

ANALYSIS OF HYPERSPECTRAL FIELD DATA FOR DETECTION OF SUGAR BEET DISEASES

Rainer LAUDIEN*, Georg BARETH, Reiner DOLUSCHITZ*****

Department of Agricultural Economics

Division: Agricultural Informatics and Farm Management

University of Hohenheim

Stuttgart, Germany

** laudien@uni-hohenheim.de, ** bareth@uni-hohenheim.de,*

**** agrarinf@uni-hohenheim.de*

Abstract

Every year, diseases cause lower sugar beet qualities compared to the average. For this reason, both field data and remote sensing data are needed to detect and analyse diseases affecting this crop.

The goal of this study is to show that hyperspectral measurements present the differences between healthy and diseased sugar beets concerning their spectral reflectance. Therefore, a hyperspectral spectroradiometer was mounted stationary on a developed measurement device to collect field data. To indicate the difference between healthy and unhealthy plants, the reflection results were elaborated with hyperspectral and spectral vegetation indices.

This paper discusses a methodological approach to explain the contrast between healthy and diseased sugar beets by using a hyperspectral spectroradiometer.

Keywords

Hyperspectral field data, radiometer, remote sensing, sugar beet diseases, GIS

1. Introduction

This paper presents the aims, problems and methods of data collection and information analysis of hyperspectral field data pertaining to sugar beet diseases.

At the University of Hohenheim, a research project with the title "Application of remote sensing and geographical information systems (GIS) for sugar beet companies" started in March 2002. The overall aim is to create a user-friendly management information system, which represents the supply chain of cultivating sugar beets. The study was enabled by cooperation between a sugar company in southern Germany, and the University of Hohenheim, Germany. One specific objective of the project is to use hyperspectral field data to detect *Rhizoctonia solani* var. *betae*, which is a fungal infection of sugar beets (see Riekmann and Steck, 1995 for details). A hyperspectral radiometer was used to collect field data. In contrast to multispectral remote sensing, the hyperspectral measurements acquire very narrow, contiguous spectral bands throughout the visible, near infrared, and mid-infrared portions of the spectrum.

The spectroradiometer measurements were taken during a field campaign and were located by GPS. Due to the spatial resolution of the spectroradiometer, an additional piece of measurement equipment was designed and used to collect the spectral reflectance of sugar beet leaves. A low-cost GPS solution coupled to a CE computer was used to locate the sampling spots.

2. Method

To detect the spectral differences between healthy and diseased sugar beets, the hyperspectral spectroradiometer “FieldSpec HandHeld” by ASD (Analytical Spectral Devices) was used to collect the field data. The ASD handheld spectroradiometer has a wavelength range of 325 nm to 1075 nm, with an interval of 1.6 nm and a viewing angle of 25 degrees. For further FieldSpec details, see: <http://www.asdi.com>.

