LINKING REMOTE SENSING WITH LEAF AREA INDEX OF SUGAR BEET

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ABSTRACT

Remote sensing and vegetation indices can be used to characterize the canopy of plant stands with a non-destructive method on a large scale. Leaf area formation of sugar beet in spring and early summer is a good parameter to describe the developmental stage of the plants. For yield formation, the early closure of the canopy is very important. Many factors, however, influence the leaf area development of sugar beet.

This study aimed at testing, whether differences in leaf area development of sugar beet can be estimated by remote sensing and calculation of the NDVI (Normalized Difference Vegetation Index, ratio between NIR and red radiation). For this purpose sugar beet field trials were carried out in 2001 and 2002 with different treatments (N application, sowing date, weeds, plant density, damage due to herbicide application, soil tillage). Leaf area index of sugar beet varied from 0.5 to 8.0 m^2 m^{-2} as affected by treatments und season. The NDVI gave a good impression of differences in leaf development in the sugar beet field, although it did not respond as distinctly to treatments as the leaf area index. Therefore, the relationship between leaf area index and NDVI was not linear.

ABRÉGÉ - ASSOCIER LES ENREGISTREMENTS DE LA TÉLÉDÉTECTION ET L'INDICE DE VÉGÉTATION DES BETTERAVES SUCRIÈRES

Les enregistrements effectués par télédétection et les indices de végétation peuvent servir à caractériser, par une méthode non destructive, les structures foliaires des peuplements de plantes. Le développement des surfaces foliaires des betteraves sucrières au printemps et au début de l'été est un bon paramètre pour décrire les stades de développement de la plante. Le recouvrement précoce et sans lacunes par la surface foliaire revêt de l'importance dans la évolution du rendement. Il existe toutefois un grand nombre de facteurs qui influent le développement des surfaces foliaires de la betterave sucrière.

Cette étude avait pour but de déterminer si des différences dans le développement des surfaces foliaires des betteraves sucrières se laissent déterminer au moyen de la télédétection et du calcul du NDVI (Normalizied Difference Vegetation Index, rapport entre le l'infrarouge et rouge proche). Dans ce but, des essais en champs ont été réalisés en 2001 et 2002 au moyen de différentes variantes (fertilisation azotée, date de semis, mauvaises herbes, densité de peuplement, dégâts dus aux herbicides). L'indice de végétation des betteraves sucrières a varié entre 0.5 et 8.0 m^2 m^{-2} en fonction de la variante et

de la période de végétation. Le NDVI a bien restitué les différences de développement foliaire des betteraves sucrières, bien qu'il n'ait pas réagi de façon aussi nuancée que l'indice de surface foliée. Pour cette raison, la relation entre l'indice de surface foliée et le NDVI n'était pas linéaire.

KURZFASSUNG - BEZIEHUNG ZWISCHEN FERNERKUNDUNGSAUFNAHMEN UND BLATTFLÄCHENINDEX BEI ZUCKERRÜBEN

Fernerkundungsaufnahmen und Vegetationsindices können genutzt werden, um die Blattentwicklung eines Pflanzenbestands mit einer nicht-destruktiven Methode zu charakterisieren. Die Blattflächenentwicklung von Zuckerrüben im Frühjahr und Frühsommer ist ein guter Parameter, um Entwicklungsstadien der Pflanze zu beschreiben. Für die Ertragsbildung ist das frühe Schließen des Bestandes von Bedeutung. Allerdings gibt es viele Faktoren, die die Blattflächenentwicklung von Zuckerrüben beeinflussen.

Ziel dieser Untersuchung war es herauszufinden, ob Unterschiede in der Blattflächenentwicklung von Zuckerrüben mit Fernerkundung und der Berechnung des NDVI (Normalized Difference Vegetation Index, Verhältnis zwischen Nahinfrarot und Rot) erfasst werden können. Zu diesem Zweck wurden Feldversuche in 2001 und 2002 mit verschiedenen Varianten durchgeführt (N-Düngung, Aussaattermin, Unkraut, Bestandesdichte, Herbizidschaden, Bodenbearbeitung). Der Blattflächenindex der Zuckerrüben variierte von 0.5 bis 8.0 $m^2 m^{-2}$ in Abhängigkeit von Behandlung und Vegetationszeit. Der NDVI gab die Unterschiede der Blattentwicklung der Zuckerrüben gut wieder, obwohl er nicht so differenziert reagierte wie der Blattflächenindex. Daher war die Beziehung zwischen Blattflächenindex und NDVI nicht linear.

INTRODUCTION

For yield formation of sugar beet the development of the leaf area and the rapid closure of the canopy in early summer is very important (SCOTT & JAGGARD 1993), since the major variable of productivity is the fraction of available light intercepted by the foliage (STEVEN et al. 1983). The earlier an optimal leaf area index of about 3 to 4 is obtained, the higher is the yield in autumn. There are many factors which affect leaf area formation of sugar beet in spring, such as sowing date, N supply, and plant density, but also the weed competition.

