COMPARISON OF REMOTE SENSING BASED ANALYSIS OF CROP DISEASES BY USING HIGH RESOLUTION MULTISPECTRAL AND HYPERSPECTRAL DATA - CASE STUDY: RHIZOCTONIA SOLANI IN SUGAR BEET -

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Abstract

Every year diseases cause lower sugar beet qualities compared to the average. For that reason, high resolution multispectral and hyperspectral remote sensing data has been used to detect and analyse a fungal sugar beet disease in a study area of Southern Germany.

A QuickBird high resolution satellite image was chosen to produce the results for the multispectral part of the study. The very high spatial resolution of 0.7 m in PAN mode and 2.5 m in multispectral mode let the sensor become very interesting for remote sensing analysis. Especially the red (630 to 690 nm) and near infrared portions of the spectra (760 to 900 nm) are important for agricultural applications. For the hyperspectral part, airborne hyperspectral remote sensing data has been provided by an “Airborne Visible/Near Infrared Imaging Spectrometer” (AVIS), which is operated by the Ground Truth Center Oberbayern (gtco). To indicate the difference between healthy and unhealthy plants, image classifications were produced and evaluated with hyperspectral field data. Therefore, the hyperspectral radiometer “FieldSpec HandHeld” (by Analytical Spectral Devices) was used to collect the data in the same study area where the two other sensors took their measurements. With a spatial resolution of 0.6 m, the collected field data could be used to train the supervised classifications. Reflection results can be elaborated with spectral and hyperspectral vegetation indices. To detect the sugar beet disease, the different datasets were analysed by calculating vegetation indices. Finally, the resulting images were classified into several vitality classes.

This paper presents the comparison and evaluation of the generated classification results from the two different multi- and hyperspectral sensors and discusses the possibility of detecting sugar beet diseases with innovative remote sensing systems and methods.

INTRODUCTION

The objective of this contribution is the comparison of remote sensing based analysis of the sugar beet disease Rhizoctonia solani var. betae by using multi- and hyperspectral reflectance data. Therefore, a multispectral satellite image (QuickBird) and a hyperspectral image of an airborne sensor (AVIS) were obtained for the study area. Latter is located in southeast Germany, around 150 km northeast of Munich.
Managing sugar beet diseases are more and more important for farmers and sugar beet companies with regard to documentation, pesticide application, harvesting, yield forecasting, transporting and refining. Therefore, a research project with the title “Development of a field based Management Information System (MIS) for sugar beet companies” started in March 2002 at the University of Hohenheim. The overall aim of that study is to create a user-friendly GIS based Management Information System which represents the supply chain of cultivating sugar beets. One specific objective of this project is to use multi- and hyperspectral data to detect *Rhizoctonia solani* var. *betae*, which is a fungal infection of sugar beets (Rieckmann and Steck, 1995).

Beside the usual survey which is done by professionals in several field campaigns, the usage of remote sensing systems, materials, and methods can help to recognize, detect and regionalize growth anomalies of large areas (Lillesand and Kiefer, 1994).

**MATERIAL**

**Multispectral data**

Basis for the multispectral analysis was a subset of a QuickBird high resolution satellite image of August 22nd, 2003. The satellite was launched in 2001 and is collecting reflectance data 450 kilometres above ground. The very high spatial resolution of 0.7 m in PAN mode and 2.5 m in multispectral mode delivers very accurate data for remote sensing analysis. QuickBird collects multispectral data in four spectral bands. Table 1 presents the band numbers and widths of the satellite.

<table>
<thead>
<tr>
<th>Band Number</th>
<th>Band Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>450 – 520 nm (blue)</td>
</tr>
<tr>
<td>2</td>
<td>520 – 600 nm (green)</td>
</tr>
<tr>
<td>3</td>
<td>630 – 690 nm (red)</td>
</tr>
<tr>
<td>4</td>
<td>760 – 900 nm (near infrared)</td>
</tr>
</tbody>
</table>

**Hyperspectral data**

For agricultural applications, the analysis of airborne, field- and satellite-based hyperspectral reflectance data is of increasing importance (Clevers and Jongschaap, 2001). Consequently, the hyperspectral part of the study was covered by the data of two hyperspectral devices. In contrast to multispectral remote sensing the hyperspectral measurements acquire very narrow spectral bands throughout the visible, near infrared and mid-infrared portions of the spectrum.

