SPECTRAL REFLECTANCE OF ALFALFA GROWN UNDER DIFFERENT WATER TABLE DEPTHS

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Commission VII, WG VII/2

KEY WORDS: Multispectral, Detection, Agriculture, Monitoring, Reflectance

ABSTRACT

The main objective of this study is to determine the growth response and water use effeciency of alfalfa (*Medicago sativa* L.) grown in the field under four water table levels and two rates of water supply under the climatic condition of Al-Hassa oasis in Saudi Arabia. The potential use and management of water table depth, to function as sub-irrigation system without increasing the accumulation of salts in the root zone is a valuable agricultural resource in arid regions. Therefore, the water table should be maintained at optimum depth to save both water and energy.

Plant water stress can limit productivity and has an effect on plant physiology and canopy architecture. Changes in water status of a canopy can have indirect effects on remotely sensed optical reflectance and thermal emittance, which can be measured in the field and related to crop conditions.

Biophysical and spectral measurements were taken in the field of alfalfa grown inside concrete lysimeters .Thses include biophysical variables, such as:leaf area index, dry matter content, soil moisture content, and monitoring of water table depth.

Moreover, measurements of reflected radiation from the alfalfa canopy in the field by a high resolution spectroradiometer were taken at full cover during the growing season.

Results from this study showed that alfalfa grown at water table depth between 100-150 cm was better than that grown at shallow (50 cm) or very deep water table (deeper than 150 cm). Spectral response of alfalfa was positive and showed that remotely sensed data could be used to detect water stress of alfalfa grown under the climatic and environmental condition of Al-Hassa.

This study may provide information and knwledge that can lead to better management of rrigation water and help farmers to conserve water by applying only the right amount of irrigation water. In addition, transferability of results among other agricultual crops in different areas. Moreover, detection of crop water stress in early stage by application of remote sensing technique. This study also might help in design of proper drainge depth suitable for forage crops with respect to soil and climatic conditiond.

1. INTRODUCTION

Alfalfa (*Medicago sativa* L.) has a very high yield potential compared with that of other forage crops. It also is an integral component of many crop rotations because of its ability to fix nitrogen, improve soil structure and tilth, and control weeds in subsequent crops. In Saudi Arabia, alfalfa is considered of highly economic value, it accounts for about 30% of crop production. It was studied extensively in the past regarding culture, growth, tolerance, yield, irrigation, etc. However, the research in drainage requirements of alfalfa in the region is very limited. Recently, alfalfa is now cultivated in large areas and large scale agricultural projects, so is very important the crop is monitored regularly to study the influencing factors of its growth and productivity by remote sensing technology.

Alfalfa is very responsive to water stress. The reduction in yield could reach up to 41%, when ET was reduced to 56% of the maximum (Asseed *et al*., 1981) The consumptive use of alfalfa was determined by Asseed *et al*. (1981) as 28800 m^3/ha/year for non-stress condition under Al-Hassa climate.

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The potential of using drainage systems, i.e. the management of water table depth, to function as sub-irrigation system without increasing the accumulation of salts in the root zone and is a valuable agricultural resource in arid regions (Benz *et al.,* 1984).

Plant water stress can limit productivity in both natural and agronomic plant communities. Short term as well as long term water stress has the same effects on plant physiology and canopy architecture. Changes in water status of a canopy can have indirect effects on remotely sensed optical reflectance and thermal emittance.

Surface temperature (T_S) is a major component in the energy balance equation. Several models have been developed to evaluate crop water use, water stress, crop yield and soil moisture (Reginato *et al.,* 1976; Idso *et al.,* 1981; Price, 1982; Reginato *et al.,* 1985; Jackson *et al.,* 1987).

Several authors have investigated the combination of the thermal band 6 of Landsat TM with the reflective bands in the Red and NIR, band 3 and band 4, respectively. The relationship between NDVI and T_S is linear with negative slope (Gurney *et al.,* 1983; Hope, 1986; Moran *et al.,* 1990). This relationship could be diagnostic of plant water stress, particularly, at large NDVI values. For a given meteorological condition, the surface of bare soil would tend to have a stable maximum surface temperature once soil moisture is depleted. Accordingly, spatial variability in plant available moisture (in the root zone) would not be reflected in the T_S of pixels dominated by bare soil (at small NDVI values). Moreover, an increase in vegetation moisture stress will cause the T_S of pixels with large NDVI values to increase. For partially irrigated fields and homogeneous crop cover, the NDVI would be relatively unaffected by soil moisture difference, whereas T_S values would be low over the irrigated portion and high over the dry portion (Moran *et al.*, 1990). Moreover, this was explained in terms of the increase in the latent heat flux (LE) associated with greater amount of transpirationally active vegetation (Hope and McDowell, 1992). Table 1 list and define these vegetation indices.