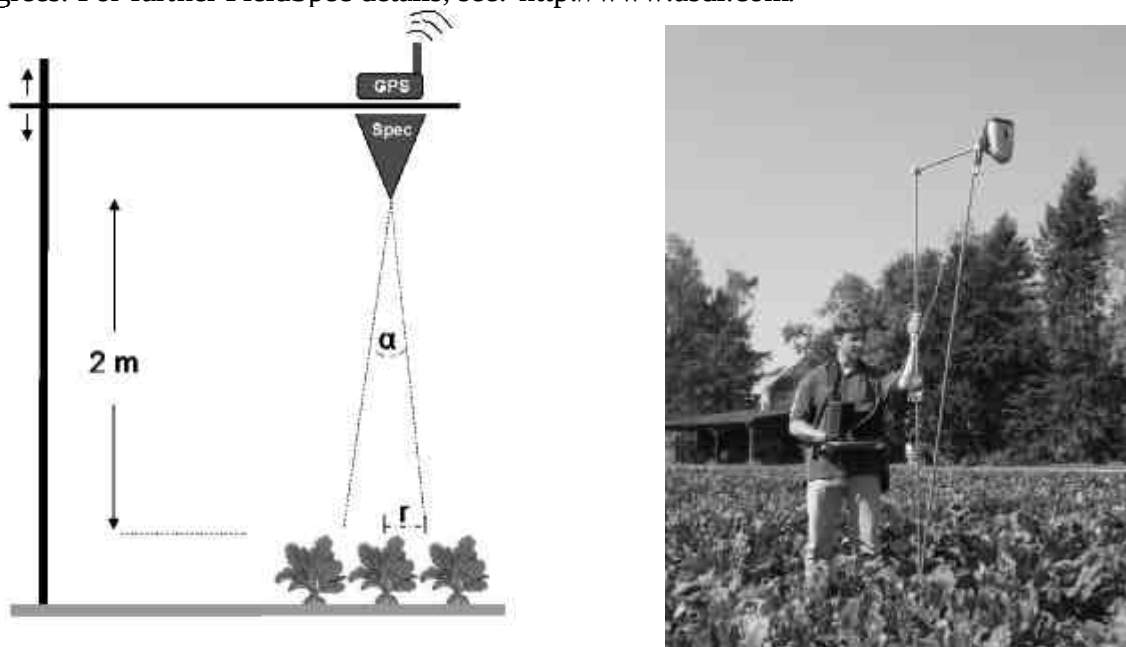


Figure 1: Designed measurement device for collecting hyperspectral field data.

To archive a useful spatial ground resolution, an additional technical device was developed and constructed in cooperation with the technical department of the University of Hohenheim. Figure 1 shows the design of the measurement device and a picture of the field campaign with the equipment. Three tent-poles, which are combined with moveable joints, form the frame of the device. The construction was designed to put the measurement equipment to the desired height above ground. A mounted spirit-level guarantees vertical measurements.

The spectroradiometer was located two metres above the foliage. The measuring viewing angle (α) of 25 degrees causes a Field of View (A) of 62 cm² with a Field of View radius (r) of 44 cm (see equations 1 and 2).

$$r = h * \tan\left(\left(\frac{\alpha}{2}\right) * \frac{\pi}{180}\right) \quad (1)$$

$$A = \pi * r^2 \quad (2)$$

To compare healthy and diseased sugar beets with the experimental field area, spectroradiometer measurements were made every 40 cm per row. The spots were located with a low cost GPS solution (Garmin III Plus) coupled to Software from ESRI (ArcPad, installed on a Compaq iPAQ CE computer).

These measurements were averaged to one spectral curve for each field experiment. The calculation resulted in two spectral curves; one stood for the healthy, the other for the unhealthy plants. This intermediate result was used to appoint and evaluate vegetation indices. This paper sets the focus on two of them (see Figure 2). The index of Gitelson & Merzylak

(1996) is shown in equation 3. The “red edge” ratio between the reflection of 750 nm and 700 nm shows the vitality of a plant (compare Figure 2).

$$rededge = \frac{R750}{R700} \quad (3)$$

where

$R750$ reflectance at 750 nm [%],

$R700$ reflectance at 700 nm [%].

The Corophyll-Absorptions-Integral (CAI) derives the chlorophyll content by measuring the area between a straight line connecting two points of the red edge and the curve of the red edge itself. Therefore, it is an approach on the basis of a spectral envelope measurement (Oppelt & Mauser, 2001a and b). To fit to the spectral bands of the ASD radiometer, the CAI was modified as follows (see equation 4 and 5):

$$mCAI = A - \int_{R545}^{R752} f \quad (4)$$

where

A area of the trapeze between $R545$ and $R752$,

f reflectance curve.

$$mCAI = \frac{(R545 + R752)}{2} * (752 - 545) - \sum_{R545}^{R752} (R * 1,158) \quad (5)$$

The modified CAI (mCAI) calculates the area above the spectral curve between 545 nm (green peak) and 752 nm (compare Figure 2). The mathematic approach is to calculate the area of the trapeze (A) between 545 nm and 752 nm and subtract it with the integral of the spectral curve between the same spectral values. This calculated index also stands for the vitality and health of a sugar beet plant.

