Evaluating Physiological Traits of Winter Wheat Genotypes Using Remote Sensing Techniques.

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the world's most important cereals and staple food, and there is increasing demand for its production. Wheat production can be enhanced through the development of improved cultivars with wider genetic background, capable of producing better yield under various agro-climatic conditions and stresses. The process of monitoring plant stress, development and phenology contributes to better understanding the relationships between environmental conditions, and crop yields. In the US Southern Great Plains, drought stress is one of the most important factors for reducing yield in winter wheat. The selection of drought tolerant and high yielding wheat cultivars is a critical strategy for wheat management under water-limited conditions. Conventional methods can be time-consuming, labor-intensive and can cause large sampling errors. Remote sensing tools have provided easy and quick measurements of plant characteristics without destructive sampling. Remotely sensed data have been useful in monitoring physiological response to early growth conditions and plant adaptations to environmental changes and also differentiate genotypes for yield potential and water relations. However, little information is known for the genotypic differences in spectral parameters and their relationship, to warrant its use as an indirect selection tool. Therefore, the objective of this study is to evaluate the growth and performance of twenty wheat genotypes under two water regimes (rainfed and irrigated conditions), using GreenSeeker®, aerial imagery and digital photography at four growth stages from emergence to heading.

MATERIALS AND METHODS

- Location: Texas A&M AgriLife Research Experiment Station, Bushland, TX (Fig. 1).
- Experimental design: Randomized complete block design with three replications. .
- 2014-2015 growing season.

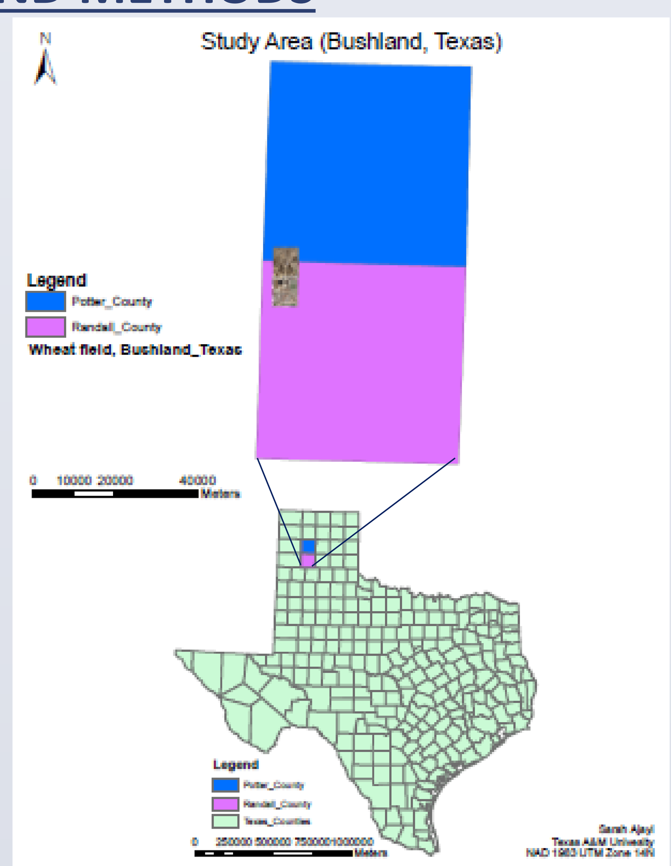


Figure 1. Study area.

Data Collection

- Aerial Imagery
- Manned aircraft (Fig. 2a) using the Tetra Mini MCA (Multiple Camera Array - Fig. 2b).
- With Spectral Range: 450 - 1000nm (nanometers); Spatial Resolution: 223 mm; Flight height: 5000 – 6500 feet Above Ground level; Scanning time: 1 frame/second; and each frame produced 12-band images.
- Growth stages: After-emergence, tillering, late-jointing and heading.
- Digital Photographs
- Digital camera was used to take plot pictures to observe ground cover (GC) using Photoshop.
- GreenSeeker ® sensor
- Instrument that recorded NDVI values; using 660 and 770nm.

