AN AIRBORNE IMAGING SYSTEM FOR MAPPING SPATIAL VARIABILITY IN SUGARCANE

By

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Abstract

IN ORDER to develop a low-cost and easy to implement technical solution to map inside-field spatial variability and to explore its relationship with nutrient and water conditions of the sugarcane crop, an experiment was conducted, based on the use of an ultra-light aircraft, equipped with visible, near infrared and thermal infrared cameras. Very high resolution images were acquired above an experimental field in which irrigation and nitrogen treatments were controlled and measured for three different sugarcane varieties. The Normalised Difference Vegetation Index (NDVI) and the surface temperature (Ts) of the experimental plots were calculated and used to interpret spatial variability in the field, in terms of growth responses to nitrogen and water treatments. The preliminary results indicate that the techniques used can produce qualitative maps showing areas of variable cane growth conditions as influenced by nutrient and water in sugarcane fields. A next step will involve combining canopy thermal and spectral properties to produce maps of the nutrient and water status of the crop, to enable the delineation of management zones inside the fields, and as a decision support tool to allow adjusting fertilisation and water applications to the actual needs of each management zone.

Introduction

The interest in applications of remote sensing to agriculture is growing throughout the world (Pinter *et al*., 2003). In Reunion Island, the sugarcane industry supports research on the use of such applications for crop monitoring.

Nitrogen or water status of the plants has an effect on the spectral and thermal response of the canopy. Nitrogen status affects the leaves' chlorophyll content (Penuelas and Filella, 1998) altering the canopy reflectance in the red band (chlorophyll absorption band). Water status affects the leaf transpiration resulting in changes in the leaf temperature – this mechanism is also valid when the canopy is considered as a whole (Idso and Baker, 1967). Any stress occurring over long periods of time affects the crop development (vegetation cover, LAI) and can be observed in the red, near-infrared (Ripple and Schrumpf, 1987; Penuelas *et al*., 1993) and thermal bands.

For crop monitoring, spectral measurements are generally made to develop indicators: the NDVI (Normalised Difference Vegetation Index), as an indicator of the photosynthetic activity of the vegetation, and the surface temperature as an indicator of the water stress (Jackson *et al.* 1977; Idso *et al*., 1978; Jackson *et al*., 1981; Moran *et al*., 1994).

Following a research project (Ribbes *et al.* 2002) whereby SPOT images were used to develop precision agriculture products at a regional scale over sugarcane areas, this study was undertaken to focus attention on mapping spatial variability at a field scale, by making use of more accurate high resolution images acquired with an ultra-light aircraft. The main aim was to provide a field-scale diagnosis method that would enable detection of stresses resulting from water and nutrient deficiencies which limit plant productivity and crop yield.

This poster presents the airborne imaging system, and the spectral and thermal images acquired with this system over an experimental sugarcane field with different water and nutrient treatments.

Materials and methods

Study site description and field measurements

The investigation was conducted in April 2006 on a 7.3 ha sugarcane experimental field located in La Mare, Sainte Marie, in the northern part of the Reunion Island. This field was separated in three randomised blocks cultivated with three varieties of sugarcane (R570, R575, R579) under three different nitrogen inputs (Kg/N – 0/N, 65/N, 130/N) and two water treatments (irrigated and rainfed) (Figure 1). For each combination of treatments (variety, nitrogen, irrigation), the size of the plot in the blocks was 135 m² and was made up of 5 rows each of 18 m length with a 1.5 m inter-row distance.

The sugarcane field was in the 3rd ratoon and in the 9th month of growth at the time of data acquisitions. Fertiliser was added in one single application two months after the previous harvest.

The mean annual precipitation in the study area is 1514 mm/year. It is important to note that 50 mm of rainfall occurred two days before the remotely sensed data were acquired.

