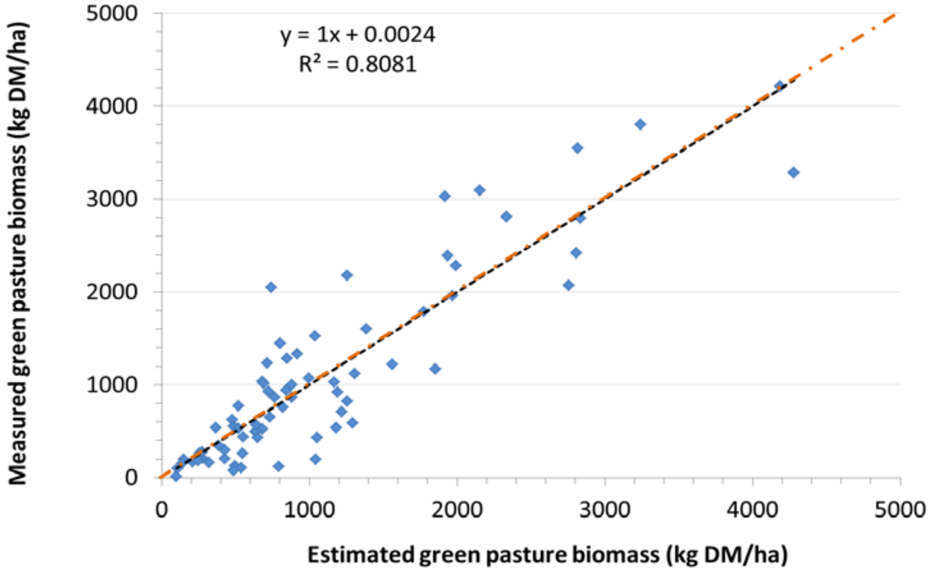

Fig 13. Relationship between estimated (NDVI x pasture height) and measured green pasture biomass at Property 1. The dashed solid black line displays the average relationship with the prediction equation and goodness of fit (R^2) displayed. The overlaying dot and dashed line represents the 1:1 relationship (i.e. perfect fit) of estimated and measured green pasture biomass.

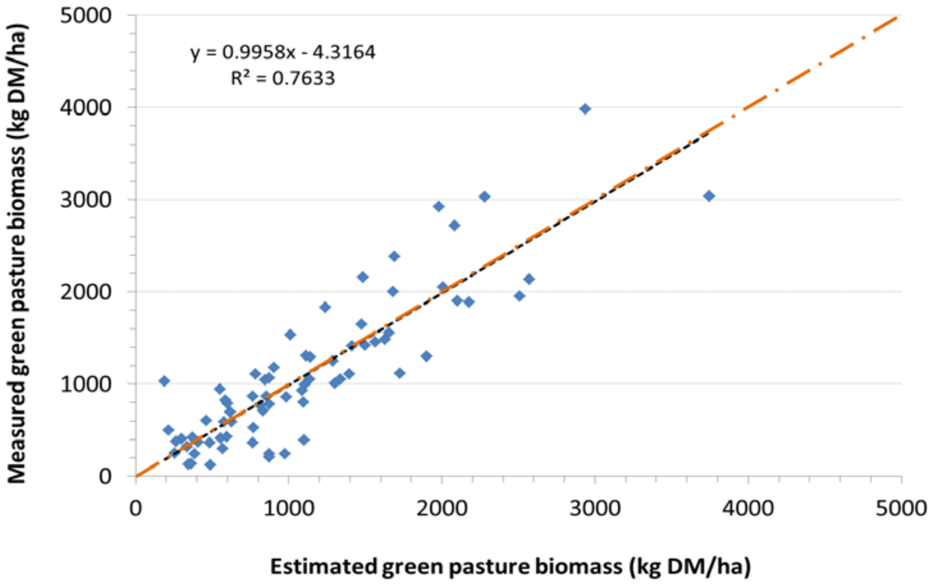

Fig 14. Relationship between estimated (NDVI x pasture height) and measured green pasture biomass at Property 2. The dashed solid black line displays the average relationship with the prediction equation and goodness of fit (R^2) displayed. The overlaying dot and dashed line represents the 1:1 relationship (i.e. perfect fit) of estimated and measured green pasture biomass.