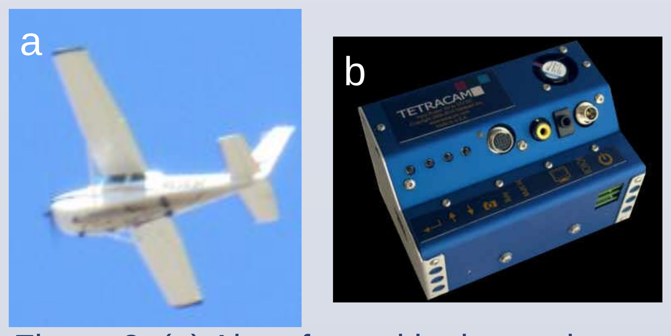


Figure 2. (a) Aircraft used in the study, and (b) the MCA camera used for collecting aerial images.

Image Analysis (Fig. 3)

- The raw aerial images were georeferenced to map projection – NAD 1983 UTM Zone 14N.
- Spectral Vegetation Indices calculated include: Normalized Difference Vegetation Indices (NDVI) and Perpendicular Vegetation Indices (PVI) used to estimate percent GC (Fig. 4a-c).
- $PVI = (NIR\_DC - RED\_DC(a_1) - a_0)/\sqrt{1+(-a_1)^2}$
- $GC = PVI_{plot}/PVI_{FC}$

Where a_0 = Intercept; a_1 =Slope; NIR = Near Infrared; DC = Digital count; and FC = Full canopy.

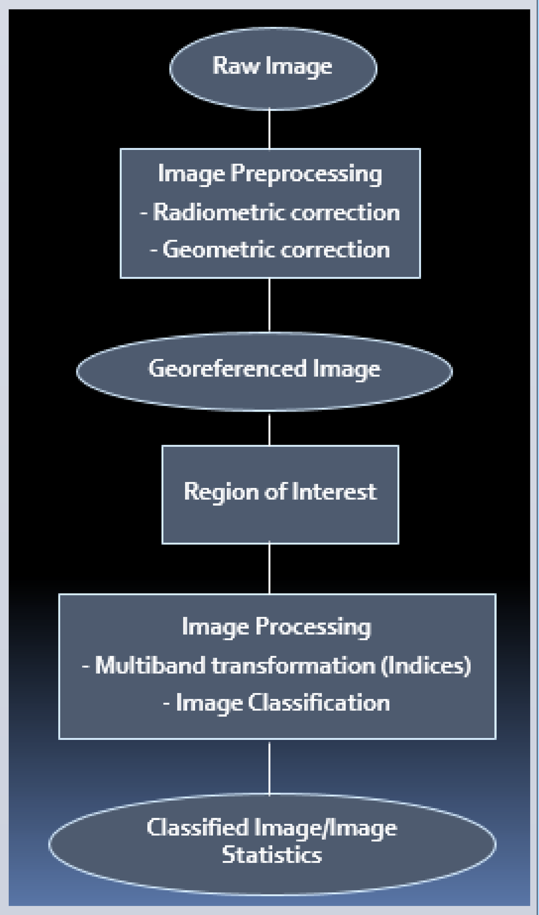


Figure 3. Flow chart of aerial image analysis.

- Regions of Interest for this study are 60 plots highlighted in Figures 5-7.
- Images were classified based on the indices to produce NDVI maps (not presented here), Scatter plots and GC maps.