The hyperspectral spectroradiometer “FieldSpec HandHeld” by Analytical Spectral Devices (ASD) was used to collect field data of an artificial inoculation trial. This very high spectral resolution device was applied to evaluate biotic and abiotic growth-anomalies of sugar beets in dependence of their spectral reflectance. The used ASD handheld spectroradiometer collects spectral data in a wavelength range of 325 nm to 1075 nm with an interval of 1.6 nm. This results numerous individual bands which represent a nearly contentious reflectance curve. The viewing angle of the FieldSpec is 25 degrees. An extra measurement equipment was developed and designed, due to the viewing angle of the FieldSpec, the spatial resolution of the airborne AVIS spectroradiometer which is described below, and the QuickBird sensor. This was necessary to collect spectral field reflectance of the sugar beet leaves with a spatial resolution of 0.6 m for the supervised and knowledge-
based classification. Additionally, a low cost GPS solution coupled to a CE computer was used to locate the sampling spots (Laudien et al., 2003).

Furthermore, airborne hyperspectral measurements were taken at August 27th, 2003 to regionalize the ground based data. For this purpose, hyperspectral remote sensing data was provided by the “Airborne Visible/Near Infrared Imaging Spectrometer” (AVIS), which is operated by the Ground Truth Center Oberbayern (gtco). The hyperspectral AVIS sensor measures spectral reflectance between 400 and 845 nm by using 63 channels and a spectral interval of 9 nm. With a spatial resolution of 4 meters, the AVIS sensor is able to detect crop vitalities very detailed (Mauser and Oppelt, 2000).

**GPS data**

Differential GPS-data was collected at selected fields of the study area to validate the multi- and hyperspectral analysis results. For this purpose a “Trimble AgGPS® 132” twelve channel receiver was connected to a SOLO CE device to store the incoming data. OmniSTAR differential GPS service was used to correct the data online.

The infected areas of the chosen fields were surveyed during a field campaign in early September 2003. In 2003, the fields of the whole study area showed single plant infection because of very dry weather conditions. As the regular symptoms of *Rhizoctonia solani* are characterized by circular infection concerning several sugar beet plants, it was almost impossible to collect polygon data via GPS. Therefore, polygons were only stored with at least 25 percent infection.

**METHODS**

The red and near infra-red parts of the reflectance spectra are important for agricultural applications (Kumar et al., 2001). The significant difference of the reflectance at the red portions of the spectra compared to the near-infrared ones can be used to predict vegetation conditions. Therefore, Dockter et al. (1988) and Lichti et al. (1997) could use hyperspectral measurements to point out spectral differences in winter wheat and sugar beets.

Multispectral or hyperspectral vegetation indices can be calculated, by using the red and near-infrared portions of the spectra as well (Apan et al., 2003; Lillesand and Kiefer, 1994). The index values are significantly correlated to the vitality of the detected plants. In this study, the hyperspectral vegetation index (HVI) of Gitelson et al. (1996) was modified to analyse the AVIS and QuickBird datasets (see equation 1 - 3). The indices were calculated to indicate the difference between healthy and diseased sugar beets on the one hand and to compare the results of the multi- and hyperspectral analysis on the other hand. Equations 2 and 3 present the two modified spectral vegetation indices (VI). The spatial analysis as well as the index calculation and classification were accomplished by using the GIS Software ArcGIS™ 8.3 by ESRI® (Minami, 2000).

\[
HVI_{\text{Gitelson et al.}} = \frac{R750}{R700}
\]

where

- \( R750 \) = reflectance at 750 nm [%],
- \( R700 \) = reflectance at 700 nm [%].
Comparison of remote sensing based analysis of crop diseases by using high resolution data

\[ V_{I_{AVIS}} = \frac{AVIS\_Band48}{AVIS\_Band41} \]  \hfill (2)

where
\[ AVIS\_Band48 = \text{reflectance at 753.58 nm [\%]}, \]
\[ AVIS\_Band41 = \text{reflectance at 702.54 nm [\%]}. \]

\[ V_{I_{QuickBird}} = \frac{QB\_Band4}{QB\_Band3} \]  \hfill (3)

where
\[ QB\_Band4 = \text{reflectance at QuickBird channel 4 [\%]}, \]
\[ QB\_Band3 = \text{reflectance at QuickBird channel 3 [\%]}. \]

In a first step, the above characterised indices were calculated for the two input datasets. Furthermore, the HVI of infected sugar beets was identified with the FieldSpec data on August 20th and 27th. The HVI value of the QuickBird collecting day (August 22nd) was interpolated from the field measurements (see Table 2). The calculated HVI values were used as an input threshold for the analysis to mask most of the abiotic growth-anomalies. This enabled the production of a binary image which contains only higher values than the index minimum to delete field border effects.

