final report

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Virtual Group – Real time estimation of biomass

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Executive Summary

Accurately assessing feed-on-offer is a key component for the effective allocation of feed to different classes of stock. Producers currently assess feed-on-offer visually, based on an estimate of average height and sward density. Without clear reference criteria this becomes a subjective exercise and introduces errors into feed budgeting.

This project formed part of MLA's Producer Research Site program of the southern Feedbase Investment Plan. In particular, it supported the MLA-funded project B.GSM.0010 – Real time pasture biomass estimation.

The potential for normalised differential vegetation indices (NDVI) to measure feed-on-offer was assessed at six high rainfall Victorian sites between 2014 and 2016. Up to three assessments were made each year at each site. At each harvest the NDVI of between 12 and 15 quadrats was measured using an active optical sensor (GreenSeeker®) and correlated against the herbage yield for the quadrat.

In the second year, additional measurements were made with a CropCircle® sensor to examine the potential for different wavelengths to improve the correlation with feed-on-offer. The data obtained was analysed at UNE as a component of the B.GSM.001 project

Cooperating producers visually assessed feed-on-offer at the harvests, which was then compared to actual yields.

The correlations between NDVI and feed-on-offer varied between sites and seasonally and there was no one consistent calibration applicable to all situations. Correlations improved when the height of the sward was included as a variable. However, in the majority of harvests, height alone was superior to NDVI and in just over half of the situations, height was comparable to, or better than, the relationship between NDVI and height.

Different producers had different abilities to accurately assess feed-on-offer. Some had a high level of consistency in their assessments, although they were often consistently above or below the actual figures. Feed-on-offer was more likely to be overestimated at low feed availabilities and over estimated at high availabilities, particularly if senescent material was present.

In the absence of robust calibrations for NVDI at the trial sites and the reasonable correlations between feed-on-offer and sward height, greater emphasis should be placed on encouraging the use of rising plate meters for assessing feed-on-offer.

This project received additional collaborative support from Agriculture Victoria, allowing the group to increase the scope of the research undertaken.

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1. Background

Accurately assessing feed-on-offer is a key component for the effective allocation of feed to different classes of stock. Producers currently assess feed-on-offer visually, based on an estimate of average height and sward density. Without clear reference criteria this becomes a subjective exercise and introduces errors into feed budgeting.

The ability to consistently accurately measure feed-on-offer, either remotely or through a method that could be standardised for repeatability between employees, etc., should facilitate better feed utilization and therefore increase profitability for producers.

This project supported the applied research being undertaken at UNE - *B.GSM.0010 – Real time pasture biomass estimation* – by assessing the applicability of the research findings in practical farming environments.

The six members of the group were drawn from five Bestwool/Bestlamb groups – Benalla, Mansfield (North East Victoria), Barwon, Shelford (Central Victoria) and Casterton (Western District) - as a means of evaluating that the technology across a number of production systems and pasture types in a wide range of environments, with the expectation that information developed would have a wider distribution through sharing with the other members of their group.

The 6 businesses farmed a total of 11,800 ha. Four of the six businesses had cattle (approximately 550 adult cattle per property), 5 had sheep, (approximately 4,100 adult sheep per property) and 2 businesses also grew crops on about 1,900 ha of the total area farmed by the group.

The group members expressed a strong desire to better assess and use feed-on-offer measurements to improve feed budgeting.

Most of the group members had undertaken training courses and been involved in the Lifetime Ewe program, where assessment of feed-on-offer is an integral component.

The group members currently use visual assessments (or sticks) to make decisions about feed allocation. The members wanted a tool that would give consistency in measurements between users (where there was more than one person taking measurements on a property) and one that would improve the ease and accuracy of measurement. A key focus of all members was the appropriate allocation of feed, particularly in winter, to provide adequate feed for different classes of stock.

Group members are currently using feed assessment to differing levels of intensity. For example, some measure feed-on-offer for lambing paddock preparation and selection, rotation of cell grazing paddocks and feed budgeting, while others are using it to ensure good growth rates for growing stock.