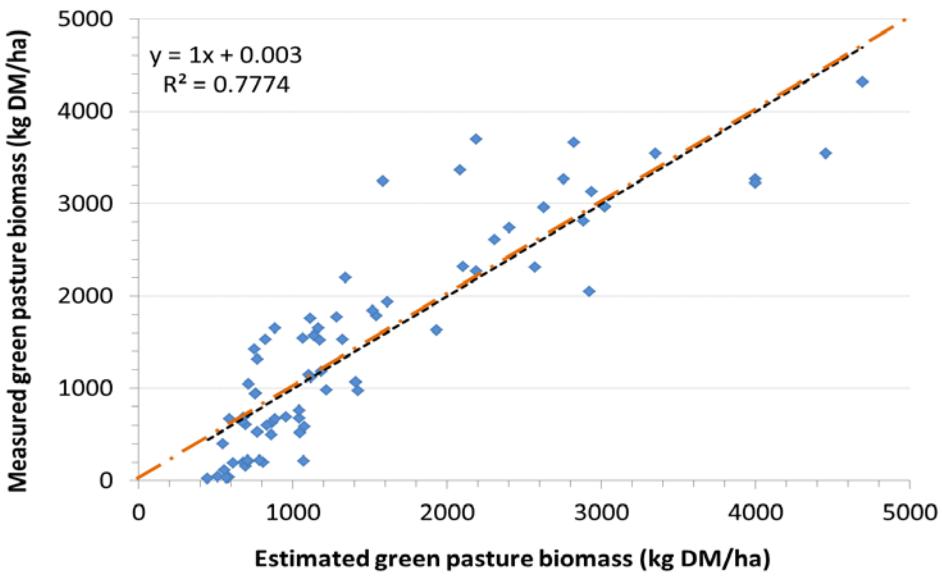

Fig 15. Relationship between estimated (NDVI x pasture height) and measured green pasture biomass at Property 3. The dashed solid black line displays the average relationship with the prediction equation and goodness of fit (R^2) displayed. The overlaying dot and dashed line represents the 1:1 relationship (i.e. perfect fit) of estimated and measured green pasture biomass.

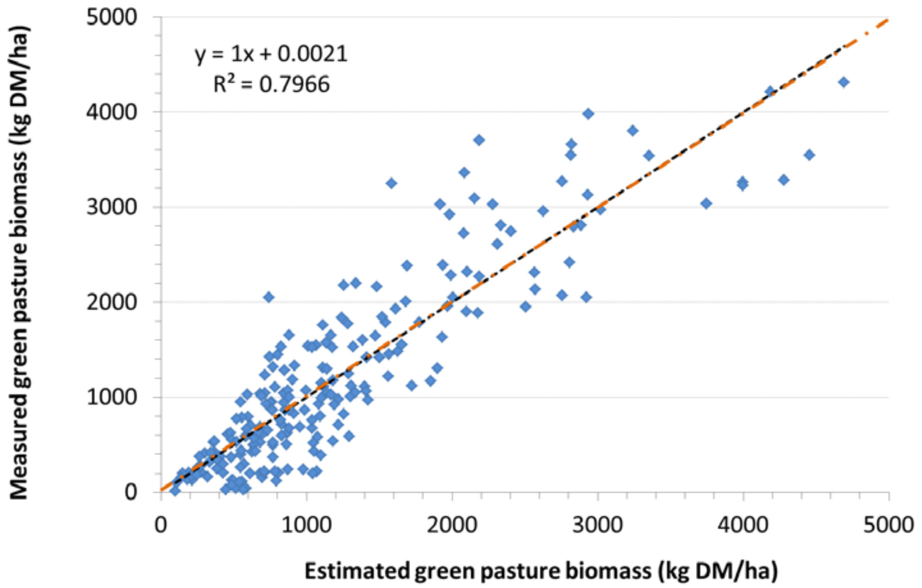

Fig 16. Relationship between estimated (NDVI x pasture height) and measured green pasture biomass for all properties. The dashed solid black line displays the average relationship with the prediction equation and goodness of fit (R^2) displayed. The overlaying dot and dashed line represents the 1:1 relationship (i.e. perfect fit) of estimated and measured green pasture biomass.

