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Control of land-cover during winter using radar data

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ABSTRACT: This paper examines the use of ASAR images for detecting ploughed parcels in winter. In the frame of the Common Agricultural Policy, in some Member States controls have to be carried out to ensure that farmers do not plough parcels above a given slope in winter and remote sensing may support these controls. This study examines the potential of radar time series as an alternative to optical imagery since weather conditions are not favourable for the acquisition of such imagery at this period of the year.

This study made over Wallonia was divided into two parts. The first part, based on a limited number of parcels visited in the field by the Walloon authorities, focused on the ploughing detection, while the second part was dedicated to bare soil recognition using the farmers' declared crops as pseudo ground truth. The possibility to discriminate between ploughed and not ploughed parcels was analysed using the maximum likelihood classifier applied to 3 dates SAR compositions while the discrimination between bare soil and vegetation was tested using an unsupervised classification.

The results showed that ploughed parcels were well recognised by the classifier (producer's accuracy of 75%) but also that other land uses and in particular sown land were confused with ploughed land (user's accuracy of 33%). Discriminating bare soil and vegetation parcels appears to be feasible with producer's accuracies of around 70%. Separating these two cover types should allow limiting the parcels set to be visited in the field to potentially ploughed parcels.

1 INTRODUCTION

The 2005 reform of the Common Agricultural Policy (CAP) introduced the obligation for farmers to respect the so-called Good Agricultural and Environmental Conditions (GAEC) in order to receive the full amount of aids they are entitled to according to their crop areas (Cf. Council Regulation 1782/2003). One of these GAECs which are defined by the Member States aims at protecting the soil from erosion by requiring a winter cover and/or prohibiting the ploughing of certain arable parcels.

The CAP subsidies represent around 40% of the European Union annual budget, of which approximately 20 billions are distributed to 5 millions farmers (in 2005) as direct aids for crops. Because of the importance of these amounts, Member States (MS) have the obligation to carry out various controls on the farmers' applications. For what regards the control of GAECs, the regulation foresees that on-the-spot (OTS) checks should be carried out on at least 1% of the applicants concerned (against at least 5% for on-the-spot checks of parcel areas).

Since the 1992 CAP reform, remote sensing has been used by MS for the OTS checks of areas. In 2005, on average 50% of the OTS checks of areas were carried out in 22 of the 25 MS of the European Union using some kind of remote sensing imagery. Usually high resolution imagery ($\sim$10 m pixel size) is used for checking the crop whereas parcel area measurement is carried out with very high resolution imagery ($\sim$1 m pixel size, satellite or airborne). The growing popularity of Control with Remote Sensing (CwRS) may be explained by the fact that this technique allows to carry out the OTS checks without contacting the farmer; in other words, it focuses inspections in the field to parcel with suspected or real anomalies (i.e. discrepancy between the declared area/crop and the measured area/interpreted crop). In most cases, these inspections are necessary because the remote sensing observation alone (i.e. without field visit) is not considered as a sufficient evidence for applying the penalties foreseen by the regulation.

As a result of the introduction of the 2005 CAP reform, there has been a need to assess to what extent Remote Sensing could support the control of GAECs. This study aims at addressing this question for a particular GAEC that was in force in Wallonia Belgium in 2005: the prohibition of ploughing parcels with a slope exceeding 10% between harvest and 15 February of the following year. However, ploughing for sowing a winter crop or a cover crop (green manure) is allowed. Also a shallow work of the soil is allowed, i.e. a bare soil parcel is acceptable provided it has not been ploughed. Parcels with stubble are also considered as acceptable.

In practice for the 2005 campaign, the Walloon Administration requested a high resolution optical image between 1st December 2004 and 1st February 2005 with the aim of identifying ploughed parcels over this period. A visit to the selected doubtful or problem parcels was then carried out before 15 February so as to comply with the minimum number of GAEC checks.