2. Project Objectives

This project forms part of MLAs Producer Research Site program that is part of the southern Feedbase Investment Plan. In particular, this project supports the MLA-funded project *B.GSM.0010 – Real time pasture biomass estimation.*

The PRS project objectives were to:

By 1 August 2017:

1. Develop active optical sensor calibrations for phalaris/sub clover and perennial ryegrass/sub-clover pastures for the critical animal production times of early mid-winter, mid/late winter and mid/late spring.
2. Compare existing methods of pasture biomass estimation to the use of the optical; sensor for ease of use, convenience, accuracy, time required and repeatability.
3. Collect producer feedback on the development of a mobile device application (MDA) including the information it should contain, its format, links, to existing software, ease of use and robustness.
4. Explore and test if the optical sensor in conjunction with other technologies can be used for measuring dead/dry feed and or quality.
5. Establish how the use of active optical sensor measurements can assist producers to make useful decisions leading to financial gains.

3. Methodology

3.1 Research Sites

The sites, all long-term grazing paddocks, were as follows:

- Mansfield ("Davilak").
- Euroa ("Killeen")
- Shelford ("Leighburn")
- Rokewood ("Warrambeen")
- Carapook ("Witnell")
- Warrek ("Lyndoch")

All pastures, with the exception of Mansfield in 2014 and Carapook, were phalaris/sub-clover based. The first year site at Mansfield was perennial ryegrass and the site at Carapook was a cocksfoot pasture. The site at Mansfield was changed in the second year to a phalaris based pasture due to severe pugging of the pasture. The soils at Euroa and Rokewood were derived from volcanic parent material, while the others were derived from sedimentary parent material.

3.2 Treatments

Four treatments tested in the project were:

- GreenSeeker sensor– measuring near infrared and red wavelengths (NDVI).

NDVI (Normalised Difference Vegetation Index) is a measure of vegetation density and condition. It is influenced by the fractional cover of the ground by vegetation, the vegetation density and the vegetation greenness. It indicates the photosynthetic capacity of the sward.

NDVI is calculated from the red and near-infrared reflectances (*rRed* and *rNIR*) as:
NDVI = (rNIR - rRed) / (rNIR + rRed)

- Crop Circle sensor– measuring other combinations of wavelengths.
- Pasture height – measured with a falling plate.
- Visual assessment of pasture biomass.

3.3 Monitoring

Six trial sites were established in 2014 of which, three were coordinated by Meridian Agriculture and three were managed through the Agriculture Victoria (AgVic). AgVic were only able to service two sites in 2015, and Meridian Agriculture undertook to monitor four sites in that year. AgVic continued with two sites in 2016 and Meridian Agriculture reduced its number of sites to two (Euroa and Mansfield), but still achieved the monitoring of the total number of sites contracted.

Initially, 15 quadrats (0.467 sq. m in size) were cut to ground level with hand shears at each harvest. In consultation with the Research Leader, the number of quadrats was reduced to 12 in the second and third years. At each harvest, quadrat sites were selected to provide a range of NDVI readings. Pre and postharvest NVDI measurements with a GreenSeeker ® sensor and photographs were taken at each site at each harvest. Pasture height was measured using a handmade falling plate device prior to harvest. In 2015, additional wavelength measurements, were taken pre and postharvest with a Crop Circle® sensor to see if correlations with feed-on-offer could be improved. The harvest dates for the sites are shown in Table 1**.**

Table 1. Harvest dates

Year	Site					
	Euroa	**Mansfield**	**Rokewood**	**Shelford**	**Carapook**	**Warrek**
2014	11 Jun 2014	11 Jun 2014	07 Jul 2014	04 Jul 2014	19 Jun 2014	27 Jun 2014
	12 Sep 2014	08 Sep 2014	27 Aug 2014	28 Aug 2014	01 Sep 2014	26 Jun 2014
	27 Oct 2014	28 Oct 2014	31 Oct 2014	30 Oct 2014	11 Nov 2014	11 Dec 2014
2015	26 Jun 2015	26 Jun 2015	30 Jun 2015	29 Jun 2015	09 Jul 2015	08 Jul 2015
	25 Aug 2015	26 Aug 2015	18 Aug 2015	19 Aug 2015	13 Aug 2015	13 Aug 2015
	21 Oct 2015	*	14 Oct 2015	13 Oct 2015	09 Oct 2015	03 Oct 2015
2016	17 Jul 2016	18 Jul 2016	08 Jul 2016	09 Jul 2016		
	17 Aug 2016	16 Aug 2016	23 Aug 2016	22 Aug 2016		
	28 Sep 2016	27 Sep 2016	06 Oct 2016	05 Oct 2016		