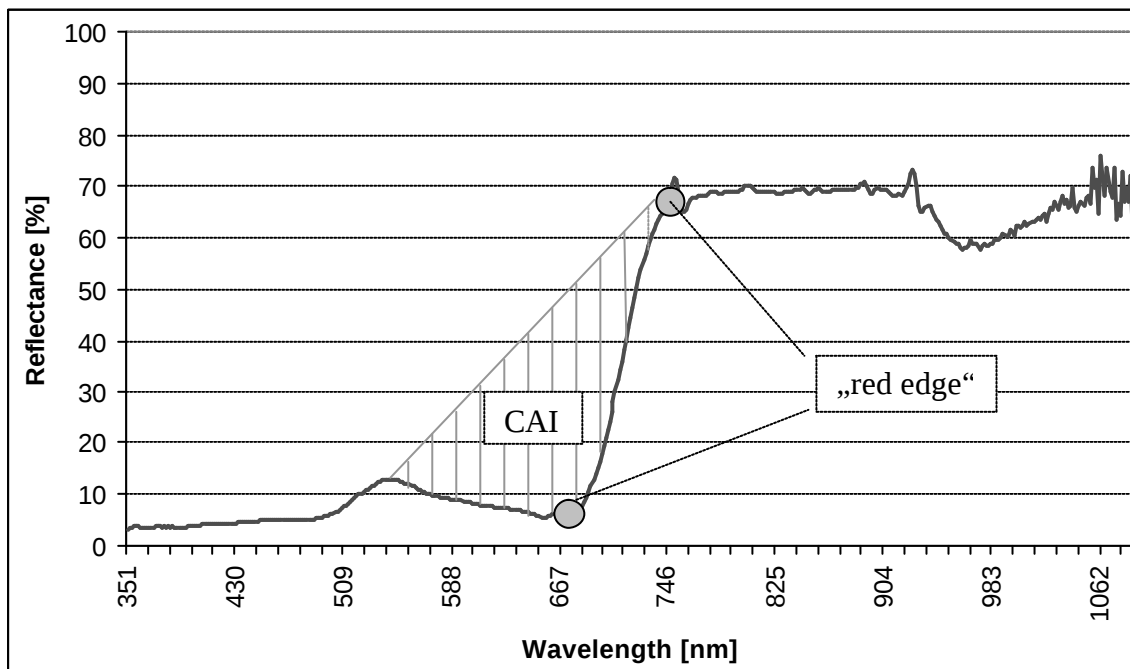


Figure 2: Spectral curve of healthy sugar beets with “red edge”

(the two points represent the wavelengths for the ratio) and CAI (area above the curve).

3. Results

Hyperspectral analysis of the data presents the differences between healthy and diseased sugar beets concerning their spectral reflectance. Figure 3 shows a picture of the field experiment. Healthy sugar beets are presented at the left side, while the right one shows plants which are diseased with *Rhizoctonia solani* var. *betae*.