Leaf area index can be determined by harvesting the foliage, which is very laborious and time consuming, or by a non-destructive method with optical sensors. In recent years, remote sensing and vegetation indices were more and more used to describe and characterize the canopy of crops with a non-destructive method on a large scale.

This study aimed at testing, whether differences in leaf area development of sugar beet can be estimated with remote sensing. Furthermore, the relationship between NDVI and final root yield was studied.

MATERIAL AND METHODS

Field trials with sugar beet were carried out on 2 sites in Germany (Harste, Parensen) in 2001 and 2002. Treatments were varied as follwows: N application: 0, 160, 200 kg N/ha (including mineral N in soil at sowing), sowing date: normal, late; weed infestation: without, medium, high; plant density: 50, 85, 120 thousand plants/ha, damage due to herbicide application: with, without; soil tillage: plough, deep loosening, shallow mulching; with 4 replicates for each treatment in a randomised design. For each plot (21.6 m^2) leaf area index and NDVI were measured twice during the season: in July and in Aug./Sept. Final root yield was determined in October (10,8 m^2).

Leaf area index was determined manually with an optical, non-destructive method (Licor2000). The data represent the average of 4 measurements per plot.

Multi-spectral observations were made during overflights with a small areoplane. The NDVI (Normalized Difference Vegetation Index) was calculated as the ratio between the reflection in near infra red (NIR) and red wave length:

$$NDVI = (NIR - red) / (NIR + red)$$

NDVI is a means to distinguish very distinctly canopy from soil, because plant pigments (chlorophyll a+b, carotinoides) reflect radiation in a very characteristic way.

RESULTS AND DISCUSSION

The NDVI gave a good impression of differences in leaf development in the sugar beet fields (Fig. 1). In June, the leaf area index of sugar beet varied from 0.5 to 3.0 m^2 m^{-2}, whereas in Aug./Sept. it ranged from 3.0 up to 8.0 m^2 m^{-2} as affected by treatments. The NDVI increased from 0.2 to 0.7 with increasing LAI up to an LAI of 3.5 m^2 m^{-2}. However, it did not respond as distinctly to treatments as the leaf area index. Particularly in late summer, when leaf area index varied from 3.0 to 8.0 m^2 m^{-2}, NDVI did not indicate differences anymore. Thus the relationship between leaf area index and NDVI was not linear.

STEVEN et al. (1986) reported a sufficiently close relationship between light interception and foliage cover for sugar beet. The productivity of beet crop is thus directly related to the amount of light intercepted by the foliage. Maximal productivity is obtained with an optimal leaf area index of 3 to 4 m^2 m^{-2} (RÖVER 1994). When this optimal leaf area is exceeded, further increase of leaf area does not result in increased yield formation. Therefore, a distinct differentiation of leaf area index in the lower range is necessarily needed to assess crop development, but not for leaf area indices above the optimum.

Root yield in October, although it varied due to treatments between 40 and 90 t per ha, did not show any relationship to leaf area index or NDVI during the season. This was independent on whether the measurement was carried out in July or in Aug./Sept., although in July crop development determined by leaf area index or NDVI could be attributed to treatments, whereas in Aug./Sept. no differentiation in NDVI could be detected. The incident solar radiation was

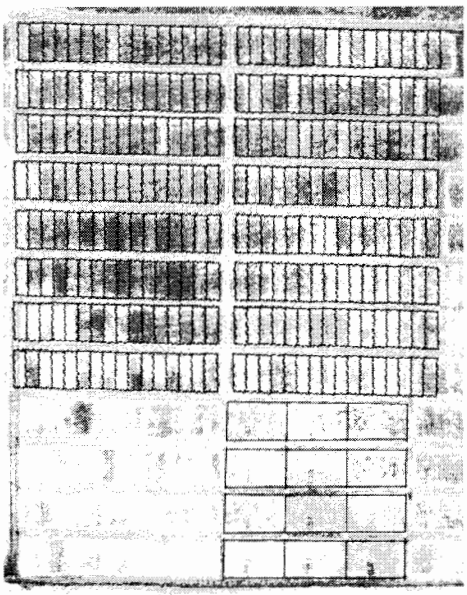

Fig. 1: Trial field with sugar beet in Harste, June 2001, NDVI from bright (low) to dark (high)

similar in all the plots for each year, so that the light interception mainly depended on leaf area. However, in both years the relationship between leaf and root yield (harvest index) was very variable, indicating differences in assimilate partitioning due to treatments. That may be attributed to most favourable weather conditions for sugar beet growth with a lot of rainfall in 2001 and 2002, so that no drought conditions occurred during summer and leaf area indices of up to 8 m^2 m^{-2} were obtained. Therefore, leaf area did not give any indication for yield formation. Further investigations are needed to describe yield formation by means of NDVI measurements as also described by BOUMANN (1995), or JAGGARD (1992).

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