* No measurements taken due to failed spring

The total amount of pasture harvested was recorded and a subsample sorted for botanical composition and measured for moisture content Herbage yields and were converted into kilograms green dry matter/ha as both green or total dry matter/ha (green plus dead and senescent pasture). It was expected that there would be a closer relationship of NDVI with kg green dry matter than between NDVI and total dry matter.

It was intended that three harvests would be taken at each site each year during the growing season. The seasons in 2014 and 2015 finished abruptly due to poor spring rainfall. No final harvest was taken at the Mansfield site in 2015 and the final harvests at the other sites contained samples from pastures which were starting to senescence.

Where co-operators were available on the day of assessment, they were asked to visually assess the feed-on-offer prior to sampling or, if the quadrats had been cut, on adjacent areas which had similar feed availabilities.

An objective of the trial was to see if the optical sensor, in conjunction with other technologies could be used for measuring dead/dry feed and or quality. A CropCircle sensor was used during 2015 to examine if other wavelengths improved food-on-offer calibrations and lidar (light detection and ranging) was used by Agriculture Victoria at Hamilton in the Western District of Victoria, to investigate its value in remotely measuring sward height.

The herbage subsamples used for dry matter determination and botanical composition were retained. UNE have identified samples from key harvests which have been forwarded for quality analysis.

Yield data, botanical composition data, Greenseeker® and Crop Circle® readings and pre and postharvest photos were forwarded to UNE after each harvest for statistical analysis.

3.4 Statistical analysis

Detailed analysis of the results of the harvest data was undertaken by the research scientists at UNE (initially Andrew Robson and subsequently Karl Anderson). The analyses included regression analysis, with the transformation of some data and elimination of outliers. Locally, for the group, the relationship of unadjusted NDVI data with green dry matter, and green dry matter and total dry matter relationships with producer estimates were undertaken and reported to group members.

3.5 Extension and Communication

Because the research work is at an embryonic stage with little concrete outcomes there has been little value in disseminating the results widely. However, group members were provided with feedback from the trials and if available attended annual review meetings.

The Virtual group had their first project meeting on 15/2/2014 to discuss the project topic and to seek agreement with UNE researchers (Mark Trotter) on participatory R&D activities, what research questions were to be investigated, and plan how the project might proceed.

Annual review meetings with the researchers and producers, focussing on the progress of the project, were held on 19/2/2015, 15/4/2016 and 1/2/2017.

These meetings also collected producer feedback on the development of a mobile device application (MDA) including the information it should contain, its format, links, to existing software, ease of use and robustness.

A key objective of the project was to establish the benefits to producer's decision making through using the GreenSeeker. The constraint to this was the GreenSeeker was not accurate enough to carry out an evaluation of if and how producers change their decision making following the use of the GreenSeeker. Instead the group investigated how using the biomass measurements in general can assist in making useful decisions leading to potential financial gains.

This was done through surveying three group members using the following survey questions.

1. How and when are you currently measuring pasture biomass?
2. Why are you measuring at that time?
3. How does it change what decisions you might make?

4. What do you think is the value of measuring pasture biomass?

4. Results

2014 and 2015 were years of below average rainfall at all sites and resulted in early finishes. Consequently, the last harvests at all sites occurred at a time when the pastures were beginning to senescence.

Yield data, botanical composition data, Greenseeker® and Crop Circle® readings and pre and postharvest photos were forwarded to UNE after each harvest for statistical analysis and have not been duplicated for this report.

4.1 Calibration development using NDVI & height

The GreenSeeker data for Euroa, Mansfield Rokewood and Shelford in 2016 is shown in Tables 2 - 5. There is no data presented for the Warrek and Carapook sites as these were not harvested in 2016. The tables show the correlation coefficients, calculated independently from UNE analyses, for measured green feed-on-offer, for the natural log of the pasture height (cm) multiplied by the NDVI measurement and for height (cm) alone.

