Examining the potential for active optical sensors to provide biomass estimation in improved and native pastures

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Abstract
This study examined the potential for Active Optical Sensors (AOS) to provide estimates of green biomass in improved and native pastures. Two sampling campaigns were undertaken across two pasture types (improved and native) in September and October 2011. The AOS was found to correlate poorly with the green fraction of the sward in September when senescent material dominated the sward, particularly in the improved pastures. In contrast the AOS demonstrated good correlations with green dry matter in October when there was a higher proportion of green material in the sward. The correlation was particularly sound for the improved pasture (r^2 0.91) and better than expected for the native pasture (r^2 0.63). This study demonstrates the potential for AOS to provide rapid estimates of biomass in both improved and native pastures and suggests that further research be undertaken to further quantify the value of these sensors.

Key Words
Active Optical Sensor, Precision Agriculture, CropCircle, Pasture, Remote Sensing

Introduction
Obtaining accurate information on the quantity of pasture remains one of the key problems for both researchers and producers (Trotter, 2010). Several tools and techniques have been developed that enable rapid point estimates of pasture biomass in fields and research plots, for example: simple height measures, rising or falling plate and capacitance probes (Sanderson *et al.*, 2001). Whilst these techniques are often relatively accurate they cannot provide estimates across large spatially diverse pastoral landscapes without considerable effort. To overcome this problem several other sensors have been developed including the rapid pasture meter (Yule *et al.*, 2006) and pasture reader (Awty, 2009). These systems rely on measuring the height of the sward and relating this to biomass. Whilst these systems are reported to have a reasonable level of accuracy they are largely calibrated for highly improved pastures (e.g. perennial ryegrass dairy pastures) where height to biomass correlations are known to be favorable. In addition these highly improved swards frequently have a high proportion of green to dead leaf fractions enabling these height based sensors to provide good estimates of the green fraction of the sward. It is this green fraction of the sward which is often of most interest to producers and researchers seeking to understand the potential animal productivity from a given pasture. However, many pastures used in grazing systems do not consist of a high proportion of green matter with a large fraction of senescent material present at different stages of the growth cycle. Both producers and researchers alike desire reliable and rapid estimates of the green fraction of these pastures to enable better research outcomes and more accurate grazing management.
Recently, there have been several studies investigating the potential for Active Optical Sensors (AOS) to provide estimates of the green fraction of mixed phenology swards (Flynn *et al.*, 2008; Trotter *et al.*, 2010). These sensors function in a similar way to remote sensing platforms in that they measure the amount or light reflected from the plants. However, AOS contain their own light source and through modulation of the emitted light enable estimation of the light reflected in both visible and near-infrared ranges independent of ambient light conditions (Lamb *et al.*, 2009; Trotter, 2011). An added advantage of AOS is their ability to be linked to a GPS and provide rapid estimates of biomass characteristics across large areas (Trotter *et al.*, 2010). Even though there has been some investigation

of the correlation between these sensors in mixed phenology pastures (Trotter *et al.*, 2008) there remains some doubt of the ability of AOS to provide accurate green fraction estimates particularly in native pasture systems that dominate the Australian grazing landscape (Barnes *et al.*, 2011). This paper reports the preliminary results of a project examining the accuracy of AOS in estimating the green fraction of two different perennial pasture swards, one dominated by introduced grass and legume species and the other an unimproved native dominated pasture on the Northern Tablelands of NSW, Australia.

Methods

This study was undertaken in conjunction with a larger trial comparing the methane emissions from improved and native pastures. The improved pasture areas were located on creek flats and consisted of ryegrass, fescue, brome and white and subterranean clover. The native pastures were located on a hill adjacent to the flats and were dominated by native species such as redgrass, danthonia, poa tussock with some naturalised temperature species (e.g. brome and red clover). Two sampling campaigns were undertaken in September and October 2011 to collect biomass cuts and AOS scans. The AOS used in this study was a Holland Scientific ACS210 which measures light reflectance in the 650nm (red) and 880nm (NIR) ranges. The median quadrat technique was used to select an area for harvest at pre-selected points across paddocks. The AOS was used at a height of 80cm and a single point scan taken within the quadrat. Both red and NIR reflectance values were recorded using the crop circle. After being scanned with the AOS the quadrat was cut to ground level bagged, dried and then sorted in green and dead fractions. Sample dry weights were converted into kilograms/hectare (kg/ha). Data analysis was undertaken in Microsoft Excel with red and NIR reflectance values converted into the normalised difference vegetation index (NDVI = (NIR-Red)/(NIR+Red)) and these correlated with the green biomass fractions. Relationships (coefficients of determination) were assessed by fitting an exponential regression in Microsoft Excel.