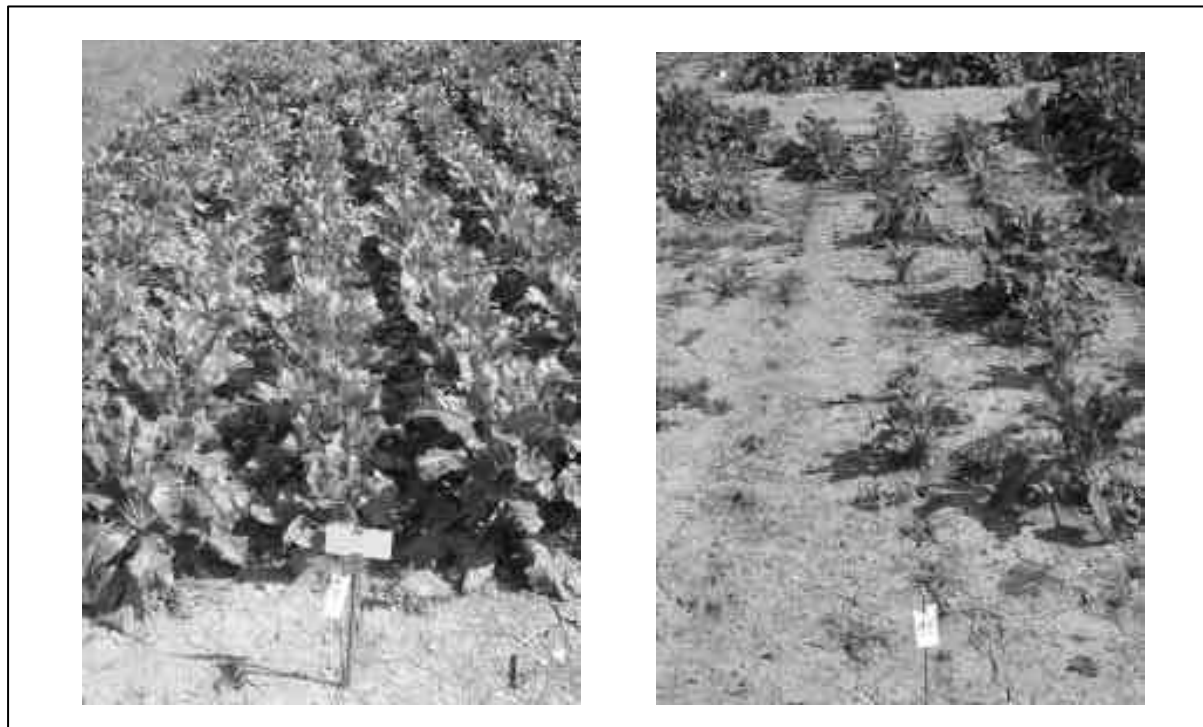


Figure 3: Pictures of the field experiment (healthy on the left and diseased sugar beets on the right).

As the pictures were taken in the beginning of September 2002, the difference between the two experiment areas was clearly visible. The involved plants were nearly dead at this phase of disease.

Hyperspectral measurements, shown in Figure 4, represent the two plant rows of the experimental field study. Every line stands for one measurement with the ASD and represents the average of the measured Field of View.

The reflectance curves of healthy sugar beets are characterised through low reflectance in the blue and red portion of the spectrum. The “green peak” and the high reflectance in the near infrared portion of the spectrum are also visible. Healthy plants show nearly all the same reflectance curve because of their homogeneous growth and vitality.

The reflection curves of diseased sugar beets are completely different. Their “spectral fingerprint” (= spectral curve) rises from the blue portion of the spectrum to the Near Infrared nearly continuous, except the part of the infrared shoulder, which shows also a lower slope and length in contrast to the healthy one. The “green peak” is slightly visible and the reflectance in the Near Infrared is in comparison to healthy plants significantly lower.