The correlation coefficient (r^2) of a regression analysis describes the strength of these relationships. An r^2 of 1 reflects a perfect correlation/association. An r^2 greater than 0.7 (70% of the variation is explained by the relationship) is considered desirable.

Table 2 Correlations (r^2) with feed-on-offer for 2016 Euroa harvests

	17 Jul 2016	17 Aug 2016	28 Sep 2016
NDVI	0.63	0.26	0.51
NDVI* log height	0.86	0.57	0.93
Height (cm)	0.97	0.89	0.76

Table 3 Correlations (r^2) with feed-on-offer for 2016 Mansfield harvests

	18 Jul 2016	16 Aug 2016	27 Sep 2016
NDVI	0.43	0.66	0.50
NDVI* log height	0.56	0.95	0.75
Height (cm)	0.97	0.44	0.92

Table 4 Correlations (r^2) with feed-on-offer for 2016 Rokewood harvests

	08 Jul 2016	23 Aug 2016	06 Oct 2016
NDVI	0.43	0.69	0.70
NDVI* log height	0.72	0.93	0.87
Height (cm)	0.50	0.87	0.83

Table 5 Correlations (r^2) with feed-on-offer for 2016 Shelford harvests

	09 Jul 2016	22 Aut 2016	05 Oct 2016
NDVI	0.84	0.66	0.63
NDVI* log height	0.58	0.69	0.53
Height (cm)	0.38	0.68	0.33

With the exception of the Shelford site and one harvest at Rokewood, the inclusion of the natural log height function, markedly improved the predictability of NDVI. However, for nine out of the twelve harvests, height alone gave a better relationship than NDVI, and seven out of twelve "height alone" correlations were comparable or better than NDVI x log height correlations.

UNE undertook more complex analysis the results of which will be reported in UNE's project report (B.GSM.0010). An example of the interim analysis by UNE is shown in Table 6. A similar table was presented at the final review in February 2017 but was then amended.

Table 6 shows combined calibrations of measurements for this group. RMSE is the residual mean standard error. For example, in the autumn/winter harvests, the best correlation was height x NDVI with plus or minus 183 kg green DM/ha. N is the number of harvests.

Table 6 Summary of the UNE analysis of the Virtual Group data (Anderson, 2017)

Sites including Euroa, Mansfield (2014 & 2015) and both Shelford sites		**NDVI**	**Log Height + NDVI**	**Height**
Autumn to Winter NE & SW Vic	r^2	0.48	0.76	0.72
4 campaigns, N= 54	RMSE	286	183	197
Winter to Spring NE & SW Vic	r^2	0.25	0.78	0.76
11 campaigns, N= 123	RMSE	556	295	307
Late spring 2014 NE & SW Vic	r^2	0.70	0.78	0.44
	RMSE	482	482	770

These results of this analysis mirrors the individual site data for 2016 shown above.

With the exception of the late spring harvests in 2014, the inclusion of the natural log of the pasture height in the analysis markedly improved the correlation between NDVI and measured feed on offer and reduced the residual standard mean error. However, height alone gave similar improvements for these dates of harvest. For the late spring harvests, there was no improvement with the inclusion of the natural log of sward height and height alone was inferior.

The CropCircle data which consisted of three wavelength readings for each harvest was forwarded to UNE for detailed analysis to identify if other wavelengths or combinations of wavelengths gave better correlations with either feed on offer or particular feed components (eg dry feed). The analysis did not show an improvement in correlation and the use of the CropCircle was discontinued after the 2015 measurements.

4.2 Farmer assessments of feed-on-offer

When available at the harvests, producers assessed feed-on-offer for each of the quadrats, which were then compared to the measured yields.

Table 7 shows the data from those harvests where producers estimated feed-on-offer.

Different producers had different abilities to accurately assess feed-on-offer.

Producers generally were more consistent in their assessment of feed as indicated by the generally better between for their assessments (32 assessments out of 48) compared with the NDVI/feed-on-offer correlations.

However, they were often not accurate, being above or below the actual figures. Feed-on-offer was more likely to be overestimated at low feed availabilities. There was a marked under-estimation of feed in the last harvests of 2014 when there was a high level of feed present and when the pasture was beginning to senescence. Estimates at the final harvest in 2015 were better, most likely because there was a much lower level of feed-on-offer and in 2016 when pastures were still actively growing.