Since acquiring a cloud free optical image in winter may prove difficult above 45–50° of latitude N (moreover the sunlight may be too low), it is worth exploring whether ASAR data which can be acquired by all weathers could support the identification of ploughed parcels. The advantage of ASAR data is that their acquisition can be programmed so as to acquire a series of images at predefined dates over the whole period of interest.

2 OBJECTIVES

The main objective of this study was to assess the usefulness of ASAR data for identifying ploughed parcels. However due to the limited ground data set and in particular the low number of ploughed parcels, the study was extended to bare soil recognition with the idea of limiting the field inspections to bare soil parcels as the most suspected.

The parcel slope was not considered in this study as restricting the analysis to parcels with a slope above 10% could result in a very low number of ploughed parcels since farmers tend to respect the regulation.

3 STUDY AREA AND DATA

The 2005 control sites located in Wallonia were taken as study area. This is a quite intensive agricultural region with many small fields and an average parcel area of 2.75 ha. The relief variations are rather low, however steep slopes (above 10%) can be found in small parts of the region.

The declaration data for the campaign 2005 over the SOIG site were provided by Wallonia Administration as well as the vector boundaries of the parcels declared in 2004 (Figure 1). The main declared crops were permanent pastures (24% of the parcels), winter wheat (23%), corn (15%) and sugar beet (8%). Since applications are lodged in spring (around 15 May) and parcel vectors are updated by the Administration on the basis of the farmers' applications, the 2005 applications data and parcel vectors were not available at the time of the control of the winter cover (from 01/12/2004 to 15/02/2005). This constraint implies that in practice the parcels vectors of the previous campaign

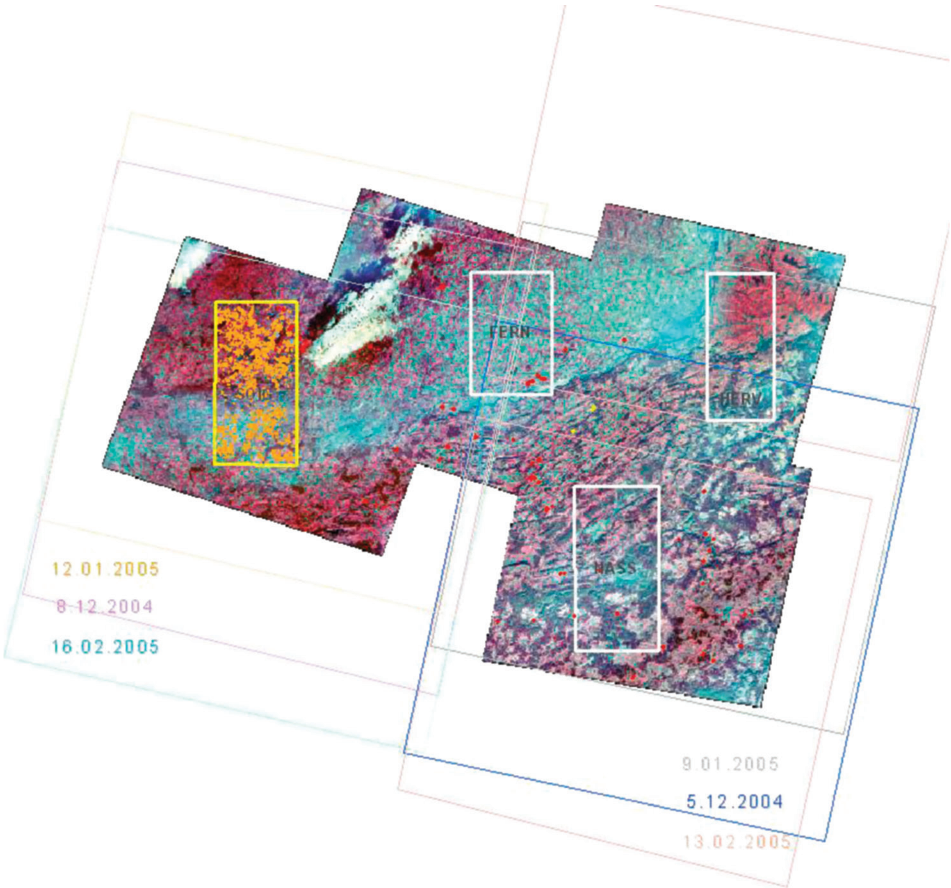

Figure 1. Study area over SPOT image. The transparent rectangles indicate the test sites. In the background the ENVISAT scenes are displayed as frames with dates.

