CLASSIFICATION OF WEED PATCHES IN QUICKBIRD IMAGES: VERIFICATION BY GROUND TRUTH DATA

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ABSTRACT

Current methods for mapping weeds in arable land include manual sampling approaches and online computer-based methods with special sensors. Both methods are expensive, time consuming and not suitable for constructing regional maps of weed status. This study investigated the use of a visual interpretation of high-resolution satellite images from the *QuickBird* satellite in order to detect weeds in a field of sugar beets (*Beta vulgaris* L.) near Bonn in Germany. The study compared this visual interpretation with the data acquired applying a *WeedScanner* survey of the same area. This method allows an exhaustive survey of weeds in the field. The analysis showed that dense clumps of Canada thistle (*Cirsium arvense* L.) were accurately detected in the satellite images, but that small and sparsely occurring weeds could not be reliably detected. The results prove the limitations of remote sensing in the context of weed control but they also show that there is a great potential for early decision making for particular weed species.

Keywords: Site-specific weed control, *Cirsium arvense* L., WeedScanner.

INTRODUCTION

Precision Plant Protection often uses maps for decision support, and these maps are frequently produced from discrete sampling datasets. Maps are usually essential in a target-oriented pesticide application because it is widely accepted, for example, that weeds are heterogeneously distributed in arable land (1,2,3,4). The application of herbicides based on these weed maps is known as site-specific weed control. This method can be helpful in both saving money and resources (5). However, weed mapping is still a very time consuming procedure, hence other more effective methods or strategies to carry out the site-specific weed control are required. Online detection and image analysis methods for weeds are the most popular approaches (6,7,8,9,10). At present, these new approaches are very expensive and susceptible to interference. Current satellite-based sensor developments of higher spatial and temporal resolution as with *QuickBird* raise the question of whether or not these new sensors can detect weeds and weed patches in an adequate manner. In several studies the potential of airborne and satellite based remote sensing for the detection of weeds was described (11,12,13,14,15). In this study, relatively large ground truth datasets gathered using the *WeedScanner* technique described below (16,17) have been visually compared with satellite imagery from *QuickBird* satellite in order to answer this question. It is vital to have detailed knowledge about the adequacy of the satellite images for the described purpose, therefore the question of whether or not the resulting digital ground truth maps are closely correlated with visually recognisable structures in *QuickBird* satellite images was the main objective of this study.

METHODS

Sample area

The field experiments of this study have been conducted on a 5 ha sugar beet (Cultivar: *Macarena*) field near Bonn, Germany. By the time of the ground truth survey prior to the herbicide application in 2003 the sugar beet plants have been in growth stage 10 BBCH. The time lag between the ground truth experiments applying the *WeedScanner* technique and the respective satellite image available from the analysed area was one week. Hence, a close correlation between the datasets gathered using the *WeedScanner* technique and the satellite imagery was assumed. The *WeedScanner* technique (15,16) was applied on a 0.6 ha subset of this field (bounded by the black rectangle in Figure 1).

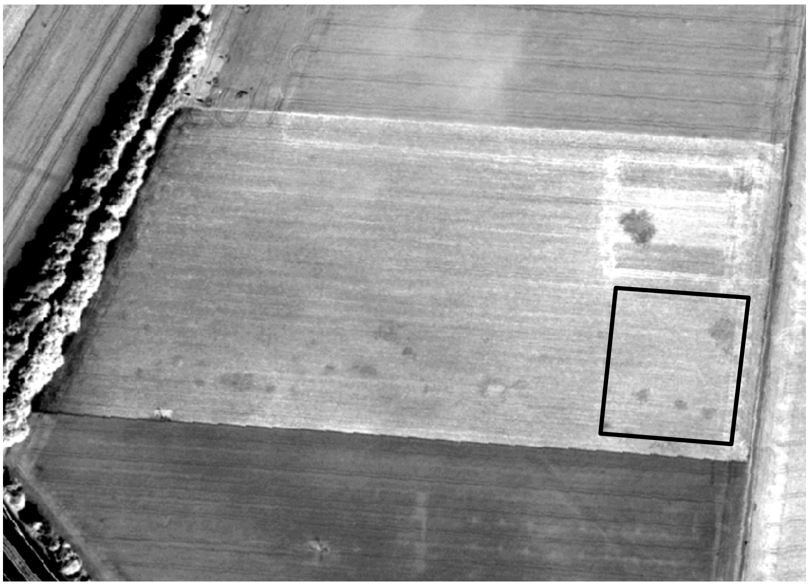

Figure 1: Subset of a QuickBird *scene (panchromatic image) from Mai 28, 2003. The black box describes the shape of the 0.6 ha subset of this arable field which was analysed with the below described WeedScanner technique. The cultivar grown was sugar beet in growth stage BBCH 10. There are visible patches of weeds in this arable field.*