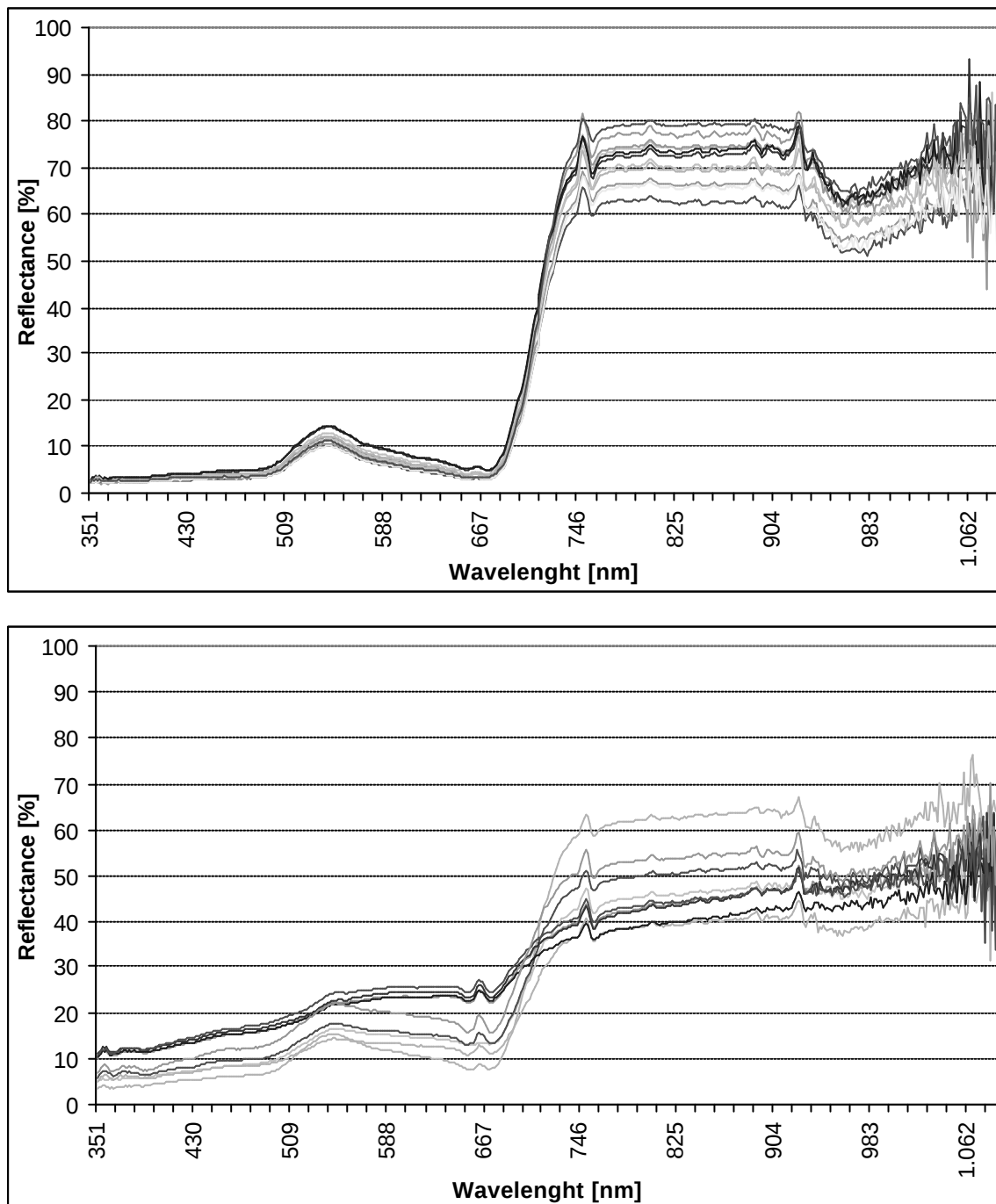


Figure 4: Reflectance curves of healthy (top picture) and diseased sugar beets (bottom picture).

Figure 5 shows the averaged reflection curves of the field experiment. This intermediate result was used to calculate vegetation indices, which stand for the vitality and health of a plant. To point out the difference and the spectral contrast between the two field experiments, spectral and hyperspectral vegetation indices were used.