In recent studies, the soil adjusted vegetation index (SAVI) has been used in the combination of spectral and thermal bands (Choudhury, 1994 and Moran *et al.,* 1994). The SAVI has the advantage of being more sensitive to the increase in vegetation cover and less sensitive to spectral changes in the soil background than the NDVI (Huete, 1988). Moran *et al.* (1994) proposed the concept of the vegetation index/temperature trapezoid (VIT) in an attempt to combine spectral vegetation index with composite surface temperature. Since spectral vegetation indices are non-linearly related to vegetation cover (Vc) then Vc is substituted in the Y-axis in the trapezoidal relationship between Vc and the temperature difference
(T_S - T_a).

Recent research has examined technologies involving remote sensing to quantify water stress. Moran et al. (1989) investigated the effect of water stress on canopy architecture in alfalfa (*Medicago sativa* L.) and the sequential effect on canopy reflectance. They found water-stressed canopies to have a lower spectral reflectance in the NIR and red wavebands when compared with unstressed canopies. A ratio of the two wavebands was most successful in estimating the onset of stress. Moran et al. (1994) investigated the concept of a water deficit index, which is defined as the ratio of actual to potential ET. This index exhibits the ability to predict ET rate and relative field water deficit for both full-cover and partially-vegetated sites. The measurement can be calculated from remotely sensed data (red and NIR) gathered with ground, aircraft, or satellite-based sensors. On-site measurements used in the calculation include net radiation, air vapor pressure deficit, air temperature, and wind speed.

The results of Shakir and Girmay-Gwahid (1998) showed that in the wave length range of 850 - 1150 nm the stressed plots showed lower reflectance than unstressed plots. However the reflectance of stressed plots was higher above the 1150 nm.

This study aims to studiy the effect of varying water table depth alfafa spectral reflectance. And to examine if water stress is likely to occure due to the variations of watertable levels.

1.1 *2. MATERIALS AND METHODS*

Spectral measurements were the measurements of reflected radiation from the alfalfa canopy, which was grown inside lysimeters, in the field by a high resolution spectroradiometer, ASD FieldSpec. The wavebands taken ranged from 400 – 2500 nm at a bi-weekly collection of reflected radiation along the growing season.Other biophysical measurements taken include leaf area index, dry matter content, chlorophyll content, , and soil moisture content

The lysimeters drain freely to the atmosphere through pipes located at the bottom of the soil mass, ended with control valves. Riser tubes was connected to the outlet pipes after the valves. The length of the risers will correspond to each water table depth.

The experiment was conducted under field condition at the Agriculture and Veterinary Training and Research Station, King Faisal University, Al-Ahsa to determine water stress of alfalfa under different levels of water tables.

A split plot design in four replicates will be used. Four water table depths: 150, 100, 50, 0 cm will be occupied the whole plot.. The soil textural class is a fine sandy loam. The experimental plot was a concrete-made lysimeters (1.30 m diameter and 2.2 m deep). The local cultivar “Hassawi” will be planted at seeding rate 60 kg/ha. The seed will be inoculated with appropriate commercial rhizobial inoculant. In each experimental plot a dosage rate of 450Kg P_2O_5/ha was given in a split application after each cut.

Normalized Difference Vegetation Index (NDVI) was computed as:

(NIR - R)/(NIR + R) where R = Red, NIR = Near Infrared wavebands in electromagnetic spectrum. Soil Adjusted Vegetation Index (SAVI) computed as: [(NIR - R)/(NIR + R+0.5)]1.5.

3. RESULTS

Figure 1,2,3, and 4 show spectral reflectance of alfalfa ranged 400-2500 nm for all treatments. As can be seen from these figures that the spectral reflectance ratio of alfalfa has been affected by the level of water table. The highst ratio was experienced for 150cm and 100cm and the lowest for 50cm and zero cm. The canopy reflectance of the non-stressed alfalfa may be mainly dependent on illumination geometry and canopy structure; hence the leaf optical properties were believed to remain unchanged.