Table 7 Comparison of the average measured green and total dry matter with the average visual estimated dry matter (kg/ha)

Harvest Date	Site	Actual green DM kg/ha	Actual total DM kg/ha	Estimated DM kg/ha	Difference Estimate vs green DM (kg/ha)	Difference Estimate vs total DM (kg/ha)	R^2 Feed on offer vs green DM	R^2 NDVI vs vs green DM
11 Jun 2014	Euroa	Harvest by UNE						
11 Jun 2014	Mansfield	1118	1118	1538	+420	+420	0.86	0.63
				1531	+413	+413	0.85	
7 Jul 2014	Rokewood	1984	1984	1854	-130	-130	0.67	0.20
4 Jul 2014	Shelford	2354	2354	2360	+6	+6	0.67	0.01
12 Sep 2014	Euroa	1020	1483	1913	+893	+430	0.12	0.57
08 Sep 2014	Mansfield	2040	2071	1675	-365	-396	0.92	0.55
				1496	-544	-575	0.92	
27 Aug 2014	Rokewood	1824	2027	1563	-171	-464	0.37	0.20
28 Sep 2014	Shelford	2216	2224	1742	-474	-468	0.34	0.03
01 Sep 2014	Carapook	1047	1926	2384	+1337	+458	0.25	0.47
27 Oct 2014	Euroa	1705	3610	2200	+495	-1410	0.77	0.93
28 Oct 2014	Mansfield	3025	3980	1850	-1176	-2130	0.88	0.72
				2045	-980	-1935	0.88	
				1900	-1125	-2080	0.91	
31 Oct 2014	Rokewood	1683	3242	1996	313	-1246	0.65	0.53
30 Oct 2014	Shelford	1119	3589	1808	+689	-1781	0.01	0.80
				1891	+772	-1698	0.04	
26 Jun 2015	Euroa			973	+514	-80	0.44	0.31
				1292	+836	-239	0.78	
		456	1053	1146	+690	-93	0.65	
26 Jun 2015	Mansfield	385	977	1208	+823	+231	0.45	0.76
				1225	+840	+248	0.61	
				1183	+798	+206	0.02	
				1229	+844	+252	0.60	
30 Jun 2015	Rokewood	1388	2212	1291	-145	+921	0.28	0.37
29 Jun 2015	Shelford	1146	1652	1267	+507	-385	0.26	0.42

25 Aug 2015	Euroa	444	997	411	-33	-556	0.09	0.66
				873	-429	-154	0.20	
18 Aug 2015	Rokewood	1943	2441	1154	-789	-1287	0.67	0.54
19 Aug 2015	Shelford	1146	1652	1267	+121	-385	0.23	0.42
21 Oct 2015	Euroa	456	1053	973	+517	-80	0.44	0.31
				1292	+863	+239	0.78	
				1146	+690	+93	0.65	
				918	+462	-135	0.43	
13 Oct 2015	Shelford	731		630	-101		0.71	0.87
			2713	1254		-1459	0.38	
17 Jul 2016	Euroa	812	1049	833	+21	-216	0.87	0.63
18 Jul 2016	Mansfield	1136	1176	1000	-136	-176	0.52	0.43
08 Jul 2016	Rokewood	907	1075	1267	+360	+192	0.83	0.43
09 Jul 2016	Shelford	1119	1167	1263	144	96	0.54	0.84
17 Aug 2016	Euroa	912	963	1309	397	346	0.57	0.26
16 Aug 2016	Mansfield	1886	2029	1545	-341	-484	0.79	0.66
23 Aug 2016	Rokewood	1429	1918	2338	909	420	0.71	0.69
22 Aug 2016	Shelford	1680	1965	1479	-201	-486	0.76	0.66
28 Sep 2016	Euroa	1741	2021	2360	619	339	0.81	0.51
27 Sep 2016	Mansfield	2000	2213	2100	100	-113	0.51	0.50
06 Oct 2016	Rokewood	2422	2930	1820	-602	-1110	0.92	0.70
05 Oct 2016	Shelford	1334	1798	1229	-105	-569	0.39	0.63

4.3 Improving producers' decision making

Producers who participated in the visual assessments of pasture enabled them to check their assessments against actual measurements by making them aware of the biases in their estimations. Although not measured it would be expected that this would result in better management decisions.