(here 2004) have to be used for checking the winter cover of the parcels of the current campaign (here 2005), with a risk of error due to changes in parcel shape.

In addition to the declared crop of these 2829 parcels, the results of the field visits that were carried out to 74 steep parcels (slope $> 10\%$) from the whole Wallonia were supplied by the Belgian Administration. These parcels were identified as potentially non compliant (i.e. ploughed with no vegetation cover) by applying a threshold on the NDVI images beyond the sites controlled with remote sensing. Four CwRS sites were all covered with Spot images acquired in early December. The value of the threshold was fixed so as to obtain a number of parcels corresponding to the minimum number of checks required by the regulation (1% of applications). Of these 74 parcels, 10 were found as non compliant with the GAEC in the field. This low rate of "success" is probably due to the low vegetation of winter crops at this time of the year, e.g. the NDVI of winter wheat may be as low as the one of a bare soil parcel in winter.

Following the request of the Walloon Administration for a high resolution optical image over the period the 1st of December to the 1st of February, a SPOT 4 image was acquired on 3 December 2004. The Walloon Administration considered itself as lucky since obtaining a cloud free optical image in winter is known to be difficult. However at the same time the date was considered too early as parcels ploughed between 3rd of December and 15th of February would not be detected on the imagery.

No radar acquisition was programmed over this site for the winter 2004/2005. However ASAR (ENVISAT1) data acquired during this winter were available. The same acquisition period as the one defined by the Walloon Administration was used and 3 images per site with the same pass and view angle were selected at 35 days intervals (see table 1 for the details of the ASAR images). Using several dates instead of one allows a better filtering of the speckle noise. It should also allow to observe land surface changes (due to vegetation development or soil work) over the period or to confirm the response of stable parcels (e.g. permanent pasture).

While the SPOT image was orthorectified by the Walloon Administration, the ASAR data were geocoded by SARMAP using the SARSCAPE software and the 40 m grid DEM of Wallonia. The data were also radiometrically calibrated, filtered using a multi temporal gamma map filter to reduce the speckle noise and normalized with respect to the incidence angle. All images were processed to the Lambert 1972 projection.

For the whole investigated area the basic weather conditions were collected between 1st of December 2004 till 16th of February 2005 over 7 stations. The rainfalls were quite regular and no large differences were observed between the test sites.

Table 1. Radar data description.

Area	Date	Mode resolution	Satellite/Polarization	Angle	Pass
SOIG (west)	08 December 2004 12 January 2005 16 February 2005	IMS 25×25m	ENVISAT 1 VV	IS2 19,°2-26,°7	Descending
NASS (east)	05 December 2004 9 January 2005 13 February 2005				

4 METHODOLOGY

The intensity of the radar response, i.e. the backscattered energy, is dependent on how the radar energy interacts with the surface. Surface roughness close to the radar's wavelength (5.6 cm in the case of the C-band of the ASAR sensor) is the cause of strong backscattering. Ploughed soil should hence have a strong response while dense vegetation is expected to have a low response in the ASAR images. The value of the backscatter coefficient (σ_0) for each ASAR image was calculated using the following formula [1].

$$\sigma_0[\mathrm{dB}] = 10 \log_{10}(\sigma_{0\mathrm{lin}}) \tag{1}$$

where:

$s_0(\sigma_0)$ is the backscatter coefficient,
$s_{0\mathrm{lin}}(\sigma_{0\mathrm{lin}})$ is the backscatter coefficient in linear form equaled to the power of amplitude.

Then, keeping this value of σ_0 multitemporal compositions were created. The study was split into two separate parts: the first part was focused on the ploughing detection, while the second part was dedicated to bare soil recognition.