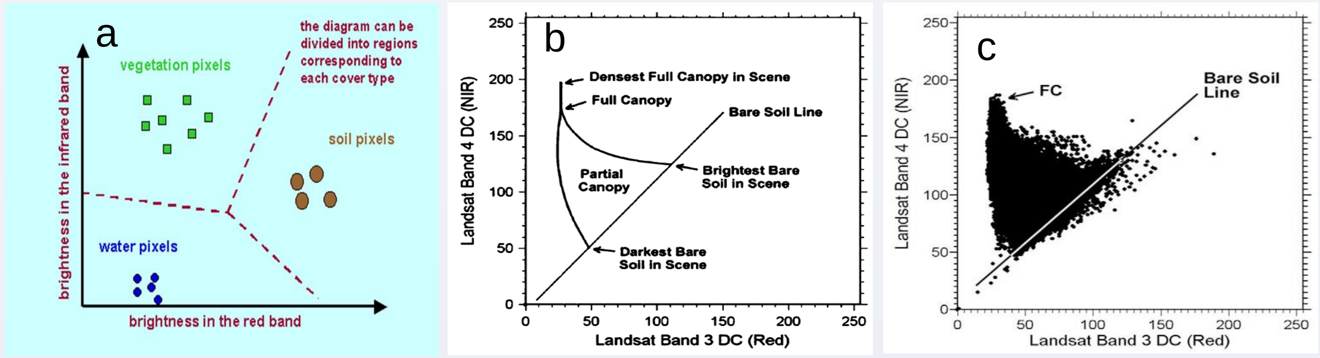


Figure 4. Diagrammatic representations of the features of a) the distribution of points in a NIR-Red scatterplot (Richard and Wise, 2001); b) Including the bare soil line and full canopy point; and c) Scatterplot of pixel DC values in the NIR and red spectral bands extracted from a Landsat-5 Thematic Mapper image (Rajan and Maas, 2009).

RESULTS

After-Emergence | **Tillering** | **Late-jointing** | **Heading**

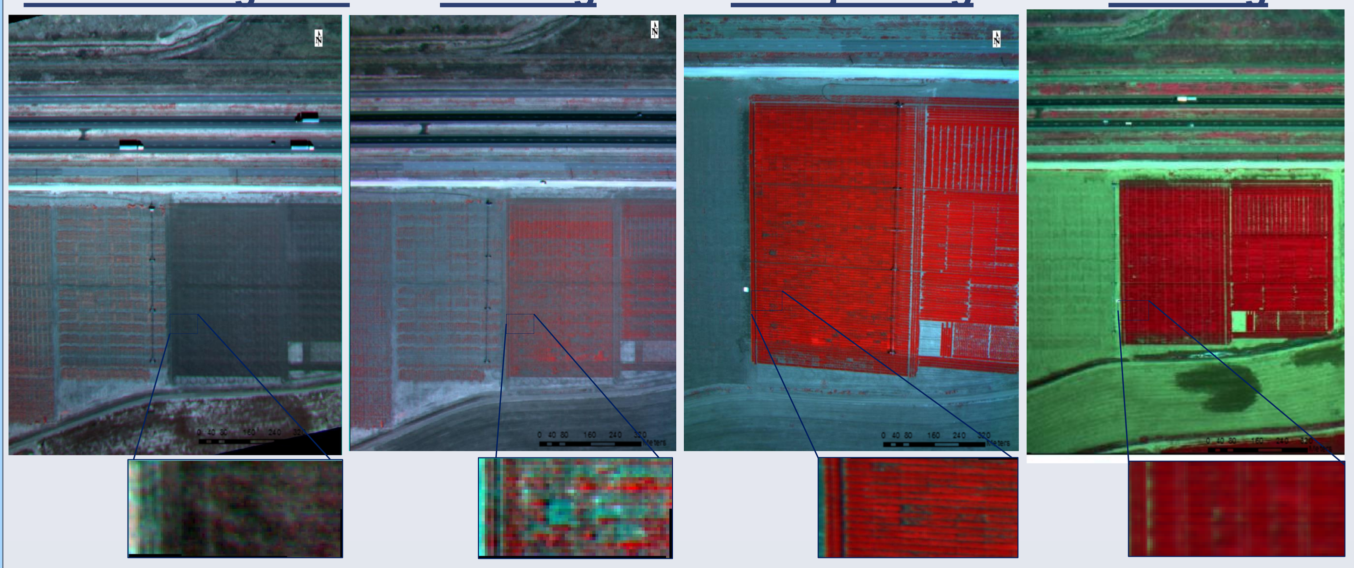


Figure 5a. Aerial Images of Irrigated fields in Bushland, TX; displayed in color infrared.