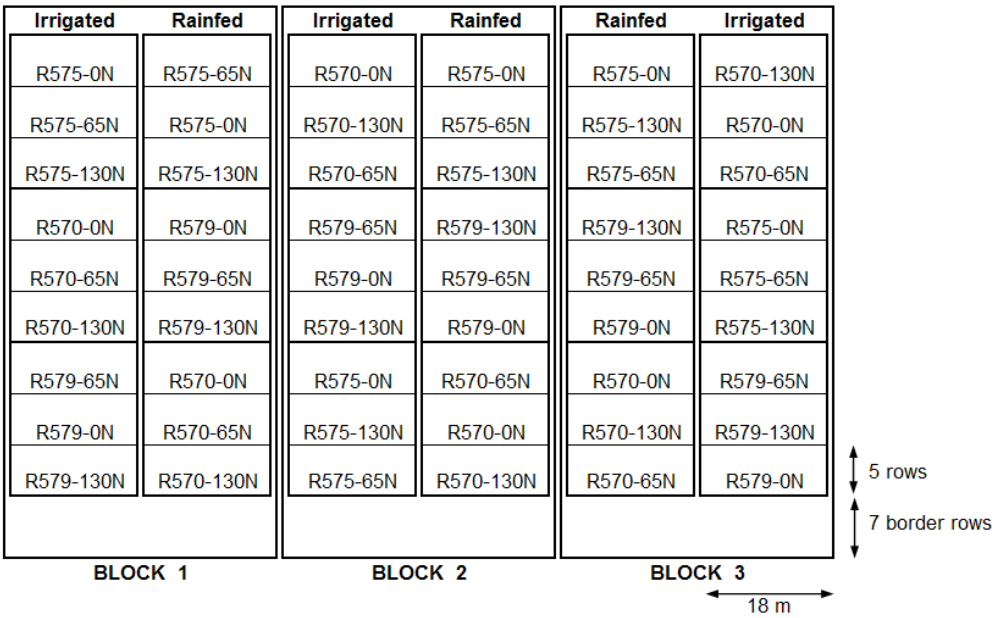

Fig. 1—Layout of the experimental field.

Data acquisition

The data acquisition system consisted of an ultra-light aircraft equipped with sensors that captured and measured the sunlight reflected in four different spectral bands and the radiation emitted by the Earth surface.

To capture the radiometric signal in the visible bands (blue, green and red), a CANON 350D commercial camera was used. A similar type of camera was adapted and equipped with a 710-855 nm band pass filter to measure the radiation in the near infrared spectral band. The radiation emitted by the canopy was also measured by using a thermal infrared (TIR) camera (NEC TH 7800) and was transformed into surface temperature (Ts) (emissivity ε = 1). This temperature corresponds to a canopy temperature (Tc) when vegetation dominates the field of view minimising the effect of soil (Norman *et al*., 1995).

On 19th April 2006 at 11:25 a.m solar time, a first set of images was acquired in vertical mode over the experimental field, at an altitude of 500 m. The ground resolution of images was 8 cm for those taken in the visible and near infrared bands and 55 cm for those acquired in the thermal band.

Image processing and relevant calculations

The first step in image processing was to conduct a geometric correction to the images by referencing them to an existing referenced image, ground control points, and GPS data on the boundaries of the field. An NDVI image was then generated using the following equation according to Rouse *et al*. (1973):

$$NDVI = \frac{(NIR - R)}{(NIR + R)}$$

where R and PIR are the reflectances recorded by the sensors in the red and near infrared spectral bands respectively. In our case, the index is calculated using the digital numbers recorded by the cameras in these two spectral bands.

The mean NDVI and Ts for each plot were then calculated after subtracting one metre buffer from the original edge of the plot polygon to eliminate mixed border pixels.

Results and discussion

Figures 2 and 3 show the images of the NDVI and surface temperature (Ts) variability of the sugarcane crop in the experimental field, respectively, with respect to the location of the different nitrogen and water treatments. The NDVI values over the sugarcane plots ranged from 0.4 to 0.63, and for Ts from 28.1 to 33.2°C.

In general, the spatial patterns of the NDVI correspond to those of Ts. Ts values were on average higher for rainfed plots, and decreased with increasing nitrogen inputs. The opposite effect is observed for the NDVI, and reflects a negative correlation between Ts and NDVI ($r = -0.84$), as observed by Moran *et al*. (1994).