4.1 *Ploughing detection*

The time response of the parcels visited in the field was examined in order to assess whether ploughed parcels could be discriminated from non ploughed parcels, i.e. parcels with vegetation, stubble or in bare soil condition. The classification was executed separately for the SOIG (west) and NASS (east) sets of radar images.

The training set was made of 7 samples for the multitemporal image of SOIG. The samples of parcels ploughed (2), sown (2) or with stubble (2) were collected among the 74 parcels visited in the field; the sample of permanent pastures was taken from the declaration data. The samples signatures were extracted using thresholds in the spectral space so as to obtain samples as ''pure'' as possible ($+/-$ 2 or 2.5 dB from the seed s_0 of each class). The multitemporal image was then classified in 7 classes using the maximum likelihood technique at pixel level. A standard reclassification procedure was done to create a 4-classes image. The same workflow was implemented for the NASS set of radar images. Finally the majority class (ploughed, sown, stubble or pasture) was assigned to the polygons corresponding to the 74 parcels. The accuracy assessment is presented in the next section.

4.2 *Bare soil recognition*

Since the ground truth data available was very limited (74 parcels of which only 10 ploughed) and in order to take profit of the 2829 parcels of SOIG for which declaration data was available, the study was extended to the recognition of bare soil parcels. The ASAR data were classified in 12 classes using an unsupervised per-pixel classification (K-means algorithm). According to their temporal signature and with the support of the Spot image, these 12 classes were later assigned to one of the following 2 super-classes: bare soil or vegetation. The majority class was then assigned to the parcels.

The validation of the bare soil and vegetation super-classes was made using the declared crop of the 2829 parcels from the 2005 campaign. The extrapolation of the information was based on the following rule: Parcels declared with winter crops (i.e. winter wheat, winter barley, winter rapeseed), temporary grass or permanent pastures were considered as covered with vegetation, whereas parcels declared with spring/summer crops (i.e. crops sown in spring from February to May) like corn, sugar beets or potatoes were assumed to be bare soil. For these latter there is no certainty that the parcel was in bare soil condition (indeed parcels with a slope exceeding 10% should have been sown with some green cover by farmers respecting the GAEC). However, since all parcels declared in the site were considered independently of the slope, the bare soil parcels were expected to be found among the parcels declared with summer crops. Although the main target is the detection of ploughed parcels, detecting bare soil parcels is useful for the control of GAEC as it reduces the set of candidate parcels to visit.

5 RESULTS AND ANALYSIS

The use of radar data requires appropriate definition of the relations between land cover (or rather changes of land cover) and backscatter signal over the period of interest. Figure 2 displays the temporal signatures of the most frequent land covers taken from the visited parcels (sown land, ploughed land or stubble). Forest and water which have the lowest σ_0 values are not included in the study. As a general rule, vegetation has low σ_0 values whereas ploughed parcels show relatively high σ_0 values although confusion may exist between ploughed parcels and parcels sown or with stubble. Also a large difference in σ_0 value, which does not seem to be due to rainfall, can be observed between the SOIG and NASS February images. Therefore, the analysis of each temporal composition was done separately.

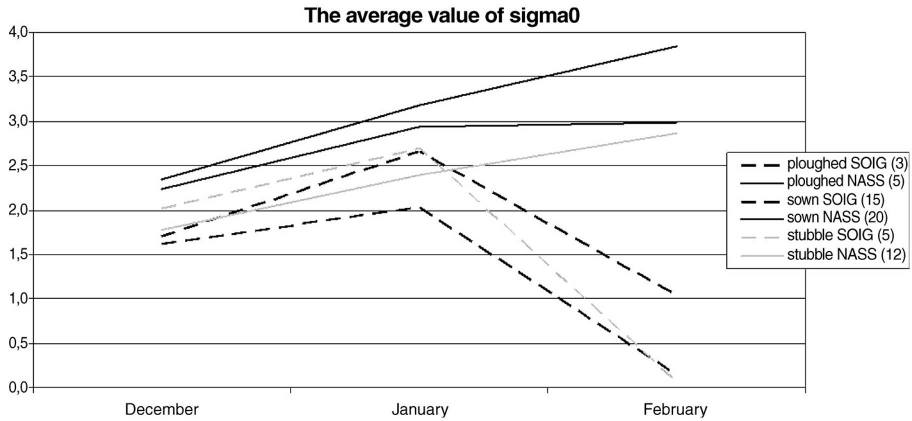

Figure 2. Average σ_0 for different types of land cover (the number of parcels used to calculate the average value of σ_0 is given in brackets).