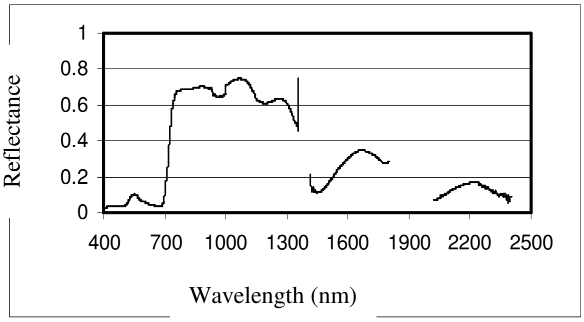

Figure 1. Spectral reflectance of alfalfa under 150 cm water table

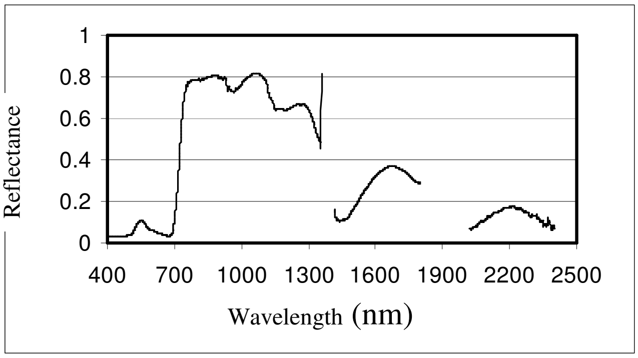

Figure 2. Spectral reflectance of alfalfa under 100 cm water table

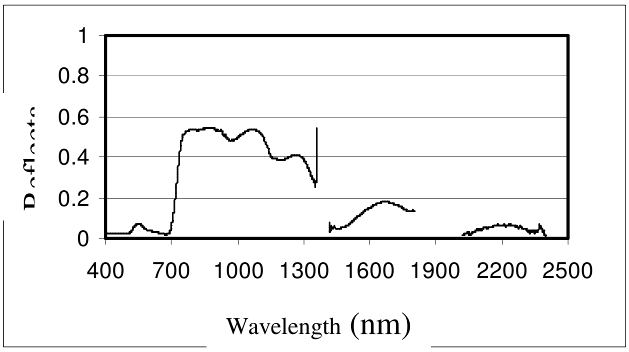

Figure 4. Spectral reflectance of alfalfa under 50 cm water table

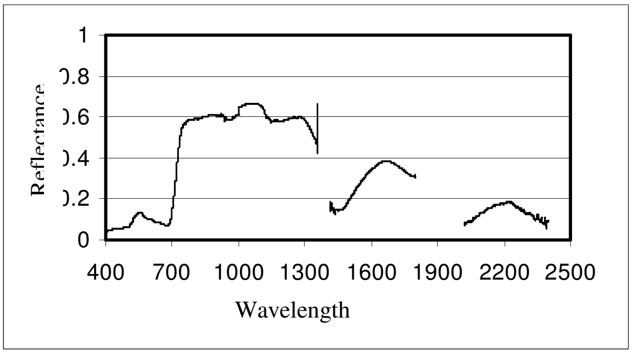

Figure 3. Spectral reflectance of alfalfa under 100 cm water table

Moreover, NDVI and SAVI was computed for all the treatments (figure 5) was shown that SAVI has the ability to demonstrate alfalfa response to vartiation in water table level.

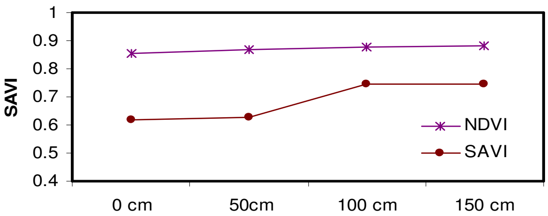

Figure 5.NDVI and SAVI of alfalfa grown undervarying water table depths

In addition to that, the relationship between canopy surface temperature and vegetation indices was studied. Figure 7 show the Ts-Ta-SAVI (temperature difference and soil

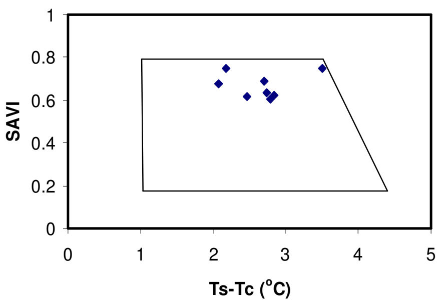

Figure 6 Temperature diference – SAVI trapezoid of alfalfa adujsted vegetation index.

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5. ACKNOWLEDGEMENTS

The Authors wish to thank Kung Abdulaziz City for Science and Technology (KACST), Riyadh, for the financial support for this study (grant L.G-17-5). Thanks also extended to Training and Research Station, King Faisal University, Hofuf, for the facilities provided to this research.