***WeedScanner* datasets**

The *WeedScanner* technique consists of a small custom-built vehicle on which 3 digital 3CCD chip camcorders (Sony TRV900) capture continuous video sequences of the surface of the grounds. This video information is transformed into georeferenced 2D digital raster images covering the whole trial area which are then manually analysed. The required ground control points (GCPs) have been gathered applying DGPS. The precise *xy*-coordinates of every single weed plant (shown for *Cirsium arvense* L., *Matricaria* ssp. and monocotyledonous plants in Figure 3) can be easily determined in this way. For further details about the *WeedScanner* technique and the image processing refer to (15,16) and the results presented in Figure 2.

Satellite dataset

The satellite imagery applied was collected from the high-resolution satellite *QuickBird* in late May 2003. This sensor has the characteristics presented in Table 1. Due to the viewing angle of the sensor close to the experimental area at Klein-Altendorf near Bonn of about 24° off-Nadir the spatial resolution was 0.7 m in the panchromatic image and 2.8 m in the multispectral image respectively.

Methods of analysis

The satellite image was delivered as Standard Imagery Bundle with panchromatic and multispectral image. Standard Imagery Products are radiometrically corrected and geometrically corrected by a parametric operation with direct sensor orientation and GTOPO30 digital elevation model (18). A subset of the image was used in the subsequent analysis. This particular subset contains the experimental area, which was analysed applying the *WeedScanner* technique to gather *ground truth* datasets. On this subset the *NDVI* (Eq. 1) was calculated from the multispectral data. The NDVI is calculated from the reflectance of the red and near infrared wavelengths. This ratio is commonly known as a reliable measure of vegetation vitality and biomass (9):

$$NDVI_{\text{(Red)}} = \frac{(IR - R)}{(IR + R)} \qquad (1)$$

Finally, the *NDVI* of each region containing weed patches within the training area (black rectangle in Figure 1) was calculated. Applying these results a supervised classification of the whole sugar beet field was made (Figures 2a-f).

Table 1: Technical data about the QuickBird satellite. Changed according to DigitalGlobe.

***QuickBird* Characteristics**		
Launch Date	October 18, 2001	
Orbit Altitude	450 km	
Orbit Inclination	97.2 degree, sun-synchronous	
Speed	7.1 km second^{-1}	
Equator Crossing Time	10:30 a.m. (descending node)	
Orbit Time	93.5 minutes	
Revisit Time	1 to 3.5 days depending on latitude (30° off-nadir)	
Swath Width	16.5 km x 16.5 km at nadir	
Metric Accuracy	23 metres horizontal (CE90%)	
Digitization	11 bit	
Resolution	Pan: 0.61 m (nadir) to 0.72 m (25° off-nadir) MS: 2.44 m (nadir) to 2.88 m (25° off-nadir)	
Image Bands	Pan:	450 - 900 nm
	Blue:	450 - 520 nm
	Green:	520 - 600 nm
	Red:	630 - 690 nm
	NIR:	760 - 900 nm

RESULTS AND DISCUSSION

One of the main objectives of this study was to test whether it is possible to distinguish single weed species in remote sensing datasets from *Quick Bird* satellite according to their spectral reflectance. Figure 2a shows the multispectral satellite image RGB-coded and Pan-sharpened. The dark spots in this image represent *Cirsium arvense* patches since these dark spots are congruent with the results from the ground truth datasets from the *WeedScanner* technique presented in Figure 3. The other weed species plotted in Figure 3 could not be identified unambiguously in the satellite image due to a limited overall density per square meter or because of a very early growth stage of these weeds with little biomass.

The false-colour infrared image presented in Figure 2b also shows the areas of the above described *Cirsium arvense* patches with an intensive infrared (red colour) reflectance. In addition to these areas, the false colour image also shows broader areas of higher near infrared reflectance. In these areas an increased general weed density was present as observed visually in the field. The correlation between increased weed density and the NIR intensity was also detected in the training area as shown in Figure 4. In the NDVI image (Figure 2e) only *Cirsium arvense* patches were obvious as bright spots. Analysis of the classification showed that it detected the *Cirsium arvense* patches (Figure 2f) but not the more subtle variations in reflectance.

The results of this study prove that it is possible to detect the infestation of arable fields with broad leafed weeds in patches larger than about 0.7m diameter or about 25% of the *Quickbird* pixel area, such as patches of *Cirsium arvense* L. in early growth stages in sugar beet. However, this study also reveals – as mentioned before – that it is not possible to detect any of the other weeds examined in this particular field in May.