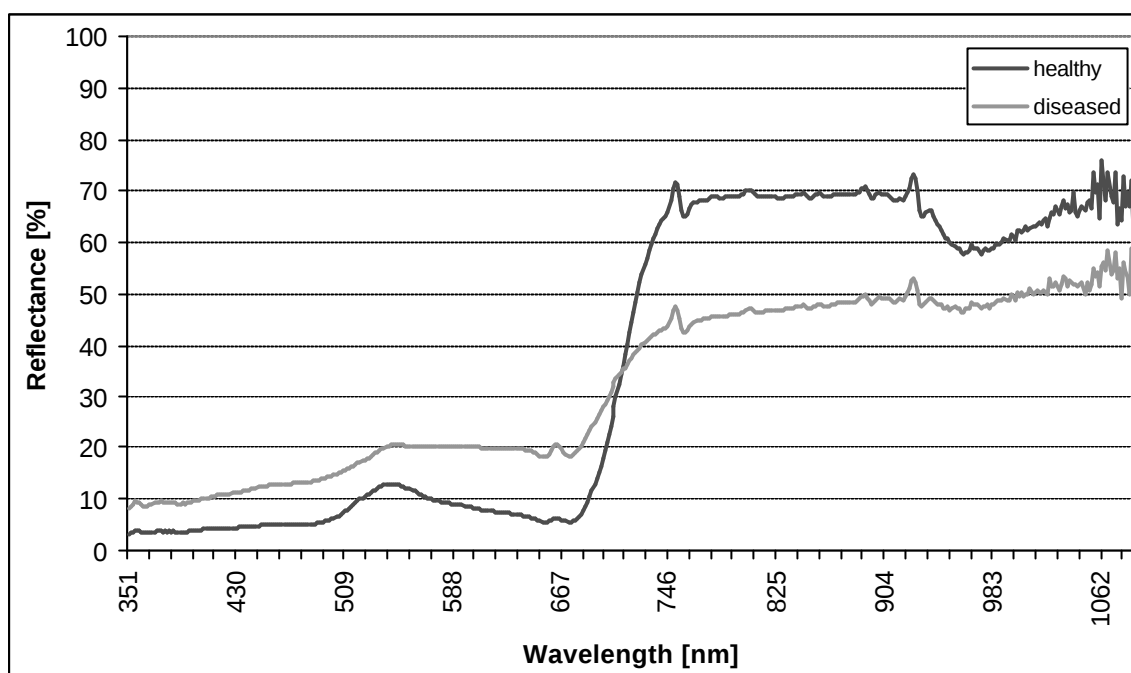


Figure 5: Averaged reflectance curves of healthy and diseased sugar beets.