4.4 Extension and communication

The following activities were undertaken as part of the project.

Extension to the wider community was not actively undertaken while trying to verify the accuracy of the GreenSeeker. Thirteen extension activities were engaged in involving 53 participants **(Table 8).** It includes providing email and verbal updates to group meetings.

Table 8 Extension activities

Date	Event/ Activity	No of Extension Activities	No of participants	Distribution
1-Jul-14	Project planning initial meeting	1	12	
1-Dec-14	Email Sept Update of results	1		6
	Email results of producers assessments (Nov)	1		6
1-Jul-15	Email Jan Update of results			
	MLA Annual Review Meeting	1	15	
1-Dec-15	Email Nov update to group members	1		10
	Annual review April 2016	1	7	
	Email results Jan 2016	1		4
1-Jul-16	PRS June Workshop	1	2	
	Annual review April 2016	1	6	
1-Dec-16	Email results 9th Dec 2016	1	7	
1-Apr-17	Final review meeting 2-2-2017	1	4	
	Letters sent to participants	1		7
Total		**12**	**53**	**33**

A snapshot case study was prepared for the group.

4.5 Participant reactions

At the start of the project group members had some pre conceived ideas around optical sensors for measuring biomass. They knew these existed (from cropping), but thought they were expensive, inaccurate, had limited pasture calibrations and for only a small number of species. Few knew of any commercial tools that were available. Producers in the group rated their current knowledge at 1.4 out of 5, range 1 to 2 (0= no knowledge, 5 = full knowledge), with the advisor rating a 4 (the advisor had been on a recent MLA review of potential technologies for use in the grazing industries).

By the end of the project the members were familiar with the GreenSeeker optical sensor and NDVI measurement. The group had knowledge that visual assessment was generally inaccurate. Height was an important measurement but the GreenSeeker was not consistently better than just taking a height measurement.

There was recognition that when producers feed budget and end up with different feed levels than predicted, there is a tendency to adjust the assumed pasture growth rate rather than question their assessments of feed on offer thus potentially creating errors in two key factors.

The group saw real time assessment of pasture biomass as a key need, whether it was the GreenSeeker or other types of sensors eg satellites. However, the benefits would need to outweigh the costs involved with the most important attributes needed to be accuracy and repeatability and ease of use.

There was disappointment that the project didn't achieve the goal of what was thought to be a very worthwhile project. As a result, there was a waning of the initial enthusiasm during the program. However, those members who participated in the food-on-offer assessments valued the ability to compare their assessments with actual yields.

4.6 Producer Research Site Program

There were modifications made throughout the project on methodology rather than on the research topic.

For example, it became evident at an early stage that there were issues in achieving consistent relationships between NDVI and feed-on-offer between sites and between seasons. As a result, access to a Crop Circle® sensor was obtained and additional wavelengths were measured during 2015 to see if different spectra would improve the accuracy of assessment. These data were provided to UNE.

The on-farm component of the overall project tested the robustness of assumptions regarding the applicability of NDVI alone for measuring feed-on-offer. In apparent contrast to other locations, sites for this group identified significant limitations in the technology. Reasons for the discrepancies in different states have been suggested by Karl Anderson as to do with more seasonal variations experienced in Victoria over the project period.

The producer group was keen for the sensor to measure both total (including dead) and green material. This was because these producers potentially only had green feed for five or six months of the year unlike Armidale that had green feed all year round. Producers stressed the importance of having a device that could measure pasture all year round.

5. Discussion

The objective in assembling a group of producers as a virtual group was to provide an opportunity to promote the technology across a range of farming systems and environments.

5.1 Outcomes in achieving objectives

Objective 1

Develop active optical sensor calibrations for phalaris/sub clover and perennial ryegrass/sub-clover pastures for the critical animal production times of early mid-winter, mid/late winter and mid/late spring.

Calibrations were developed for a range of pasture types. However, the calibrations varied depending on the time of year and were site specific.