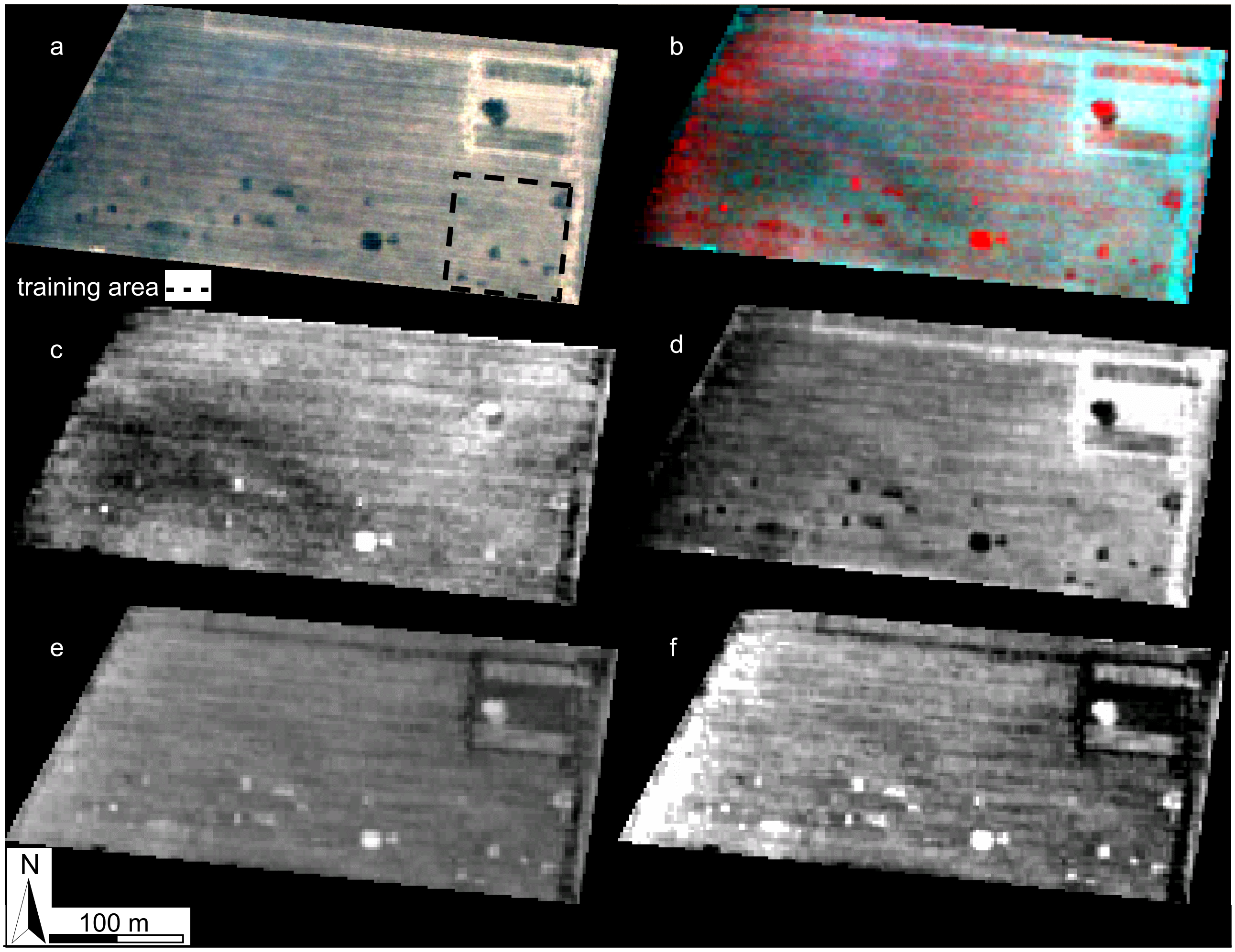

Figure 2: a) Pan-sharpened multispectral satellite image RGB-Code b) false colour infrared image NIR-G-B = RGB; c) NIR band (760-900 nm); d) Red band (630-690 nm); e) NDVI *image; f) classified* NDVI *image.*