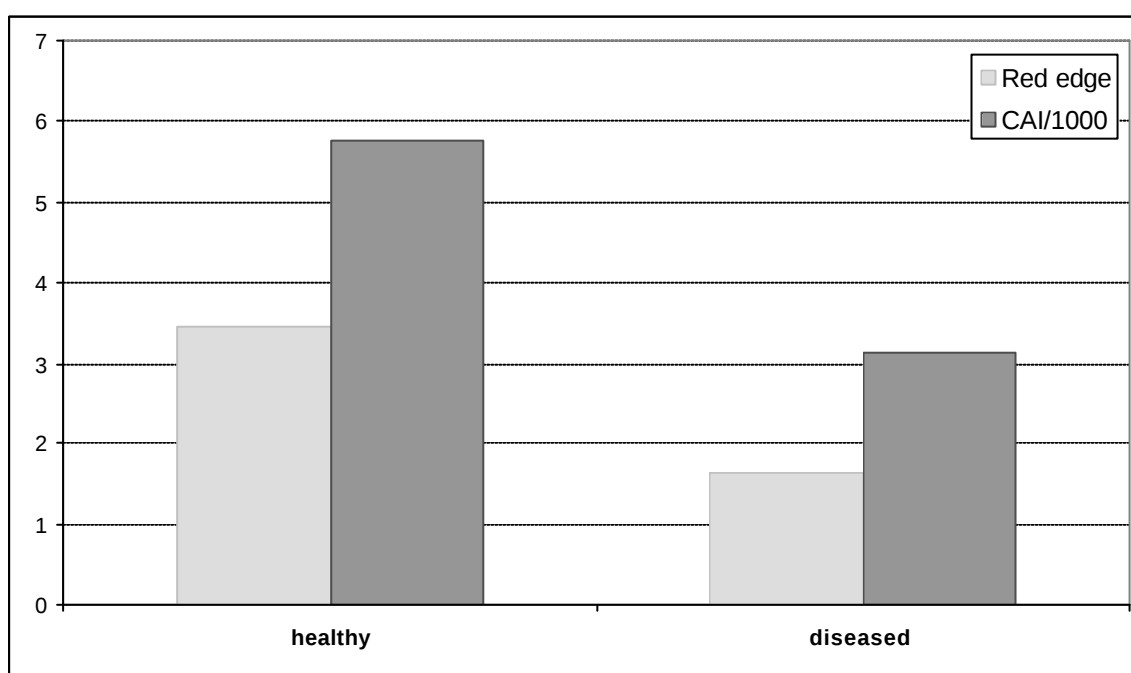


Figure 6: Spectral and hyperspectral vegetation indices ("Red edge" and CAI) to quantify the differences between healthy and unhealthy sugar beets.

Figure 6 shows the result of the calculation. Healthy and diseased sugar beets are well-defined in both indices. While the red edge and the CAI of healthy plants show high values, those of the diseased ones are clearly lower.

4. Conclusions

In this study, a typical sugar beet disease was analysed using hyperspectral remote sensing measurements. Field data was collected with a hyperspectral radiometer, mounted on a newly developed technical device. The methodological approach of this study was chosen according to Dockter et al. (1988) and Lichti et al. (1997). They also used hyperspectral measurements to point out spectral differences in winter wheat and sugar beets. Their results are comparable to those of the described study.

The generated reflection curves showed a significant difference between healthy and diseased sugar beets. The reflection of healthy plants in comparison to diseased ones is clearly higher at most portions of the spectrum, especially at the near infrared sector. Additionally, the “green peak” at circa 550 nm is visible, in contrast to the reflectance curves of unhealthy sugar beets. These facts were also visible using two vegetation indices. The “red edge” was chosen as an often-used spectral index. As the measurements collected hyperspectral data, the CAI-Index represented the hyperspectral indices. Higher values at the “red edge” and also at the CAI show a higher grade of plant vitality. The indices of diseased sugar beets presented lower values.

Considering the presented results of the first field campaigns and, due to the task of the early detection of *Rhizoctonia solani* var. *betae*, the authors will intensify the field experiments in 2003. Unhealthy and healthy sugar beets will be detected from the early shooting stage with the handheld spectroradiometer. Additionally, multitemporal airborne hyperspectral data analysis with evaluation against the field measurements will be used to develop a method for early detection of *Rhizoctonia solani* var. *betae* and yield losses.

LITERATURE

- Dockter, K., Kühbauch, W., Boochs, F., von Rüsten, C., Tempelmann, U. and Kupfer, G. (1988): Die spektrale Reflexion von Zuckerrübenbeständen im sichtbaren und infraroten Wellenlängenbereich während des Wachstums, *Mitteilungen der Gesellschaft für Pflanzenbauwissenschaften*, 1, pp.55-57.
- Gitelson, A., and M.N. Merzlyak, (1996): Detection of red edge position and chlorophyll content by reflectance measurements near 700 nm, *Journal of Plant Physiology*, 148, pp.501-508.
- Lichti, C., Stickel, E. and Maidl, F.-X. (1997): Feldspektroskopische Messungen als Hilfsmittel für eine teilschlagbezogene Bestandesführung, *Mitteilungen der Gesellschaft für Pflanzenbauwissenschaften*, 10, pp.271-272.
- Oppelt, N. and Mauser, W. (2001a): The Chlorophyll Content of Maize (*Zea Mays*) Derived with the Airborne Imaging Spectrometer AVIS. 8th International Symposium “Physical Measurements & Signatures in Remote Sensing”, 8-12 January, Aussois, France, pp.407–412.
- Oppelt, N. and Mauser, W. (2001b): Derivation of the Chlorophyll Content of Maize. International Workshop on Spectroscopy Application in Precision Farming, 16–18 January, Freising, Germany, pp.52–56.
- Rieckmann, W. and Steck, U. (1995): Krankheiten und Schädlinge in der Zuckerrübe. Verlag Th. Mann, Gelsenkirchen, Germany, pp.42-43.