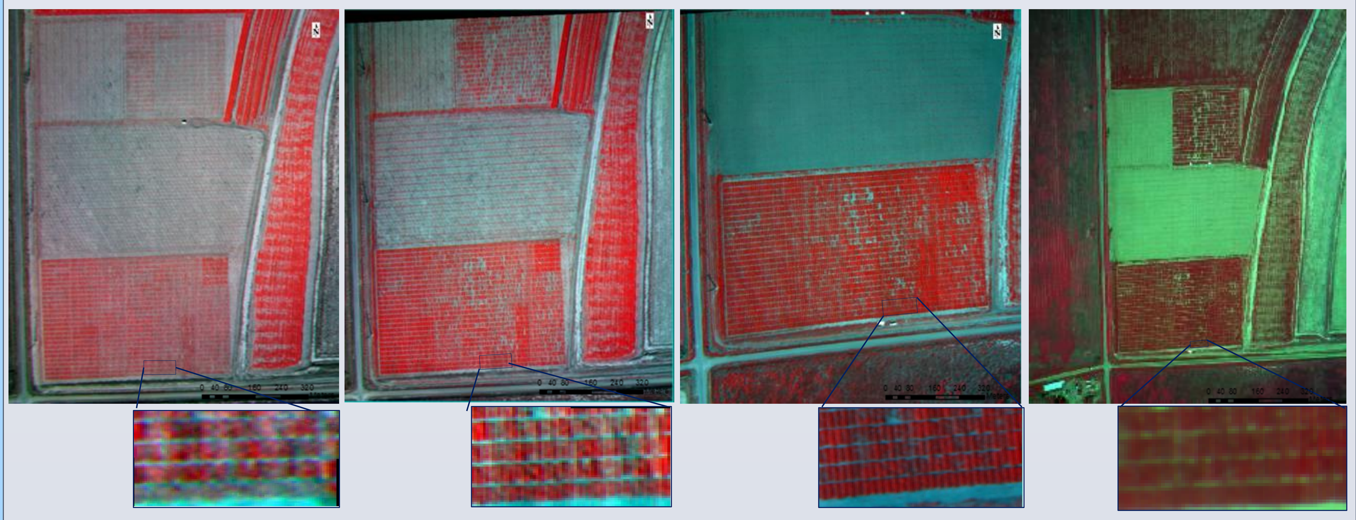


Figure 5b. Aerial Images of Rainfed fields in Bushland, TX; displayed in color infrared.

- PVI values were calculated using the scatterplots (Fig. 6) and then used to estimate %GC; dividing PVI for each plot (colored points in red circle) by PVI for full canopy, to produce the %GC maps (Fig. 7a-b)