Table 2: Index minima (HVI) of the the FieldSpec measurements at the two collecting dates.

<table>
<thead>
<tr>
<th>Device</th>
<th>Collecting Date</th>
<th>Value (HVI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>QuickBird</td>
<td>22.08.2003</td>
<td>&gt; 1.80</td>
</tr>
<tr>
<td>AVIS</td>
<td>27.08.2003</td>
<td>&gt; 1.85</td>
</tr>
</tbody>
</table>

Considering the hypothesis that the threshold value indicates the minimum reflectance of sugar beet leaves, the multiplication of the input VI image and the masked image results in a raster image which does not contain most of the abiotic parameters anymore. Figure 1 shows this method considering the AVIS input as example.

![Figure 1: Knowledge based analysis method.](image)

In the last step the results of the VI calculations (AVIS and QuickBird) were classified into nine vitality classes by using the “Quantile Classification Method” of ArcGIS™ Spatial Analyst. To validate and compare the two classified outputs, the GPS polygons of the field campaign were added to the ArcGIS™ 8.3 project as an overlay layer.

**RESULTS**

Figure 2 and 3 show the AVIS and QuickBird VI classifications of two selected fields. The value ranges of the calculated VI were in both cases between 1.8 and 3.4. According to the leaf vitality of sugar beets, the value of the index is increasing with healthier and decreasing with unhealthier plant conditions.
The two images were classified into nine vitality classes. The lower classes were assigned to low index values, the higher ones to high index values. Significant differences concerning plant vitalities within the fields can be identified. Darker areas refer to diseased spots, lighter ones to healthier parts of the fields.

The analysis of both images show similar results concerning within-field plant vitalities. However, due to the higher spatial resolution, the QuickBird classification image presents a sharper texture. This matter of fact is clearly visible by comparing the two figures. Beside the variation of different plant vitalities the tillage direction within the fields is also illustrated in Figure 3.
The overlay of the GPS polygon layer confirms the difficulty of surveying single infected plants within a field. With the matter of fact that the stored polygons include at least 25 percent infected sugar beets, they do not show detailed the spatial distribution of the diseased plants. This information can be generated by using remote sensing data. Regarding to its spatial resolution, detailed vitality information concerning spatial location and intensity can be derived with such remote sensing sensors.

**DISCUSSION**

In this study, a typical sugar beet disease was analysed by using multi- and hyperspectral remote sensing data which were classified on the basis of hyperspectral field data. The comparison between the calculated results of the two different sensors indicates a good correspondence. In contrast to the conventional disease survey, shape and structure of the infected areas within the selected fields can be spatially identified.

The classification of the QuickBird scene presents a sharper image. This corresponds to its very high spatial resolution of 2.5 meters. In this context, the multispectral data could be preferred. A disadvantage of such high resolution optical satellite sensors is the dependency of the repetition rate and the cloud cover for data sampling. In contrast, airborne sensors are more flexible for collecting reflectance data. The immense advantage of the hyperspectral data is its very high spectral resolution. The possibility of analysing datasets by using hyperspectral vegetation indices i.e. the Optimized Soil-Adjusted Vegetation Index (OSAVI) for the detection of plant vitalities offers more opportunities (Apan et al., 2003). Very narrow spectral bands characterize the leaf reflectance a lot better than multispectral averaged ones. Therefore, the mathematical possibilities of band calculations and combinations for the creation of new vegetation indices are disproportionately enhanced.

The infection of the disease and its outbreak were not typical in 2003 and the spatial resolutions of the input datasets were too low for detecting single affected plants with a significant accuracy. The GPS polygon measurements showed not the quality of those having been collected in previous years, because circular affected areas within the selected fields did not occur. Furthermore, the “mixed pixel phenomena” covered that unusual situation, too.

Regarding the detection of plant/sugar beet diseases, the usage of one single remote sensing image is crucial. The differentiation between biotic and abiotic influences on plant vitalities is difficult. Therefore, a multitemporal, knowledge based approach should be applied to identify the disease.

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**REFERENCES**


