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The relationship between a satellite derived vegetation index and wool fibre diameter profiles

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Abstract

Satellite data provide a systematic and reliable method for recording pasture availability. Pastures from Space (PfS) provides estimates of pasture growth on a weekly basis throughout Australia. The wool fibre diameter profile (FDP) changes in response to feed intake and offers a mechanism for recording the nutritional status of sheep. The aim of this project was to define the nature of the relationship between FDP and a normalized difference vegetation index (NDVI) from PfS. The FDPs and weekly NDVIs were scaled to the same time period for 62 FDPs from 26 flocks throughout Australia. FDP and NDVI were graphed together and relationships were categorised as strong (39), neutral (17) and poor (6). Cross correlation and regression of rate of change of FDP and NDVI curves provide further characterization of the relationship. Supplementary feeding and temperature were factors that may contribute to poor correlations. Where strong relationships exist between FDP and NDVI, they could be used to predict tenderness and average diameter of the wool clip in a region. The relationship could also be used to predict the impacts of climate change on wool production.

Keywords: sheep, FDP, NDVI, supplementary feeding, grazing environment, climate change

Introduction

Researchers have linked changes in the fibre diameter profile (FDP) with the nutritional environment of the animal (Jackson & Downes, 1979; Thompson & Hynd, 1998; Doyle *et al.*, 1999). The FDP reflects the nutritional status of the animal over the period that the wool was grown. The Normalised Difference Vegetation Index (NDVI) measures the amount of green biomass and is the basis of predictions of quantity of feed on offer and pasture growth rate made by Pastures from Space (Hill *et al.*, 2004).

Brown *et al.* (2002) used parameters such as rate of change from FDPs to explain differences in staple strength. They found differences in the FDP parameters between environments and sires. Reis (1992) reported that the length of the staple is stimulated by feed intake to a greater extent than the fibre diameter. Cottle (1987) found that the ratio between fibre length and fibre diameter^2 was constant. When nutrition is good the wool fibre grows rapidly in length and has a larger diameter.

Brown *et al.* (2002) used three points to derive two rates of change in fibre diameter (Roc1 and Roc2) that predict attributes of the FDP relating to staple strength. If a relationship between FDPs and pasture availability from satellite data can be established it has potential to define the nutritional environment of grazing animals to predict size and average diameter of the wool clip. The aim of this project was to define the nature of relationships between FDPs and NDVI.

Material and Methods

Sheep Cooperative Research Centre (Sheep CRC) Project 1.2.7 “Merino wool meat interface” involved a total of 31 flocks. The flocks were spread throughout Australia and provided a large variation of grazing environments. An average FDP was calculated for rams and ewes for each flock. The length of a wool fibre does not grow uniformly over time (Reis, 1992) and as a consequence, it is not possible to relate the diameter of the fibre (measured at 5mm intervals) at a particular point with a specific date. However, in this study it was assumed that the wool grew at a uniform rate from lambing to sampling.

Weekly NDVI data were provided by CSIRO, Pastures from Space (PfS) from Moderate Resolution Imaging Spectroradiometer (MODIS) data and calculated using the PfS methodology (Donald *et al.*, 2004). Eight 250m by 250m cells were selected for each location. NDVI data were scaled between 0 (lambing) and

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1 (sampling) to represent the wool growing season. An adjustment of 3.5 weeks was made to account for the delay between pasture being consumed and wool emerging from the sheep's skin (Schlink *et al.*, 1999).

Relationships were categorised as Poor, Neutral or Strong depending on how well the NDVI and FDP curves aligned and a tally of frequency in each group made. Examples of the categories are illustrated in Figure 1. Cross correlation was performed with a maximum offset of -7 to +7. An offset of +2, for example, would mean that a change in fibre diameter would lag behind NDVI by 2 time steps. Rates of change (Roc) 1 and 2 were measured on the FDP and NDVI charts using the method described by Brown *et al.*, (2002). The method of measuring Roc1 and Roc2 is illustrated in Figure 2. Regression analysis of Roc values was performed.

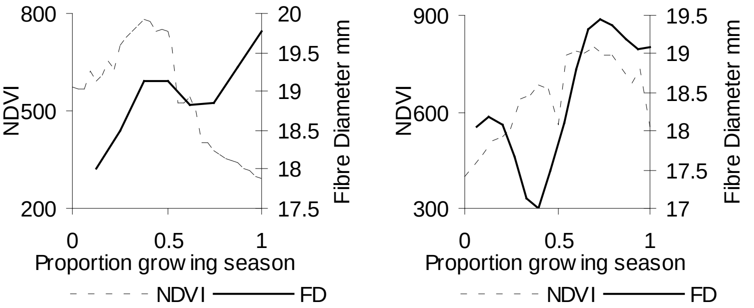

Figure 1: Examples of a Poor (left), Neutral (centre) and Strong (right) Correlations.