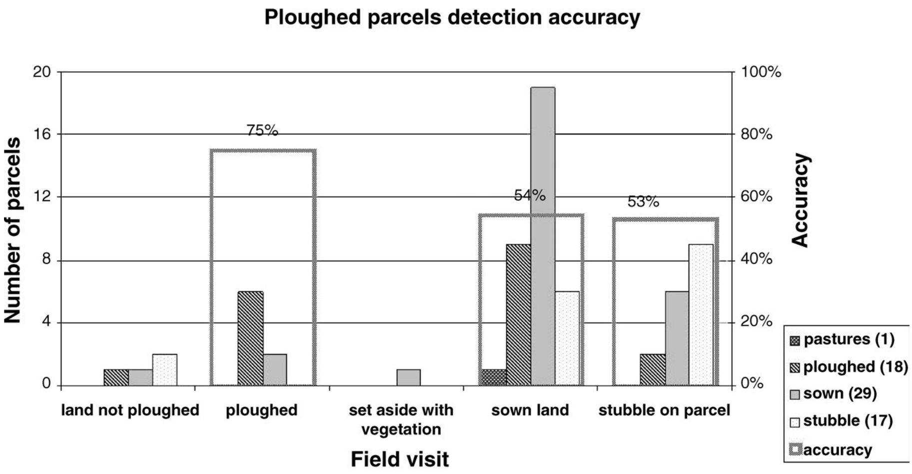

Figure 3. Validation of the ploughing detection results.

5.1 *Ploughing detection*

The per-pixel maximum likelihood classification results were checked against the ground truth data acquired between 1st and 15th of February 2005. Of the 74 parcels visited, 60 were selected to validate the classification results at parcel level: 8 ploughed, 35 sown and 17 with stubble. The rest of parcels could not be used for validation due to unclear inspection report (''land not ploughed'') or insufficient numbers of parcels for particular land covers (set aside).

Figure 3 presents the details of the classification results. Of the 8 ploughed parcels visited in the field 6 were correctly classified as ploughed, which corresponds to a 75% producer's accuracy, the remaining two being classified as sown land. ''Stubble'' and ''sown land'' were classified with 53% and 54% producer's accuracy, respectively. Confusion was observed between sown and ploughed land probably due to the different vegetation growth stages of sown land. Of the 35 parcels observed as sown land in the field, 19 parcels were correctly classified while 9 parcels were classified as ''ploughed'', probably due to the presence of very low vegetation. The overall accuracy coefficient V amounts to 57%.

Of the 18 parcels recognized as ''ploughed'', only 6 were actually ploughed while 9 were ''sown land''. On the basis of these results derived from a very limited parcel data set, an inspector sent to visit the parcels identified as ploughed on the radar imagery would found actually ploughed parcels in 33% of the cases (user's accuracy).

Moreover, the lack of information on the ploughing date and on land cover condition at the date of imagery also limited the analysis of the results (e.g. sown land could be similar to bare soil or have a developed cover).

5.2 *Bare soil recognition*

For the validation of the bare soil recognition test, a set of 2829 parcels from the 2005 campaign were used. Parcels with rare crops (i.e. crops present on less than 3 parcels

Table 2. Results of bare soil classification.