As a concept, the GreenSeeker has appeal as a means of standardising assessments between producers/employees. However, the project identified a number of limitations of the technology which need to be addressed for the development of robust feed-on-offer assessments.

Individual GreenSeekers can vary in their readings with differences up from 0.02 to 0.08 and they have no calibration adjustment.

Because the Greenseeker measures greenness, vastly different pastures can have similar NDVI readings. A short very green pasture can have the same NDVI reading as a tall not so green pasture. As well, different species have different reflectances at the same level of feed-on-offer. Further, some poor quality pastures (e.g. those containing onion grass) are green and will be measured by the Greenseeker whereas using height measurements with the stick method excludes plants that animals don't eat.

In pastures where there is little variation in NDVI (e.g. in highly fertile pastures), there can be large differences in feed estimates with small changes in NDVI.

Objective 2

Compare existing methods of pasture biomass estimation to the use of the optical sensor for ease of use, convenience, accuracy, time required and repeatability.

Currently most producers and advisors visually assess pasture based on height and a subjective assessment of sward density. Visual height measurements are calibrated generally against a ruler placed in the sward at a number of locations. Rarely if ever, are these estimates ground truthed against actual measurements.

The height measurement method (as a falling plate) was assessed in the project and generally in the majority of cases gave a better correlation with measured feed on offer than NDVI.

The ability of the co-operators to assess feed on offer varied considerable between people and between seasons. Producers tended to over-estimate feed-on-offer when pasture was short and underestimate feed-on-offer as the season progressed when there was a greater mass of feed present and particularly if pastures were senescing.

Objective 3

Collect producer feedback on the development of a mobile device application (MDA) including the information it should contain, its format, links, to existing software, ease of use and robustness.

A mobile phone app was developed to provide in-paddock assessment of feed-on-offer. The app converts height and NDVI into kg DM/ha, with paddock mapping features based on a series of calibrations derived from the PRS trials.

Feedback provided to the researcher at the final review was:

- Height correlation data created through the project should be included as a variable.
- The app assumes that there is no grazing between measurements. Therefore, the output should not be called "growth" as the measure is the net difference between the two measuring times, which may include grazing.
- An estimate of likely growth rate could be achieved by including stock number, class of stock, days in paddock, DSE rating to estimate how much pasture has been eaten. i.e. Change in feed-on offer per day between the two assessments minus feed eaten per day=pasture growth rate.
- Consideration should be given to combining the app with the Lifetime ewe app.
- Average feed-on-offer needs to take into account sward characteristics, e.g. if a paddock has 50% ground cover and an average of 750 kg DM/ha, then by extension, half the area has an average of 1500 kg DM/ha and the remaining 50% is bare. 750 kg DM/ha would not be suitable for a lactating ewe whereas 1500 kg DM/ha would. What the animal actually "sees" is half the area with adequate feed not the whole paddock with inadequate feed. For feed budgeting the area of the paddock would need to be halved.
- It is intended that the app be updated by producers entering calibrations from their farms. Given the inaccuracy of visual estimates, this will only be of use if measurements are calibrated to actual yields. This seems highly unlikely because of the time required and the need for a standardised methodology between producers.

Objective 4

Explore and test if the optical sensor in conjunction with other technologies can be used for measuring dead/dry feed and or quality.

No clear benefit was evident from the inclusion of the wavelengths measured with the Crop Circle® sensor. The use of Lidar to measure height was evaluated around Hamilton, Victoria independently of this group. The inclusion of height as a factor improved the accuracy of the relationship between NVDI and feed-on-offer, but the relationship was not markedly different from height alone as a predictor of feed-on-offer.

It seems unlikely there would be further improvements in measuring NDVI alone. Height measurements with a falling plate meter (not the ruler method) is an easy means of accounting for density but producers will want to use one device for assessment and not have to take two lots of measurements, particularly when height alone was a reasonable robust method of assessing feed-on-offer.

Discussion at the final review it was acknowledged that the GreenSeeker was used because it was relatively cheap product for producers to purchase but that perhaps the technology should have been proven first by using multispectral analysis and machine learning to identify the most appropriate wavelengths for quality and quantity.

Objective 5

Establish how the use of active optical sensor measurements can assist producers to make useful decisions leading to financial gains.