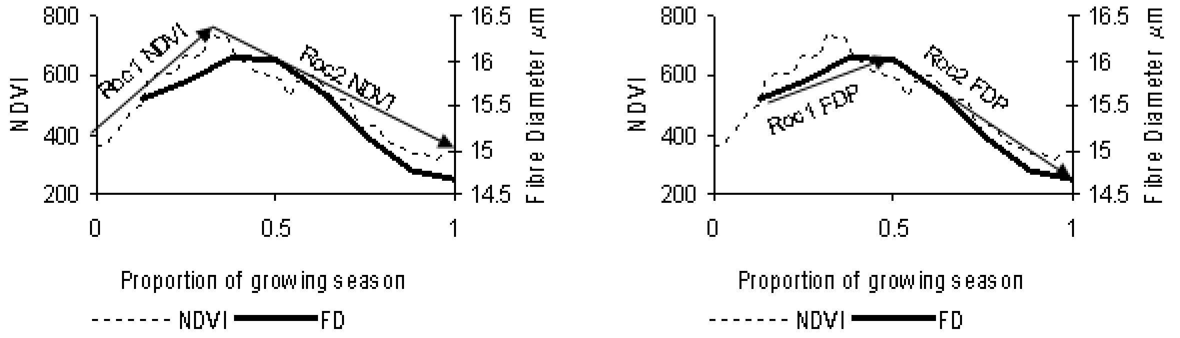

Figure 2: Roc1 and Roc2 NDVI measurement (left) and Roc1 and Roc2 FDP measurement (right).

Results

FDP-NDVI relationships were categorised as either Strong (39), Neutral (17) or Poor (6). The hypothesis that Strong, Neutral and Poor were equally distributed (i.e. a ratio of 1:1:1) was rejected using Chi square analysis ($P = 1.17 \times 10^{-6}$).

Cross correlation between NDVI and FDP was positive and significant ($P<0.05$) in the majority of cases (33). There was a trend ($P<0.10$) in 2 cases and correlations were not significant in 25 cases. The NDVI and FDP cross correlation was negative and significant ($P<0.05$) in two cases but both these flocks were supplementary fed.

Regression of rates of change values for NDVI and FPD was significant ($P= 1.99 \times 10^{-7}$). However the r^2 was low (0.26). When flocks known to be supplementary fed were omitted r^2 increased to 0.32.

It was not possible to quantify the impact of supplementary feeding on the NDVI and FDP relationship because feeding records were not available for all flocks. Many of the poor relationships could be a result of supplementary feeding as illustrated in Figure 3. The impact of feeding of Flock 11 is obvious with a sharp increase in fibre diameter as NDVI declines. In contrast, the FDP-NDVI relationship of Flock 18 (also supplementary fed) was one of the strongest recorded.

Figure 3: Relationship between NDVI and FDP of flocks where supplementary feeding occurred.

Discussion

The results show some strong relationships between NDVI and FDP. This finding is not unexpected given previous positive relationships between feeding and FDP (Schlink *et al.*, 1999; Brown *et al.*, 2002; Mata *et al.*, 2002). The relationship here was impacted, on some occasions, by supplementary feeding as other studies have shown (Reis, 1992; Masters *et al.*, 2002).

Matching NDVI with the FDP was problematic. It has been established that wool growth is rapid when nutrition is good and slow when nutrition is poor (Reis, 1992). Poor matching of NDVI and FDP was compensated in this study by cross correlation where a lag between nutritional level and fibre emergence could be introduced into the analysis. The rate of change calculation also reduced the problem of matching FDP and the NDVI because it simplified each curve into two parameters.

It was not possible to quantify the impact of supplementary feeding on the NDVI-FDP relationship but there is strong evidence it generally has an impact. However, there were some cases when the relationship was unaffected (Figure 3). More information regarding the feed used, the quantities fed and the length of feeding would be required to quantify the effects of supplementary feeding.

Pastures from Space can provide farmers with weekly estimates of NDVI and pasture growth anywhere in Australia (www.pasturesfromspace.csiro.au). Monitoring NDVI may give graziers the opportunity to regulate nutrition by providing supplements or reducing feed availability to avoid rapid changes in fibre diameter and minimise tender wool (Mata *et al.*, 2002). Farmers may be able to schedule shearing to coincide with seasonal decline in pasture availability to produce fine tipped fibres rather than weaknesses appearing in the centre of the staple.

Wool production forecasting is carried out four times a year by the Australian Wool Innovation Production Forecasting Committee. The committee forecasts the overall production and the micron profile of the clip (Australian Wool Innovation Production Forecasting Committee, 2006). The committee relies on information, such as broker returns, livestock slaughters and rainfall distribution, as well as expert opinion (James *et al.*, 2004). A more reliable forecasting system requires development of regional models that integrate flock dynamics and demographics with production. If NDVI patterns were available it may be possible to improve the accuracy of predictions of the average diameter of wool (Whelan *et al.*, 2007).

Being able to quantify the relationship between NDVI and FDP has the potential for the sheep industry to adapt to the changes brought about by climate change. Predictions of changes in pasture availability with changing rainfall patterns, can be translated to probabilities and risks of weakness in the staple in different environments. If seasonal variation becomes more pronounced weakness may start to appear in areas where, in the past, the risk was low. In addition, temperature is negatively related to digestibility (Buxton & Fales, 1994; Nelson & Moser, 1994; Henry *et al.*, 2000). Thus, increases in temperature may lead to reduced efficiency of conversion of feed to wool.

Analysis of these data is not complete. We are exploring how different grazing environments impact on the NDVI-FDP relationship and investigating how the relationship could be exploited to assist in quantifying the affect of genotype by environment interaction.

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