The use of radar images for detecting when grass is harvested and thereby improve grassland yield estimates

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Abstract

Cutting date and frequency are important parameters which, together with weather, soil conditions, botanical composition and fertilizer, determine grassland yields. However, cost- and time-efficient methods for recording cutting dates of grassland are currently lacking. Therefore, we developed a method for detecting cutting dates using changes in radar images of the sward surface. The combination of this method with a grassland yield model will result in more reliable and region-wide data on grassland yield estimates. For determining when grassland has been cut, robust amplitude-change detection techniques were used evaluating the amplitude or backscatter statistics before and after the cutting events in a test area in Germany. All detected cuts were verified according to *in situ* measurements and recorded in a GIS database. This method will be further adjusted to Sentinel-1 data which will then enable an area-wide and cost-efficient cutting-date detection service. The cutting frequency and yield data gained by this method are essential for optimising the use of grassland, for yield adjusted fertilisation, and the assessment of unused potential of grassland for alternative energies (e.g. biogas, solid fuel).

Keywords: radar, change detection, Sentinel-1, grassland, cutting date, forage yield model

Introduction

Although grasslands are essential for the livelihood of millions of people, accurate and area-wide data on grassland yields are generally not available. Cutting date and frequency are important parameters which can determine grassland yield, in addition to the effects on yield of climate, soil, plant composition and fertilisation. Thus, these parameters are required for yield modelling (Herrmann *et al.*, 2005). In the absence of yield data, cutting frequency is also currently used to calculate amounts of fertiliser for managed grassland (Wendland *et al.*, 2012). Therefore, a method to record dates when grass is harvested over large areas would not only improve estimations of grassland yields and sustainable use of fertiliser, but could also be relevant for questions of nature conservation. For example, moderately extensively used grassland can be detected, and the designation and linking of protected areas might therefore be improved (Herben and Huber-Sannwald, 2002). Thus, it is necessary to find a cost- and time-efficient method to detect cutting dates for whole regions or countries. Remote sensing techniques are useful to monitor surface changes (e.g. structure, height) for large areas. So far, it has been very expensive to get the necessary satellite images with high time resolutions for wide areas. The new European earth observation programme Copernicus has developed a set of satellites (called Sentinel) which will cover the entire world's land masses at least on a bi-weekly basis. The European Space Agency and the European Commission provide the data obtained with Sentinels on an open and free basis. The first Copernicus satellite, Sentinel-1A, carrying a radar system, was launched in April 2014 and radar images are now available routinely every 12 days and systematically for land monitoring (ESA, 2014). Together with the identically constructed Sentinel-1B (launch 2016) the revisit time of each point will be shortened to 6 days. This study aims to investigate the applicability of Sentinel-1 radar data for the derivation of agricultural information. It focusses on the detection of cutting dates in grassland as changes in the radar backscatter. Cutting of grass significantly affects the surface or vegetation structure of the grassland (height, density, shape) and therefore results in changes of the backscatter intensity of the radar signals. By comparing the reflection signals over a set of radar images acquired at a high temporal sampling frequency or with short time interval, cuts are expected to be detectable using change detection techniques and finally temporally classified. The application of change detection methods is therefore promising since the cuts and harvest events are temporally sampled in an adequate way.

Materials and methods

For the first phase of the project a series of radar images acquired by the COSMO-SkyMed Constellation was used, as the Sentinel-1A data were not yet available. Images of the 3, 7 and 15 October 2014 were evaluated. All images were HH polarized X-band full-resolution single-look complex slant data acquired in HImage mode. The radar images were georeferenced using a digital terrain model (Range Doppler Terrain Correction, SRTM) and reprojected to the coordination system 3-degree-Gauss-Krüger zone 4. For analysis and comparison the radar images were radiometrically calibrated. The corrected amplitude data was resampled to 3 m and transformed to the logarithmic scale (dB). Two kinds of filters were tested to reduce speckle and to improve the image quality: a multitemporal filter (window size 5×5) and an adaptive Frost filter (window size 7×7). All image processing was performed with SARscape (ENVI) and ERDAS Imagine. Radar data were exported as GeoTIFF (unsigned 8-bit) to visualize and analyse data in a GIS environment. Radar data were overlaid with a shapefile including a map of grassland plots with cutting dates from *in situ* measurements. The grey values of each image represent the strength of the radar return. For a qualitative comparison grey level statistics were calculated for each grassland plot illustrating the backscatter or intensity change before and after an area of grassland had been harvested.