Results and Discussion

The biomass data collected from paddocks ranged from a maximum of 7451kg/ha to a minimum of 20 kg/ha of green dry matter (GDM). The average values recorded for each month and fraction of the pasture sward (Table 1) reveal a large difference in the proportion of green and dead between the two months sampled. This is most noticeable on the improved pasture with average green fraction increasing from 15% of the sward in September to 83% in October. This shift in pasture composition had a dramatic effect on the correlation of the AOS to the green fraction of the sward.

Table 1. Average dry matter weights for pasture fractions from improved and native pastures over the two sampling periods, September and October 2011

		Dry matter (kg/ha)		
Pasture	Sample	Green	Dead	Total
Improved	September	791	4378	5169
	October	5387	1103	6490
Native	September	258	4987	5244
	October	1651	2754	4404

The combination of all the data (Figure 1A) provided a reasonable correlation between NDVI and GDM. A similar non-linear response has been observed in other studies (Trotter *et al.*, 2010) however it is worth noting that range of values (up to ~7500kg/ha) far exceeds those previously reported. It is clear from the comparison of the results from September and October that the sensor performed better when a higher proportion of the sward was green (Figure 1B and C). This trend is also clearly demonstrated in the improved pasture where the combined data (Figure 1D) reveals a poor relationship. The lowest correlation was found between NDVI and GDM during September in the improved pasture (Figure 1E) where an inverse relationship was found. This would have likely been caused by the large amount of dead material present obscuring the view of the sensor to any green material. This problem has been identified previously (Trotter *et al.*, 2010) and highlights the limitations of these sensor platforms. The highest correlation was found between the NDVI and GDM

