Comparison of NDVI seasonal trajectories and modelled crop growth dynamics

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Abstract

Wheat growth in south-eastern Australia shows a strong seasonal pattern associated with a variable 'break' of season, a dry and usually warm season finish, and poor buffering from limited soil water storage. Our main aim was to interpret seasonal growth trajectories using Normalised Differential Vegetation Index (NDVI) time series for the period April 1998-August 2007 in selected locations in South Australia. Secondary aims were to (a) assess the sensitivity of APSIM simulations (b) upscaling from point to landscape to provide insights into a range of issues including spatial water stress. The method applied to this analysis combined three independent approaches. These were (a) an examination of spatial crop class overlays to examine the spatial and temporal variability of classes in the case study region; (b) a comparison of spatial class information and APSIM modelled data; and (c) curve fitting approach to explain the peak and the amplitude. The combination of these three approaches allowed simulated growth variables from APSIM, including green cover, biomass, soil water uptake, leaf area index and yield to be compared with NDVI. Strong correlations between NDVI and simulated crop growth parameters allowed to attempt benchmarking APSIM sowing rule, as an example.

Key words

NDVI, crop growth simulation, APSIM

Introduction

The normalised difference vegetation index (NDVI) derived by dividing the difference between infrared and red reflectance measurements by their sum provides an effective measure of photosynthetically active biomass (Sarkar, 2004; Justice *et al*., 1985). Several studies discussed the suitability of temporal NDVI profiles for studying vegetation phenologies, especially those of crops (Rojas, 2007; Groten and Octare, 2002). Verlinden and Mesogo (1997) report significant positive correlations between satellite derived NDVI and observed greenness. In this study we analyse the relationship between satellite remote sensing derived NDVI and various crop variables simulated with APSIM. Strong correlations are observed between NDVI and Green Cover, LAI and Yield. Time trajectories of NDVI and Green Cover are further analysed to compare the 'onset of greenness' and season break for wheat in the study area.

The study area is located about 15kms from Loxton in the semi-arid South Australian Murray Darling Basin (Figure 1). The study area is about 4500 ha comprising a group of paddocks on Murray Mallee soils and the cropping is predominantly rainfed.

Method

NDVI indicates chlorophyll activity and is calculated from (band 3 - band 2) / (band 3 + band 2); the index is converted to a DN value in the 0-255 data range using: DN = (NDVI + 0.1) / 0.004. Once the image data in the required format was generated, the individual NDVI image files were 'stacked' together from April 1998-August 2007 on a monthly basis i.e. 113 images were combined into one image with 113 layers. The image data was subjected to an unsupervised classification with 5 classes since the group of paddocks were known to be under predominantly wheat cropping. The five class signature file was analysed and the assumption of a predominantly wheat cropping was confirmed with similar curve pattern. For ease of analysis and discussion class 3 (Figure 1) was chosen as a representative of the land cover of the paddocks.

The Agricultural Production Systems Simulator (APSIM) was set up for the study site. A continuous wheat (cultivar: Hartog) rotation was set up with a sowing rule of 15mm rainfall in the previous three days with a sowing window between April 1- July 30. Fertiliser application was 100 kg N/ha at sowing. The output variables for comparison with NDVI are LAI, Green Cover and Yield. We used correlation analysis to compare NDVI and APSIM outputs.

The LAI generated at two sowing rules is fitted with the equation:

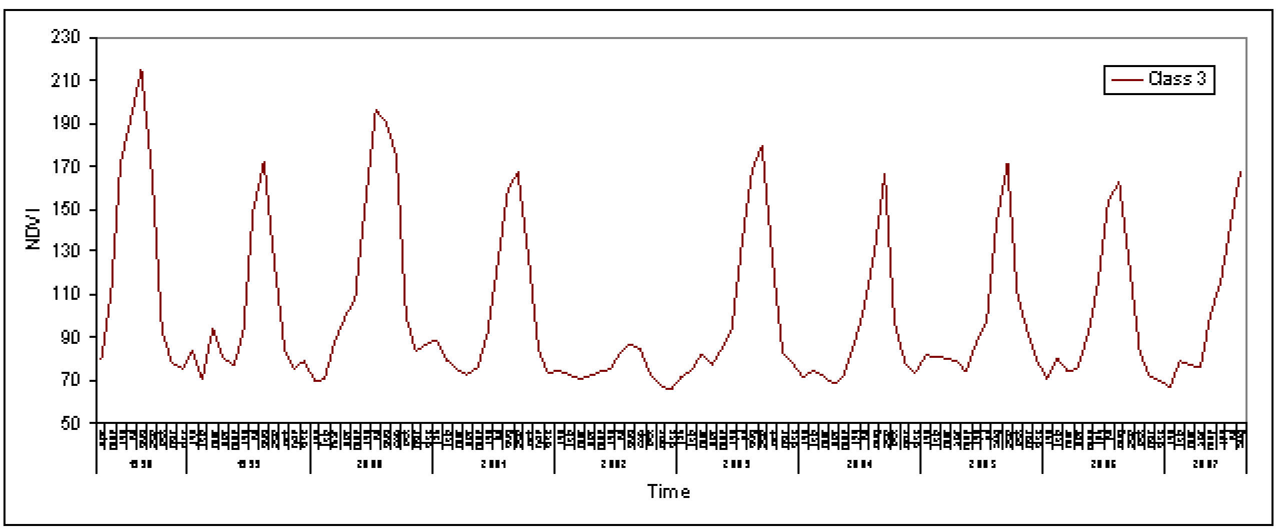
$$y = a \exp\left[\frac{1}{2}\left(\frac{x-b}{c}\right)^2\right]$$

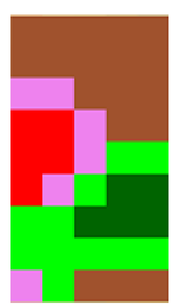
Where *a* is Amplitude
b is Centre
constraint *c*>0

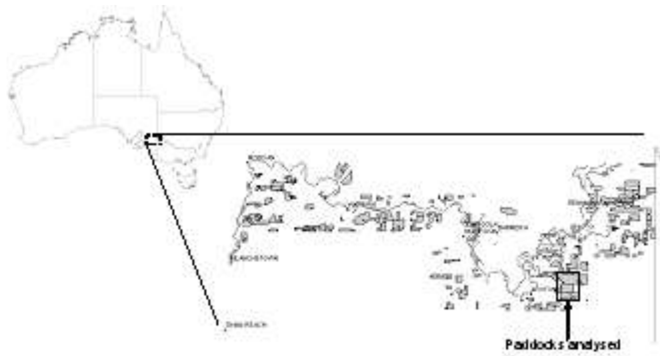
The sowing rules formulated in APSIM are (i) ‘sow IF accumulated rainfall in the last 3 days is 10mm’ (ii) ‘sow IF accumulated rainfall in the last 3 days is 15mm’.

Results

The curves for class 3 depicted in Figure 1 capture important aspects of seasonal crop growth. (a) NDVI peaks (peaks are not always in August) ranged from 87 to 215, indicative of seasonal growing conditions. For example, the curve captures the drought of 2002 and NDVI also captured the season break and end of season; for example the late season break of 2005 is distinctly captured.







Classified image of the study area.
Dark brown corresponds to class 3 (spatial representation of the curve above)