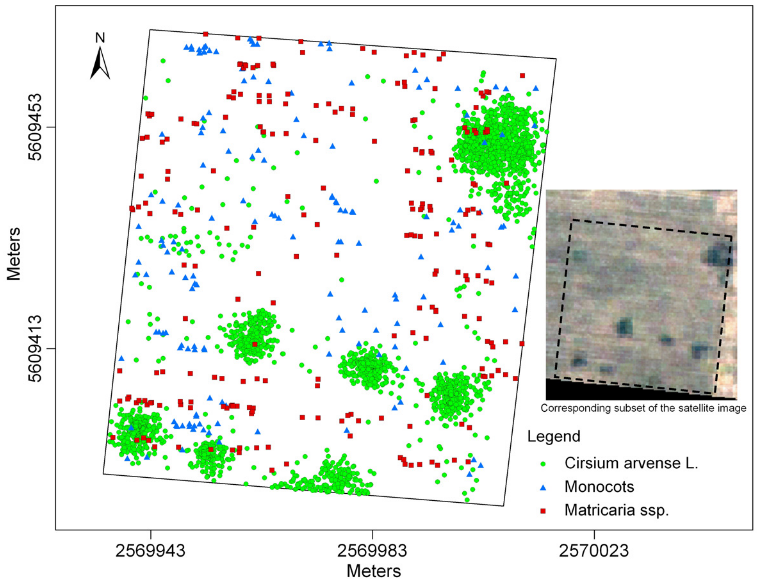

*Figure 3: The absolute positions of weeds (*Cirsium arvense *L.,* Matricaria ssp. *and* Monocotyledons*) in the earlier described arable field. These datasets were used in order to analyse the correlation with the QuickBird image.*

Cirsium arvense patches above a threshold of 2.0 metres diameter could be detected reliably due to the large difference in spectral reflectance which was indeed expected because of the limited spatial resolution of the sensor of about 2.8 metres. The large area in the left part of the field (Figure 2f) which was classified as *Cirsium arvense* patch demonstrates a commonly known problem of all optical remote sensing systems. Reflectance intensity differences caused by shadows of trees and hedges as well as the slope angle of the terrain etc. lead to significant errors in the classification results.

Single *Cirsium arvense* L. plants have a diameter of approximately 0.1-0.15 m in May and appear in large patches occasionally exceeding more than 10 metres in diameter. It is widely accepted that several other weed species are potentially detectable in satellite images (11,12,13,14,15), but especially in the case of *monocotyledonous* plants the respective weed patches are visually detectable in satellite images at advanced growth stages which limit the application of herbicides, because it is too late for an application to have a lasting damaging effect. Due to the fact that the *WeedScanner* vehicle has a height of approximately 0.5 metres the growth stage of e.g. wheat, maize and barley limit the practicability of this particular method, too. Most of the other weeds analysed neither occur in patches which are large enough to be detected by satellite images, nor do they have a sufficient leaf area as individual plant.

CONCLUSIONS

The main conclusion from this study is that there is a great potential for the precise, site-specific herbicide application in case of weeds like *Cirsium arvense* L. Other non broad-leafed weeds are visually not detectable with the *QuickBird* imagery. However, *Cirsium arvense* L*.* is a very noxious weed and farmers try to pay attention to such weeds with special (additional) herbicide applications. Applying satellite imagery in order to plan these special herbicide applications could improve the money and resource saving effects of the Precision Farming strategy. Although practical applications for single farmers are still far-off, agricultural service providers could be possible operators for this technique. Additionally, the regional knowledge about the spread and the current distribution of certain economically important weed species could be a powerful tool for regional plant protection advisors and the herbicide-producing industries. The spatial resolution of the recent generation of optical satellite sensors meanwhile is high enough for a fast and efficient generation of detailed weed distribution maps for particular weed species (e.g. *Cirsium arvense*). In order to visualise the spatial and temporal development of weed patches and population dynamics of certain weed species higher repetition rates are indispensable. These required time-lines could not be delivered by the service provider of the *QuickBird* satellite at the time of the presented study. A prior study (19) had deduced that *Cirsium arvense* should be detectable by means of image analysis of remotely sensed images due to the large diameter of this weed, its patches and their spatial distribution in arable land. This study has confirmed this deduction. Other weed species have to be detected using different approaches for data gathering, because a clear connection between particular spectral signatures has not been found. Under certain circumstances the classification result could be improved by including shape parameters in order to describe the patchy areas. First approaches using Fourier descriptors to describe the scale and rotation invariant of such shape parameters have been recently demonstrated by (20). Meanwhile image analysis methods for weed detection on the ground (21) offer high-resolution image datasets, which are able to detect single weed species and even single individual plants, but they are still cost-intensive and susceptible to interferences. Hence, remote sensing offers a good alternative for site-specific weed control for certain weed species, especially with regard to upcoming technical improvements in spatial and temporal resolution of airborne or space borne remote sensing sensors. For a more detailed detection of weed species, hyperspectral sensors provide high spectral resolution in a broad wavelength spectrum, which is very promising for future applications.

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