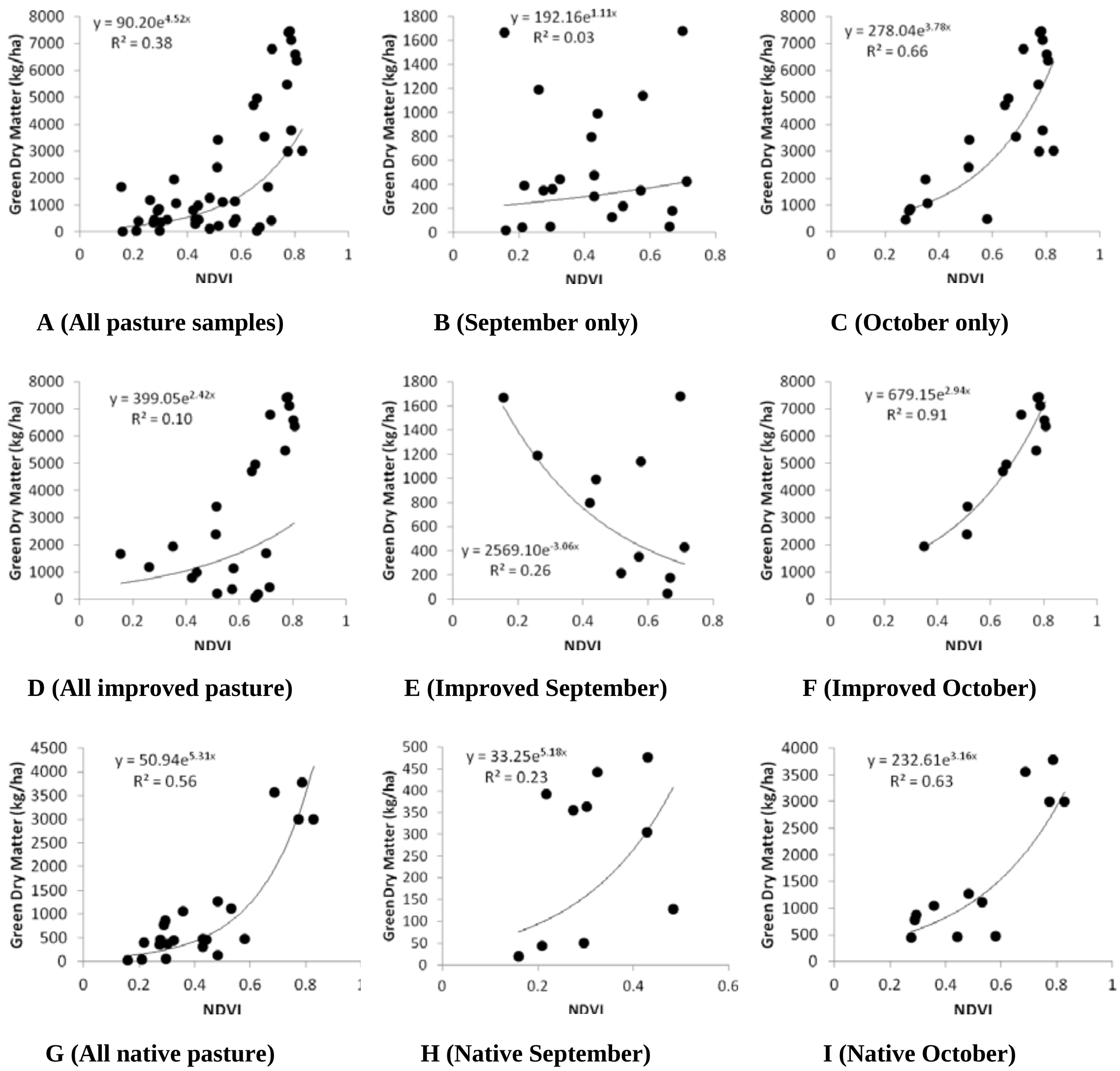

Figure 1. Non-linear regression curves and correlation coefficients of the relationship between Green Dry Matter and NDVI across all pastures (A-C), improved pastures (D-F) and native pastures (G-I).

in the improved pasture in September (Figure 1F), this was expected as the high proportion of GDM compared the senescent material has been reported to provide better relationships (Trotter *et al.*, 2008).

The relationship between NDVI and GDM was expected to be reasonable in the improved pasture (Flynn *et al.*, 2008), it was not expected to hold up for the native pasture for which this sensor has been suggested to perform poorly (Trotter *et al.*, 2008). Despite this, a reasonable correlation was reported between NDVI and GDM across both sample dates (Figure 1G) and the sensor performed well in October (Figure 1I) when the green fraction increased in the native pasture. Results in September (Figure 1H) were similar to that for the improved pasture although it should be noted that a positive correlation was found for the native pasture. This is likely to be due to the lower levels of overall biomass present in the native sward during the September sampling compared to the improved pasture. Whilst the AOS largely failed to perform accurately during the September sampling it does not discount the value of this sensor. The September pasture conditions with very high proportions of dry matter compared to green would not regularly be found on a commercial grazing property. It is also worth noting that most pasture management decisions made by producers are under conditions more like those represented by the October results. Testing under these extreme conditions (low percent green fraction) essentially provides an indicator of the limitations of this sensor. Whilst it is useful to understand these limitations the potential for AOS to provide good predictions of GDM under more normal production conditions remains. The performance on improved pasture during October demonstrates the potential accuracy of the sensor which compares favorably with other platforms being tested in more ideal pastures (Gourley and McGowen, 1991; Yule *et al.*, 2006). What is particularly encouraging is the ability of the AOS to provide a reasonable correlation with GDM in native pastures. Native pastures dominate Australian grazing production systems and more accurate biomass estimation techniques have been identified as a significant need by the industry.

Conclusion

This study has demonstrated the ability and limitations of an AOS to provide rapid pasture biomass estimates in both improved and native pastures. Whilst pastures containing large proportions of dead material compared to green material remain problematic, it is likely that AOS will provide robust estimates of the green fraction of the sward where the green fraction dominates. Further research is warranted to investigate the potential of this instrument to predict biomass across other pasture types and under different seasonal conditions. Additionally, it would be worthwhile investigating the potential of this instrument to predict the total nutritional characteristics of pasture swards.

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