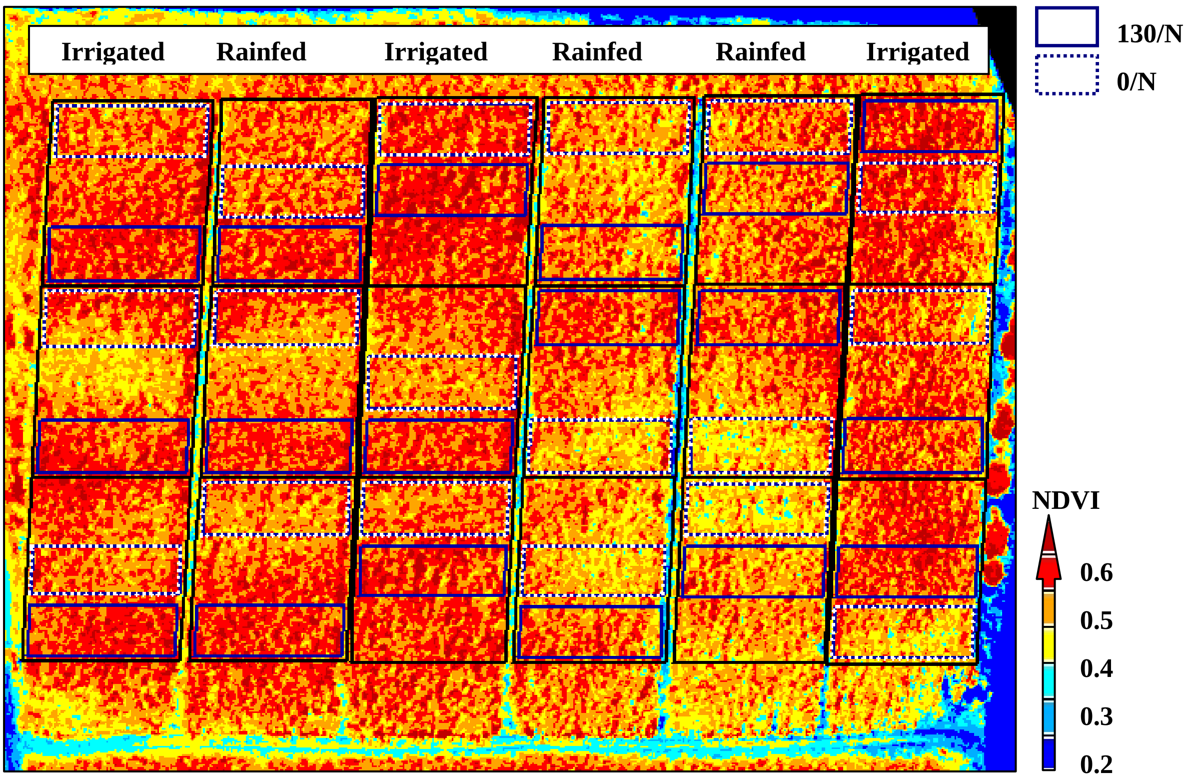

Fig. 2—NDVI of the experimental field from measurements at 11:25 am solar time on 19th April 2006.