Result of classification	Number of parcels	Average parcel area [ha]	most frequent crop types
classified as bare soil	1103	3,19	silage corn, sugar beets
classified as vegetation	1614	2,69	permanent pastures, winter wheat
not classified	25	0,79	permanent pastures, silage corn, winter wheat
total	2742	2,75	

such as spring wheat, annual fruits and kitchen garden) or parcels deemed too small (i.e. less than 4 pixels of 0.25 ha) were not considered in the accuracy assessment. Finally 1103 and 1615 parcels were classified as ‘‘bare soil’’ and vegetation respectively (see table 2). Any pixel intersecting the parcel boundary was considered as belonging to the parcel. These probable mixels may have lowered the classification accuracy.

The ‘‘not classified’’ class was made up of 25 polygons with an average area of 0.79 ha, mainly permanent pastures. Generally, parcels below 1 ha (4 by 4 pixels) are difficult to classify because of mixels. The results from the classification of the winter 2004–2005 ASAR images were compared to the declared crops of the 2005 campaign. Declared pastures and winter crops were considered to have vegetation, even if scarce for winter crops. Spring/summer crops were assumed to be in bare soil condition.

Figure 4 shows the producer’s accuracy in percentage of parcels number declared as a particular crop and classified as bare soil or vegetation. Among the vegetation class, pastures were well classified (above 92% accuracy), whereas poorer results were observed for winter crops (51% for winter wheat, 35% for spelt). Of the 15 crop types assigned to the ‘‘vegetation’’ group, 9 reached a producer’s accuracy of 70% or higher. The average producer’s accuracy for the vegetation group was found to be 74% while the user’s accuracy was 84%.

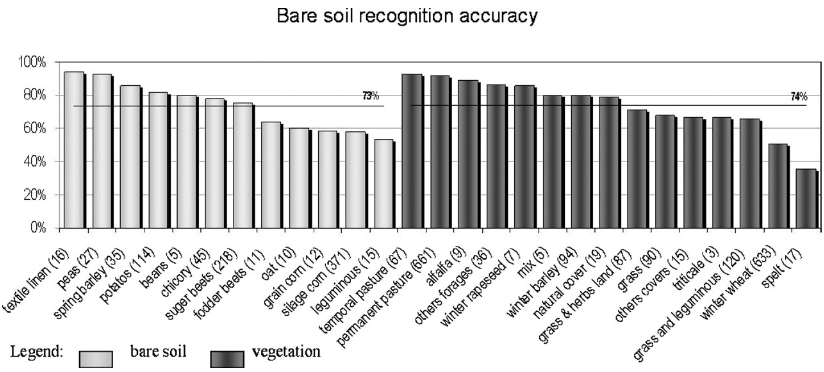

Figure 4. Accuracy assessment of bare soil recognition during unsupervised classification (in brackets the total numbers of parcels for each crop type).

Among the bare soil class, the best results were observed for textile linen and peas (more than 93% producer's accuracy) and the worst ones for corn and leguminous (less than 60% accuracy). Of the 12 crop types assigned to the "bare soil" group, 7 achieved a producer's accuracy of 70% or higher. The poorer results for summer crops may be due to the fact that the corresponding parcels may have had a green cover in winter (i.e. intercrop or spontaneous vegetation). Unfortunately information on the winter cover was not available for summer crop declared parcels. The average producer's accuracy for the bare soil group was 73% while the user's accuracy was 55%. The overall accuracy coefficient omega came to 71%.

6 CONCLUSION

This first study based on ASAR data showed that multitemporal C-band data could be used to identify ploughed parcels with a producer's accuracy of 75%. However, only 33% of the parcels identified as ploughed were actually ploughed. Confusions were observed between sown land and ploughed land, probably because sown parcels were very similar to bare soil or ploughed parcels. This study was however limited by the number of ground truth parcels (60) and the absence of information on the ploughing date and exact condition of the visited parcels.

The test confirmed also the potential of ASAR data for detecting bare soil parcels. Identifying such parcels would allow focussing the field visits to parcels that can be considered at risk with regard to the interdiction of ploughing in winter. Such parcels could be identified with a producer's accuracy of 73% with the classification method used. The average value of the user's accuracy achieved 55%. This indicates 55% probability that a parcel classified into the bare soil class actually represents that category on the ground.

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