4.1.5 Testing the accuracy of a composite prediction equation for estimating green pasture biomass with different grazing management systems and on a new and an existing property in the following year

Predictions of green pasture biomass of pastures managed with rotational and TechnoGrazing were similar, though slightly better under TechnoGrazing (Fig. 17). There is an indication that green pasture biomass was overestimated under the rotational grazing regimen. It is also possible that the difference is accounted by paddock and differences in the mix of pasture species. Using the relationships developed from Properties 1–3 in Year 1-2 of the project, green pasture biomass at a new Property (not originally included in the test data) was well estimated (Fig. 18), whereas estimates at one of the existing Properties were consistently greater than measured values.

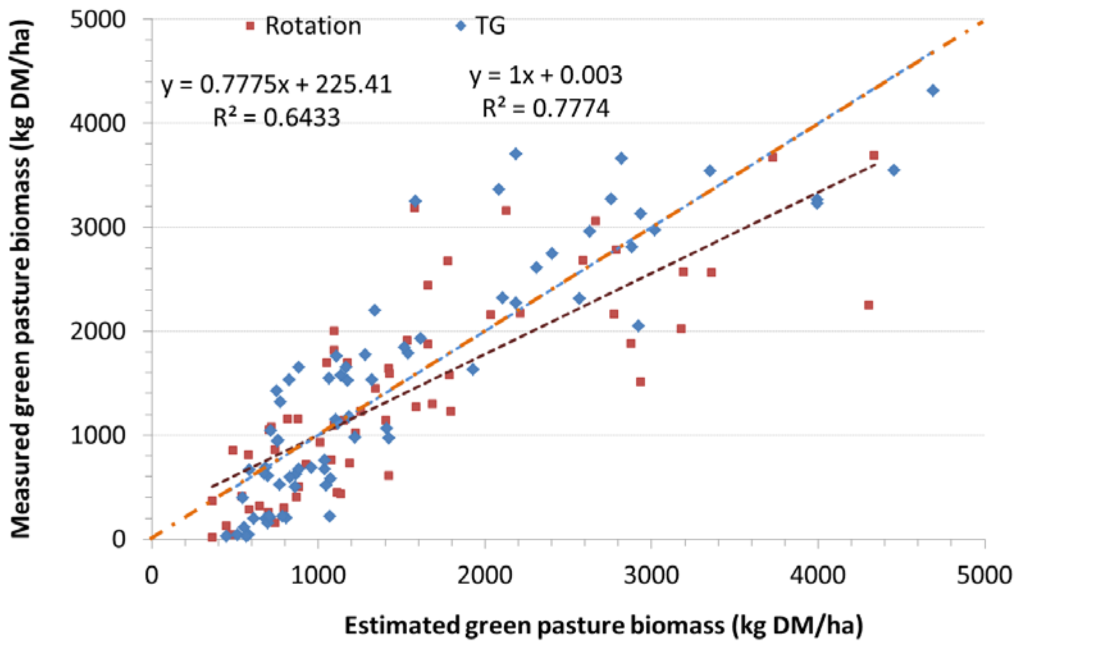

Fig 17. Relationship between estimated (NDVI x pasture height) and measured green pasture biomass for rotational and TechnoGraze® (TG) grazing management on Property 3. The dashed blue (TG) and brown (rotational) lines display the average relationship with the prediction equation and goodness of fit (R^2) displayed. The overlaying dot and dashed line represents the 1:1 relationship (i.e. perfect fit) of estimated and measured green pasture biomass.