There is no doubt that accurate feed assessment and effective feed budgeting is of significant economic value.

Producers' guesses at the additional profit they made by being able to accurately assess pastures ranged from $100 to $250/ha. Winter management had to strike a reasonable balance between the condition of the stock, the green pasture and any supplementary feeding.

As one of the co-operators stated:

"You can get $6,000 back easy if its (feed assessment) is accurate and you're making good decisions."

This outcome is dependent on robust repeatable relationships being developed to allow accurate estimation of feed-on-offer. Once this is achieved there are likely to be significant improvements in profitability through the better allocation of feed between various classes of stock. Simple, repeatable relationships across seasons have not been achieved with the GreenSeeker sensor with this group and while the inclusion of height in the analysis improved seasonal correlations, height alone in most cases provided comparable results. Consequently, it is difficult to see the place of the GreenSeeker sensor alone in the Victorian environment.

5.2 The value of the research results (Benefits/Costs)

The results from the sites measured in this group did not provide consistent between-season relationships that would make the results ready for adoption by producers.

After analysis of 3 years of data collection there were two key messages the group felt comfortable to promote for future extension and they were:

- Measure height using the most cost effective accurate method.
- Eyeballing pasture is not a sufficiently accurate way of assessing biomass, and that regular calibration is required.

5.3 Promotion of research results and its effectiveness

There is a need to consider the adoption of any technology in relation to its benefit. The need will drive the adoption of appropriate technology. While Prograze gave producers the skills to assess feed it didn't show them how to make money. Feed estimation is a key component of Lifetime ewe management courses but of considerable concern is the inaccuracy of estimation by producers in this project of feed-on-offer. It is highly likely also that trainers for these courses are not accurate in their assessments.

As there were few definitive results from the project, there was limited ability and opportunity to promote the outcomes. The major outcome has been the realisation that without constant calibration by producers, visual estimates of feed-on-offer are variable and generally inaccurate. This recognition has resulted in those producers recalibrating themselves and therefore having a better ability to assess feed-on-offer.

Confirmation of the robustness of height as a measure of feed-on-offer is a valuable outcome of the project.

Enablers to change identified in producer discussions were:

- Having an accurate device that is easy to use.
- Future research is important to find accurate, mobile and easy ways to measure height and account for density and moisture change throughout the year.
- Demonstrating the extra dollars producers can make by taking biomass measurements at critical times to make better decisions.

5.4 Effectiveness of the participatory research process

The site owners/managers were informed whenever harvests were being taken and when commitments permitted, they attended and participated in harvest and pasture assessments. Enthusiasm was high initially however as it became clear that the technique was not going to deliver a “magic bullet” involvement waned with some of the participants.

There was regular contact with the researchers during the project including annual review meetings. The results from the project caused a re-evaluation of the research methodology. While this hasn’t resulted in the development of the technology for ready use in Victoria, it enabled clarification of processes at an early stage of the project.

An issue raised with researchers early in the project was that the same NDVI reading could be obtained from a short very green pasture and with a tall, not-so-green pasture. A further issue was a difficulty in getting sufficient variation of NDVI measurements in short dense pasture. As a result of these concerns, additional wavelength measurements were taken in the second year with a CropCircle® sensor, but without improvement in predictability.

Had there been a robust calibration established for NDVI and feed-on-offer, the exercise would have been a very worthwhile exercise for the participants. As that didn’t eventuate, the major benefit was the ability of the producers to check their pasture assessment skills objectively. As indicated above, this process highlighted the variation in accuracy between seasons.

The group are keen for this topic to be further pursued and invested in to develop easy to use tools that can measure pasture height.

6. Conclusions/ Key Messages /Recommendations

The project was useful in informing the research component of the trial of practical issues as they arose early in the project, such as the limitations of NDVI alone for assessing feed-on-offer.

Cooperating producers gained experience in assessing feed on offer through calibrating their visual assessments with measured feed on offer. However, because there was no farm-ready calibration coming from the trials at these sites, there was nothing that was immediately applicable with immediate relevance to producers.

There is still a need to get a robust measure of feed-on-offer that is operator independent. The usefulness of a feed-on-offer measurement would be greatly enhanced with an assessment of feed quality.