After-Emergence | **Tillering** | **Late-jointing**

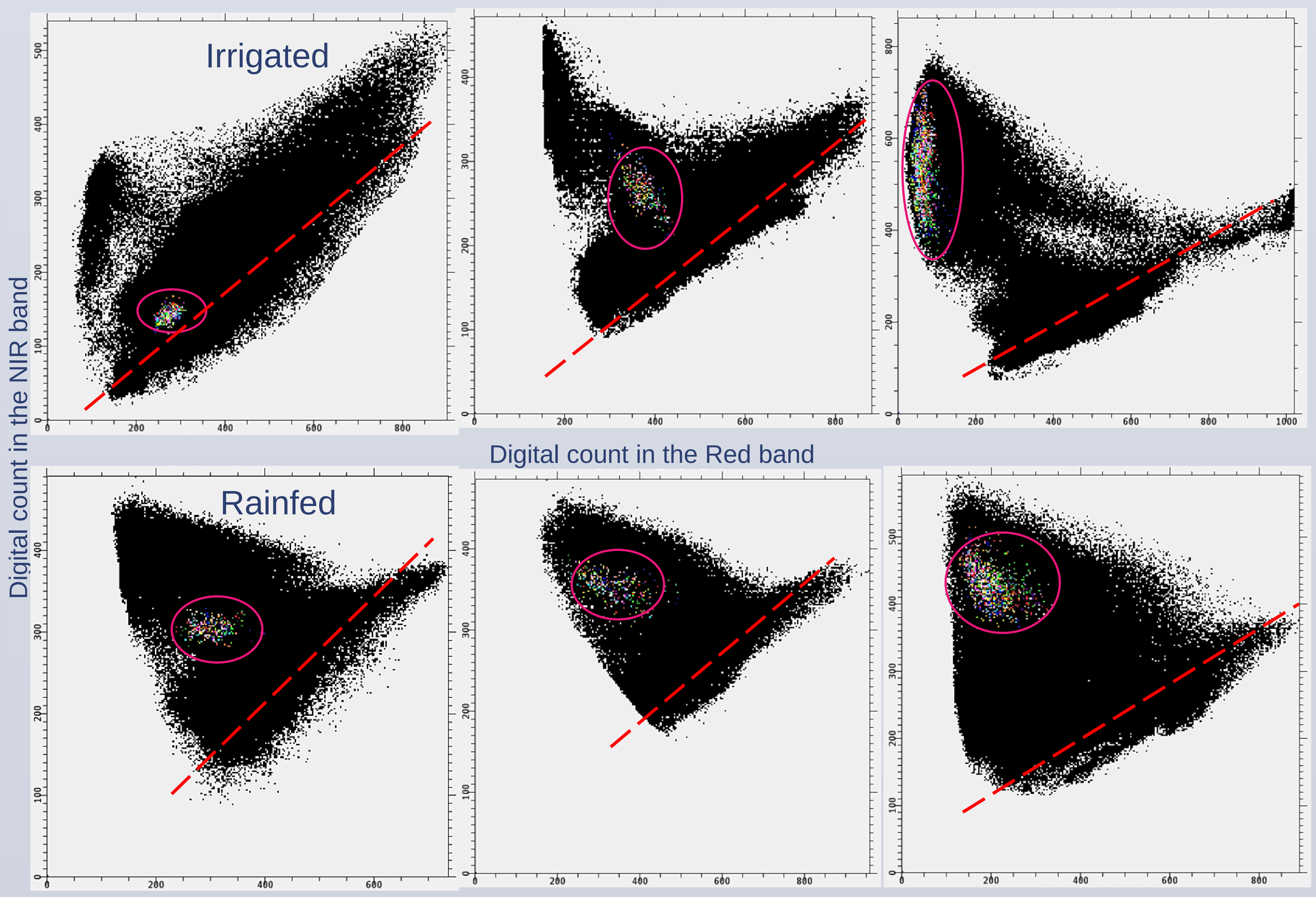


Figure 6. NIR-Red Scatter plots used to calculate PVI (Perpendicular Vegetation Index), showing the 60 plots for the 20 wheat genotypes in red circle and the bare soil in red dashed line under Irrigated and Rainfed fields in Bushland, TX.

After-Emergence | **Tillering** | **Late-jointing**

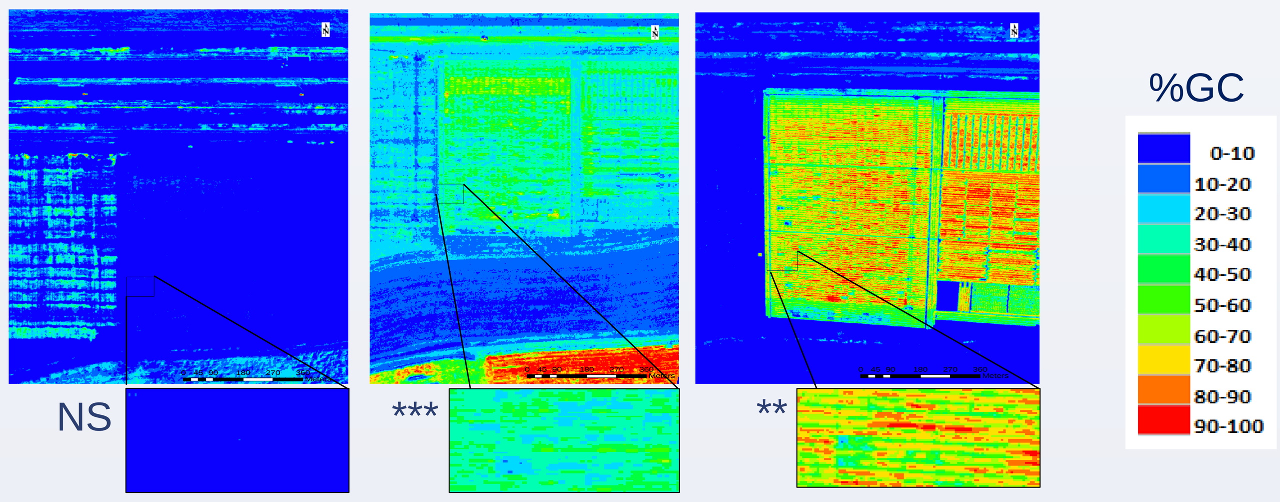
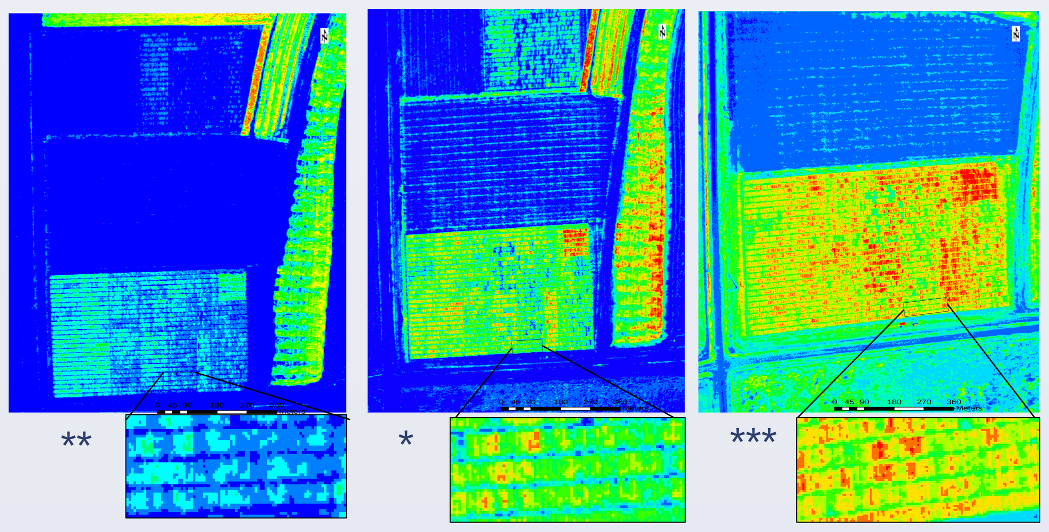