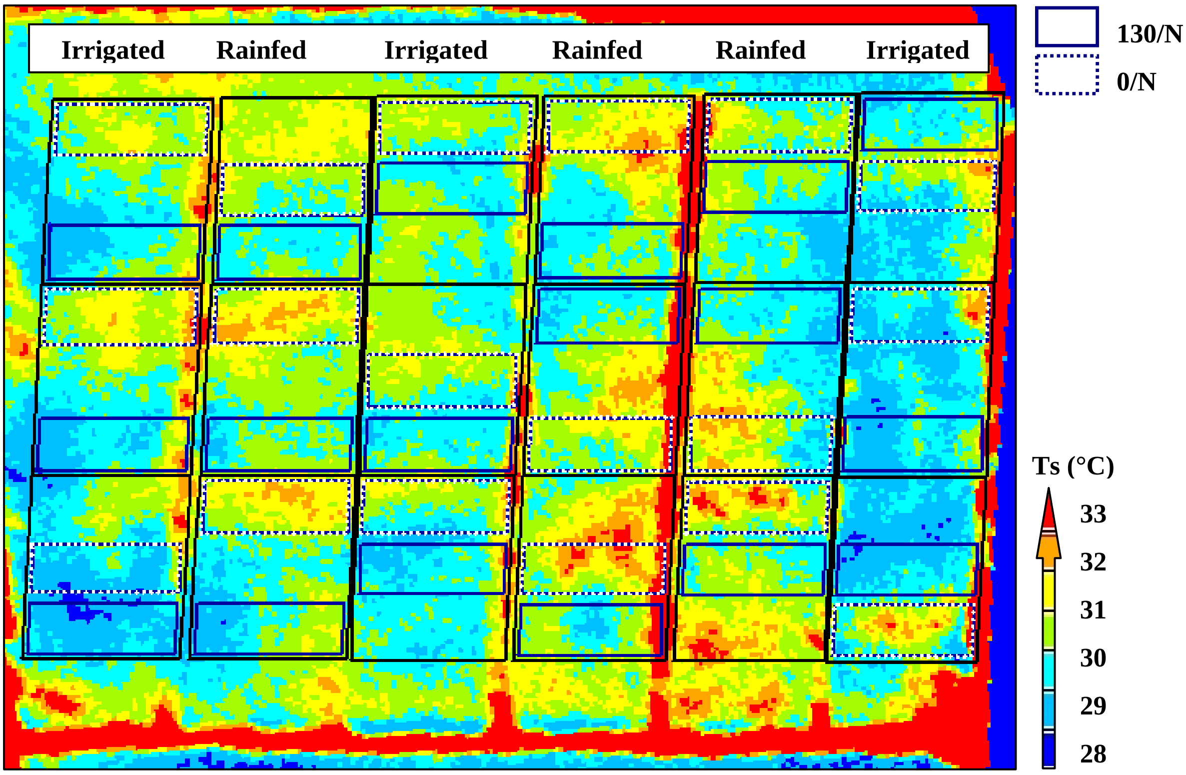

Fig. 3—Surface temperature (Ts) of the experimental field from measurements at 11:25 am solar time on 19th April 2006.

The image interpretation of the different spatial patterns is validated by the quantitative results presented in Figure 4. Both water and nutrient treatments have an effect on Ts and NDVI. The decrease of NDVI due to reduced nitrogen has similar amplitude for both water treatments.

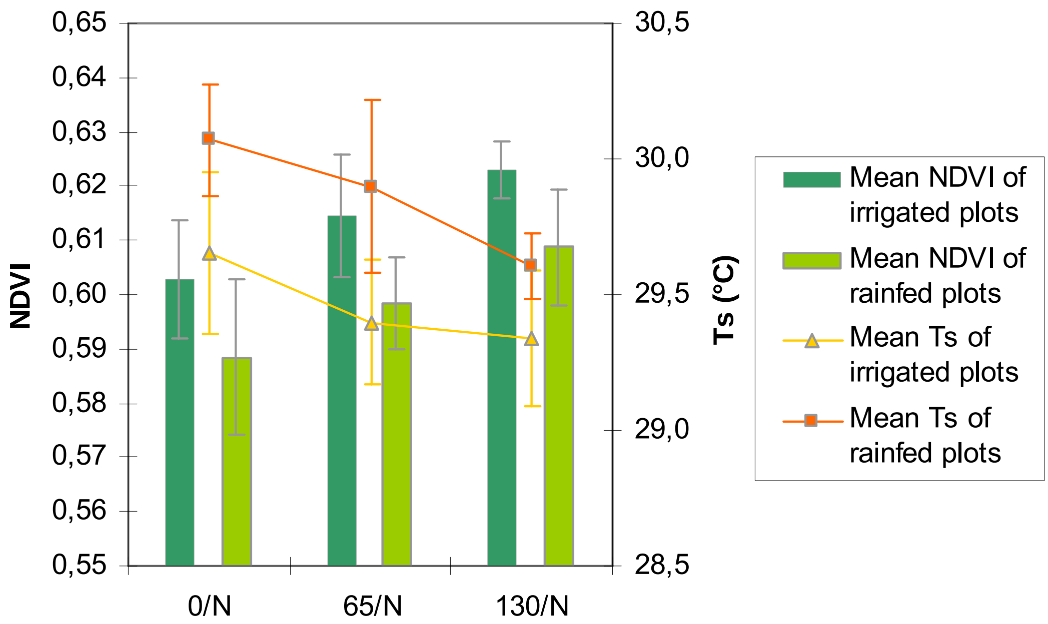

Fig. 4—Mean NDVI and surface temperature (Ts) for all varieties and N treatments. Error bars indicate ± 1 standard deviation of the mean (n = 9).

High Ts values correspond to low NDVI parts of the experimental field, a situation which reveals the soil effect in the measurements of the surface temperature.

Though the NDVI appears to be well correlated with nitrogen inputs, additional Ts measurements are necessary to distinguish the application effect of water from that of nitrogen.

In the TIR (thermal infrared) domain, long-term effects are here observed. The TIR data did not discriminate the variations of water status of the sugarcane crop at the time of data acquisition because of the heavy rainfall which occurred two days earlier. The TIR radiation recorded would be mainly influenced by the density of the canopy cover.