Results and discussion

Alterations in the grey values of radar images showed modified radar backscatter signals due to surfaces changes in the test area (Figure 1). These changes were caused by grassland cuttings, which could be verified by *in situ* measurements. In order to estimate the separability of cut and uncut grassland, mean grey values of each image were extracted and compared. Differences in means and therefore detection of the grassland cut were usually more pronounced when an image was filtered with an adaptive Frost filter (AFF) compared to the multitemporal filter (MTF, Figure 1). Of 191 tested plots (covering in total 510 ha) 171 and 135 cuts were detected using AFF and MTF, respectively. In using AFF on radar images, cuts on plots were also detected, where MTF images revealed only small (Table 1, plot 6) or no changes (plot 3 and 5) in the means of grey values. For the comparison of the plots cut between 3 and 7 October, the MTF filter showed higher differences in the grey values corresponding to approx. 3 dB. The decreased separability was caused by an ineffective filtering using the MTF, resulting in a higher remaining noise level that corresponds to a standard deviation of up to 3.5 dB (which is in the range of the mean differences). In this case the number of images was limited and minimal. By increasing the

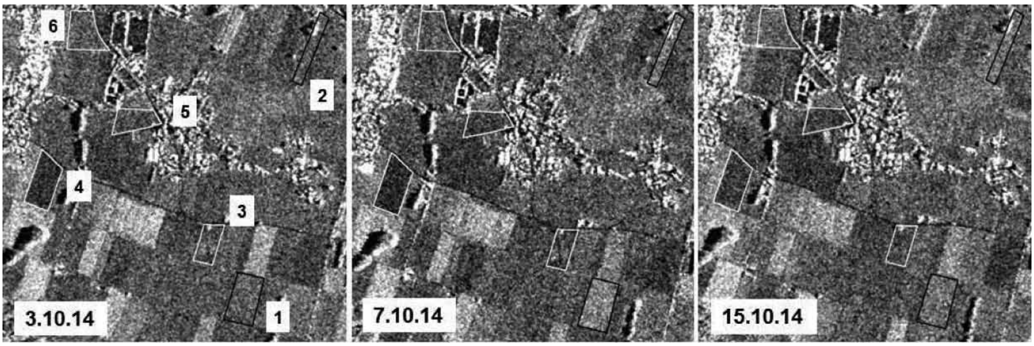

Figure 1. Alteration in radar backscatter signal/grey value (images: 3, 7 and 15 October 2014) by grassland cuts in a part of the test area; *in situ* measurements detected grassland cuts on all 6 plots during this time period (black frame: cut between 3-7 October; white: cut between 7-15 October).

Table 1. Comparison of grey values in filtered radar images of selected grassland plots; given are plot size (ha), mean grey value per plot and radar images (3, 7, 15 October 2014) filtered with multitemporal (MTF) and adaptive Frost (AFF) filter, as well as difference in means between dates.[1]

Plot	Area	Mean grey value						Differences in means between dates			
	(ha)	MTF			AFF			MTF		AFF	
		3 Oct	7 Oct	15 Oct	3 Oct	7 Oct	15 Oct	3-7 Oct	7-15 Oct	3-7 Oct	7-15 Oct
1	2.6	126	153	135	123	149	135	-27	18	-26	14
2	1.4	133	151	144	133	147	146	-18	7	-14	1
3	1.5	118	113	108	115	101	104	5	5	14	-3
4	2.4	91	90	99	85	71	95	1	-9	14	-24
5	1.6	117	108	101	112	94	96	9	7	18	-2
6	2.2	126	125	128	122	115	127	1	-3	7	-12

[1] Negative values show detected cuts by mean grey value comparison, bold numbers mark *in situ* detected cuts (plot 1 and 2 were cut between 3-7 October, other plots between 7-15 October).

number of images (for MTF) in an operational real setting the filter effect will be improved. A statistically sound analysis of separability and temporal statistics of plots will be conducted based on an increased number of acquisitions.

Conclusions

This study shows that grassland cuts can be detected using radar images of chronologically close dates. A speckle reduction with an adaptive Frost filter seemed to be more suitable to prepare the radar images for cut detection by mean grey value comparison. In the next steps, this method will be adjusted to Sentinel-1 data. After the detection process is automated, regional-wide changes of grassland management (indicated by cutting frequency) can be efficiently assessed. This automatically gained data can be integrated into a yield model.

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