Figure 7a. Percent Ground cover (%GC) maps of Irrigated fields.



Blue colors indicate bare soil

Yellow/Red colors indicate the densest vegetation canopy

Figure 7b. Percent Ground cover (%GC) maps of Rainfed fields.

- Irrigated field showed highly significant relationships among all the VIs and %GC. However, poor relationships were recorded using the NDVI_A values with the other parameters under rainfed condition (Table 1).

Table 1. Relationship between the Percentage ground cover (%GC) estimated from digital photos (dp) and PVI, NDVI obtained from GreenSeeker (gs) and Aerial (A) images, under Irrigated and Rainfed fields at tillering stage.

Irrigated			Rainfed		
Variable 1 (X)	Variable 2 (Y)	R^2	Variable 1 (X)	Variable 2 (Y)	R^2
%GC_dp	NDVI_gs	0.88***	%GC_dp	NDVI_gs	0.49**
%GC_dp	%GC_PVI	0.79***	%GC_dp	%GC_PVI	0.66***
%GC_dp	NDVI_A	0.78***	%GC_dp	NDVI_A	0.01
NDVI_gs	NDVI_A	0.87***	NDVI_gs	NDVI_A	0.002
%GC_PVI	NDVI_gs	0.95***	%GC_PVI	NDVI_gs	0.46**

† NS: No significance; *, **, and *** significant at 0.05, 0.01, and <.0001, respectively

DISCUSSION

- Genotypic variations (NDVI, and %GC) were recorded among the genotypes due to their wide genetic background, especially at tillering and late-jointing stages mostly, but rarely at the after-emergence stage.
- Significant relationships R^2: 46%-95%) provide the possibility of using the estimated parameters (%GC_PVI, NDVI) as an indirect tool to screen large numbers of wheat genotypes.
- Some challenges included are:
  - Image resolution
  - Interval between dates of aerial and field data collected; more than +/-2 days.
  - Over or under estimation of % GC (using PVI, and digital photos) may be due to different sections of the plot captured for analysis, especially under Rainfed fields.
  - Lack of yield data due to hailstorm damage.

SUMMARY

- All the remote sensing tools utilized for this study present the potential use for high-throughput phenotyping to support wheat breeders in screening efficiently for drought-tolerant and high yielding genotypes from a large number of early-generation lines and advanced wheat genotypes.
- Future work will involve more consistent field data collection at specific growth stages; additional field data collection to relate with the VIs, such as leaf area index, canopy temperature (to estimate crop water stress index), and yield.

References

- Rajan, N., and Maas, S. J. 2009. Mapping crop ground cover using airborne multispectral digital imagery. Precision agriculture, 10(4), 304-318.
- Richard J. and Wise P. 2001. Looking Back to Earth. National Museum of Australia, Australia.