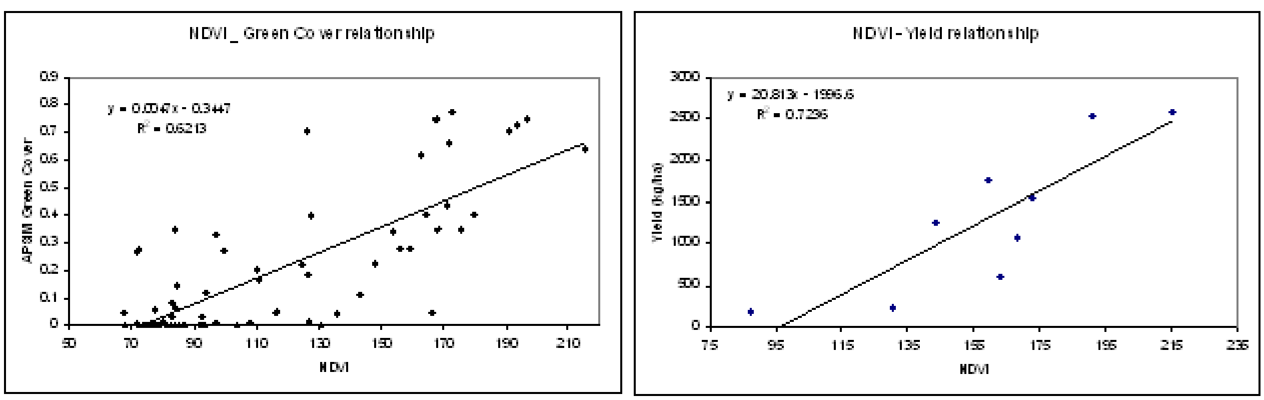
Study Area location

Figure 1: Classification of the cropped area: Temporal characterisation of class 3 from April 1998-August 2007

Comparison of NDVI and modelled crop growth

NDVI was closely correlated with modelled green cover and yield (Fig. 2)

Correlation (R^2) between NDVI and LAI at 15mm is 0.72 while for 10mm is 0.78. Also, the correspondence of centre *b* difference between NDVI and LAI at 10mm is 1 day and 3 days at 15mm. This illustrates how the combination of NDVI and modelling could help identifying agronomically relevant aspects of the farming system.



a: NDVI vs APSIM simulated Green Cover

b: NDVI in August vs APSIM yield

Figure 2: Correlations between NDVI, Green cover, LAI and Yield
Comparing the LAI based on sowing rule and NDVI

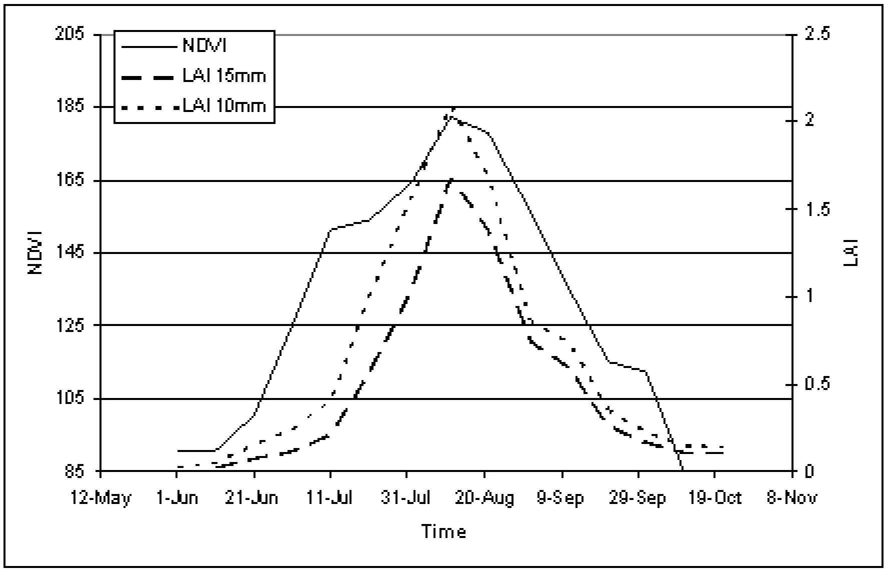


Figure 3: NDVI plotted along with APSIM generated LAI at 10mm and 15mm sowing rules.

Conclusion

Strong positive correlations between NDVI and APSIM simulated variables such as greenness, LAI and yields have been observed. The correlations can be used to extrapolate the point based APSIM simulations to paddock (or landscape level) using classified NDVI data as demonstrated in Figure 1. APSIM benchmarking (sowing rule, for example) can be attempted with this approach. Season length is an important aspect of planning and management and this approach combining point based models and area based NDVI can be a useful tool to characterise the season length in dryland agriculture.

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