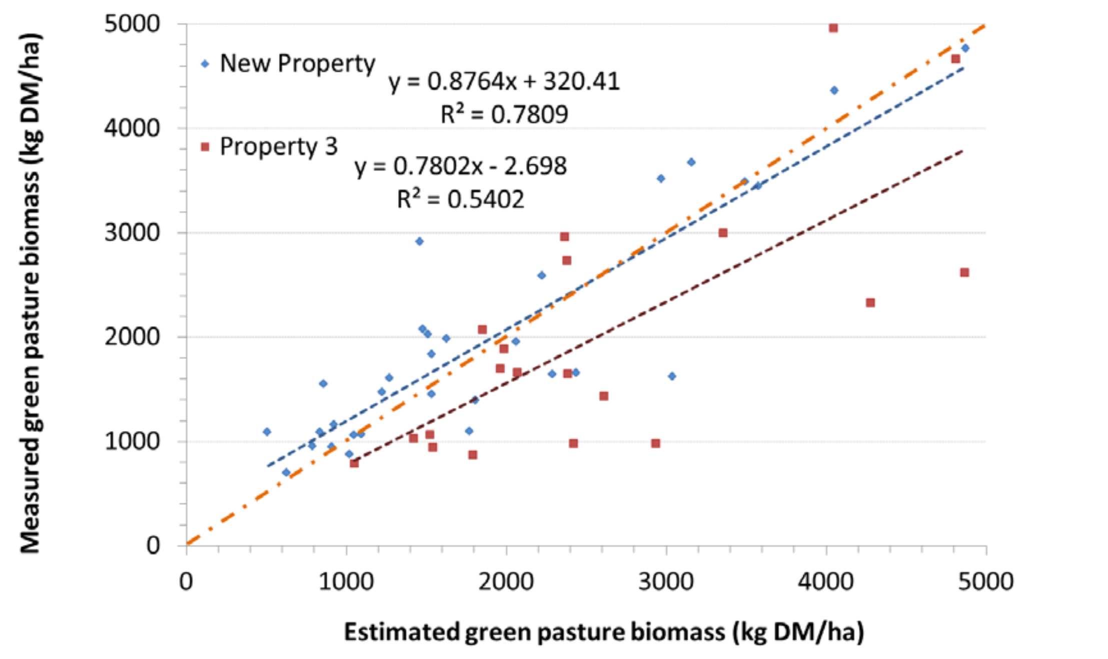

Fig 18. Relationship between estimated (NDVI x pasture height) and measured green pasture biomass for a new property and existing Property 3. The dashed blue (new) and brown (Property 3) lines display the average relationship with the prediction equation and goodness of fit (R^2) displayed. The overlaying dot and dashed line represents the 1:1 relationship (i.e. perfect fit) of estimated and measured green pasture biomass.

4.1.6 Extension activities

The producer group met with the associated project research scientists twice each year to review both local and national results and to provide feedback on project activity. These opportunities for interaction were beneficial for both producers and scientists and typically occurred on farm or at a local meeting room. The meetings also enabled the producers to undertake refresher training in pasture assessment. The key issue communicated by producers was the importance of incorporating pasture assessments into a feed budgeting approach. An understanding of the experimental design, intensity of measurement and the rigour of data analysis, meant that producers had confidence in the results.

5 Discussion

5.1.1 Technical progress

The key objective of this project was to establish a calibration curve, using NDVI values recorded from the Green Seeker active optical sensor, to estimate green pasture biomass for mixed species pastures on the Northern Tablelands of NSW. On their own, NDVI values were not a useful means for estimating green pasture biomass with problems arising from wide variation in NDVI values for a particular level of green pasture biomass (e.g. 1500 kg DM/ha green biomass was associated with NDVI readings ranging from 0.25–0.60) and high sensitivity of NDVI values to green pasture biomass above approx. 1500 kg DM/ha.

Pasture height provided a good measure of total pasture biomass and was combined with NDVI values as a means to better estimate green pasture biomass. This approach greatly improved the accuracy of predicting green pasture biomass but considerable variation in NDVI x pasture height values for a particular level of green pasture biomass remained.

Prediction of green pasture biomass from the composite relationship (across all Properties) between NDVI x pasture height and green pasture biomass provided an unbiased result with the mean residual being 342 kg DM/ha. The unbiased estimate resulted in the line of best fit being well aligned with the 1:1 relationship and highlights the potential for multiple measures within a paddock providing an accurate prediction of green pasture biomass.

The analyses presented in the Results section of this report are based on relationships within and between quadrats. In practice, these could be taken to reflect the variation of multiple measurement sites within a paddock. The unbiased nature of the estimations resulted in 'over-predictions' being matched by 'under-predictions' and an excellent average estimate of green herbage mass in the data collected in this project.