Conclusion and further developments

The preliminary results of the study have enabled the production of maps of spatial variability as influenced by nutrient and water growth conditions of the sugarcane crop. Such maps would serve as a valuable decision support tool in solving management issues and in forward planning of farming operations.

The different steps followed afford a quantitative approach to characterise and possibly correct water or nutrient conditions before they actually affect the plant development. The techniques are promising because of their simplicity and low cost implication. Compared to satellite or airborne acquisitions, this tool is tailor-made for real-time observations at field or farm scale to help in management decisions.

In future investigations, we will focus on the concept of Vegetation Index/Temperature (VIT) (Moran *et al*., 1994) that allows the application of the Crop Water Stress Index (CWSI) (Jackson *et al*., 1981) for partially covered canopies.

In 2007, additional experiments are planned in Reunion Island, and will include the use of a drone aircraft.

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UN SYSTÈME D'ACQUISITION AÉROPORTÉ POUR CARTOGRAPHIER LA VARIABILITÉ SPATIALE DANS LES CULTURES DE CANNE À SUCRE

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MOTS-CLÉS: Canne à Sucre, NDVI, Température de Surface, Eau, Nutriments.

Résumé

CE POSTER présente une expérience basée sur l'utilisation d'un ULM équipé d'appareils photos mesurant le signal réfléchi par la canne à sucre dans le visible et le proche infrarouge, ainsi que d'une caméra thermique mesurant le rayonnement émis par la culture dans l'infrarouge thermique. L'objectif est de développer une solution technique peu coûteuse et facile à mettre en œuvre pour cartographier la variabilité spatiale intra-parcellaire en lien avec l'état nutritionnel et hydrique de la canne à sucre. Des images à très haute résolution ont été acquises au-dessus d'une parcelle expérimentale dans laquelle les traitements relatifs à l'irrigation et l'état azoté étaient contrôlés et mesurés sur trois différentes variétés de canne à sucre. Le NDVI (Normalised Difference Vegetation Index) et la température de surface (Ts) des placettes expérimentales ont été calculés et utilisés pour interpréter la variabilité spatiale de la croissance de la canne dans le champ face aux traitements hydriques et azotés appliqués. Les résultats préliminaires indiquent que les techniques utilisées peuvent permettre la production de cartes qualitatives présentant des zones de condition de croissance variables influencées par l'alimentation en eau ou les apports azotés dans les champs de canne à sucre. Une prochaine étape prévoit de combiner les propriétés thermiques et spectrales de la canopée pour produire des cartes du statut hydrique et nutritif de la culture afin de permettre la délimitation de zones de gestion à l'intérieur des champs. Cette technique pourrait ainsi être utilisée comme un outil d'aide à la décision permettant d'ajuster les apports hydriques et nutritionnels aux besoins réels de chaque zone de gestion.

SISTEMA DE IMÁGENES AÉREAS PARA MAPIFICAR LA VARIBILIDAD ESPACIAL EN CAÑA DE AZÚCAR

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PALABRAS CLAVE: Caña de Azúcar, NVDI, Temperatura Superficial, Agua Nutrientes.

Resumen

CON EL PROPÓSITO de desarrollar una solución técnica de fácil implementación y bajo costo para mapificar la variabilidad espacial dentro del campo y para explorar su relación con las condiciones de nutrición y agua del cultivo de la caña de azúcar, se realizó un experimento basado en el empleo de un avión ultraligero, equipado con cámaras de espectro visible, infrarrojo cercano y detección térmica infrarroja. Se obtuvieron imágenes de muy alta resolución sobre un campo experimental en el que se controlaron y midieron la irrigación y el tratamiento con nitrógeno para tres diferentes variedades de caña de azúcar. Se calcularon el Indice de la Diferencia Normalizada de Vegetación (NDVI, en inglés) y la temperatura superficial de los lotes experimentales, los que se usaron para interpretar la variabilidad espacial en el campo, en términos de respuesta a los tratamientos con nitrógeno y agua. Los resultados experimentales indicaron que la técnica empleada puede producir mapas cuantitativos que muestran áreas de condiciones de crecimiento cañero variable como influidas por nutrientes y humedad en campos cañeros. El siguiente paso incluirá la combinación de las propiedades de cubierta termal y las espectrales para obtener mapas de la situación de nutrición y humedad del cultivo, con el fin de zonas de gerencia dentro de los campos y como una herramienta de respaldo a las decisiones para el ajuste de las aplicaciones de nitrógeno y agua en correspondencia con las reales necesidades de cada zona de administración ó gerencia.