The use of a composite relationship between NDVI x pasture height to predict green pasture biomass at other properties, across years and under different grazing regimens was explored. The composite relationship provided good predictions of green pasture biomass at a new property but poorer estimates at the same property across years. It is difficult to explain this pattern as there were no major changes in the pasture or management at the property over that time period. Differences in the accuracy of estimating green pasture biomass due to grazing management (Property 3) were small and may have just as readily been accounted by pasture differences between the paddocks.

5.1.2 Engagement of producers

Producers were highly engaged with this project because they already deemed pasture assessment and feed budgeting as a key process to guide stocking rate and grazing management decisions. In that regard the project did not lead to changes in practice but it did reinforce that pasture assessment skills benefit from refresher training. Producers tended to underestimate pasture mass with the magnitude of the underestimation increasing as pasture mass increased. The refresher activities highlighted this tendency allowing for a recalibration. It also highlighted to producers the utility from objective methods such as active optical sensors. The value of NDVI x pasture height in estimating green pasture biomass was recognised by producer members. They indicated interest in using the Biomass application to convert NDVI and pasture height to green pasture biomass but were concerned about the need to calibrate the Green Seeker devices. Ultimately adoption by producers will be improved when pasture height is also able to be automated and pasture biomass estimates are able to be ingested by feed budgeting programs.

5.1.3 Effectiveness of the participatory research process

The goal for participatory R&D is to add value to research through the input of leading producers throughout the research and development phase with the added benefit of accelerating the adoption of project outcomes. The process used in establishing the producer group involved with this project followed closely the steps outlined in MLA report B.FDP.0008, *Developing and Implementing Participatory R&D*. Briefly, the project consultant identified leading producers who were likely to be sufficiently interested to take part in the project. Secondly, the scope and details of participatory activity were identified at an initial meeting attended by the project scientist and producers. The key issue at this meeting was the interest of the producers in establishing the usefulness of the Green Seeker on mixed-species naturalised pastures, whereas the project scientist was interested in developing calibrations for mono-specific pastures. Thirdly, these differences were resolved through the development of a detailed project plan that demonstrated value for both producers and project scientists.

It was apparent that the interest of producers in establishing calibrations for the Green Seeker in mixed-species pastures had influence on project scientists. Producers were interested in this pasture type because of their dominance in grazing systems on the Northern Tablelands of NSW. It was also apparent that producers clearly communicated to project scientists that the key issue for them was using estimates of pasture biomass in a better feed budgeting process rather than the biomass assessment process itself. While these practical considerations helped shape project activities, producers benefited from a better understanding of measurement error and the required accuracy to improve on visual assessment techniques.

The informal but structured nature of project meetings, located on farm or in local meeting rooms, produced a relaxed environment. The presence of the project consultant worked to facilitate good communication between producers and scientists and the attendance of the State Facilitator brought a broader perspective and an independent presence to meetings. This structure was highly effective and, while activity followed the project plan, there remained sufficient agility to respond to the outcomes of project meetings. The participatory research process proved to be a valuable process well suited to this particular project.

6 Conclusions/recommendations

A combination of NDVI values, from the Green Seeker active optical sensor, and pasture height provided the most accurate and unbiased estimate of green pasture biomass. Across all sites and times of collection, the goodness of fit (R^2 values) for the regression of estimated and measured green pasture biomass was 0.80 with an average residual of 342 kg DM/ha. The composite (regional) equation to predict green pasture biomass provided good predictive accuracy at a new property, not part of the original test data, but provided an overestimate at the another property across years.

The results from this project highlight considerable potential for regional equations, based on NDVI and pasture height, to provide accurate estimates of green pasture biomass. However, a process to automate the collection of pasture height will be a critical next step in the commercial application. Such developments will also provide a useful means for estimating total pasture biomass.

Ultimately, estimates of green and total pasture biomass need to be included in feed budgeting approaches to enable producers to derive value through better management of pastures and livestock. This could occur in a number of ways but developing connectivity of this technology with existing applications appears a sensible approach for industry to progress.

7 Key messages

- A combination of NDVI readings and pasture height has considerable potential to predict green pasture biomass.
- Total pasture biomass was well predicted from pasture height.
- A process to automate the collection of pasture height will be a critical next step in the commercial application.
- Estimates of green and total pasture biomass need to be linked with feed budgeting approaches to enable producers to derive value through better management of pastures and livestock.