SENTINEL-1 & SENTINEL-2 DATA FOR SOIL TILLAGE CHANGE DETECTION

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ABSTRACT

In this paper, an algorithm using Sentinel-1 (S-1) and Sentinel-2 (S-2) data to identify changes of tillage over agricultural fields at approximately *~100m* resolution is presented. The methodology implements a multiscale temporal change detection on S-1 VH backscatter in order to single out VH changes due to agricultural practices only. The algorithm can be applied over bare or scarcely vegetated agricultural fields, which are identified from S-2 NDVI measurements. An initial assessment at farm scale using in situ and S-1 and SPOT5-Take5 data, acquired over the Apulian Tavoliere in southern Italy in 2015, is illustrated. A full validation of the approach is in progress over three European agricultural areas located in Italy, Spain and France. Results will be further reported in the paper.

Index Terms— Sentinel-1, Sentinel-2, soil tillage change identification

1. INTRODUCTION

The monitoring of soil tillage practices has become of huge importance in agro-environmental sciences, due to the tillage influence on the soil water balance and crop production in particular in semi-arid regions (e.g. [1]). Tillage operations affect land processes such as soil erosion, surface evaporation, run-off and infiltration, nutrient uptake, carbon sequestration and water and carbon dioxide exchanges and loss of biodiversity [2]. Furthermore, the minimal soil disturbance (no-tillage) is one of the principles of Conservative Agriculture (CA) which has been widely promoted by FAO (FAO, 2011 [3]) in order to achieve sustainable and profitable agriculture. Although CA has been spread in several parts of the world, especially in South America and Australia (FAO, 2015), the CA required further economic support for a worldwide application [4].

The availability of Copernicus Sentinel data systematically acquired over large areas at high spatial and temporal resolution opens new opportunities for identifying tillage changes over agricultural areas, which can occur sparsely in space and in time [5].

SAR data are particularly sensitive to drastic roughness changes, related, for instance, to deep ploughing, which can be an important error source for change detection approaches aimed to retrieve soil moisture (SM) content from SAR data. For this reason, a map of soil roughness changes is also useful to improve the performances of SM retrieval at "field scale" [6].

The objective of this study is to present an approach to map changes of tillage at high resolution (e.g. ~100m) by using S-1 & S-2 data, focusing in post-harvesting tillage event identification under semiarid conditions. The algorithm is based on a multiscale temporal change detection applied to S-1 cross-polarized (VH) backscatter. The method is applied to bare or scarcely vegetated fields, identified through a thresholding of the S-2 Normalized Difference Vegetation Index (NDVI).

In the next section, the proposed methodology is described. Then, a case study exploiting S-1 and SPOT5-Take5 data acquired in 2015 over the Apulian Tavoliere (Italy) JECAM test site is illustrated. Subsequently, the validation activities based on in situ data collection presently in progress over three European sites are briefly illustrated.

2. SOIL TILLAGE CHANGE DETECTION

The proposed tillage change detection combines the use of time series of radar backscatter and NDVI, measured by S-1 and S-2 systems. Indeed, the S-1 and S-2 frequent revisit time (e.g. 6 and 5 days, respectively) is an important pre-requisite to identify agricultural practices, which are usually carried out after the harvesting and before the sowing of a new crop. The ESA S-2 product adopted in the study is the

MSI L2A, whose bands B4 (665 nm) and B8 (842 nm) needed for the NDVI calculation, are at 10 m resolution. Concerning S-1, the selected ESA product is the IW GRD at 40 m pixel size (roughly corresponding ~100 m resolution), which is geocoded and temporally filtered [7]. The reason driving the product selection is to deal with SAR images with a very good radiometric resolution, i.e., below 1 dB [8], which may enable a relatively low level of false alarms in the tillage change detection [9].

The algorithm initially selects the agricultural areas using either quasi-static land cover maps, such as and the Land Parcel Identification System (LPIS) land cover, CORINE or GlobCover, or, wherever available, updated crop maps, like those developed within the SENSAGRI H2020 EU project (http://www.sensagri.eu/). As a second step, S-2 NDVI is exploited to select bare or scarcely vegetated areas, which are provisionally identified setting a NDVI threshold to 0.3 [10]. All the agricultural areas with NDVI higher than 0.3 are obscured. The further step consists of producing a map of temporal changes of the VH backscatter at two resolutions, e.g. ~100 m (referred to as high resolution) and $5 \cdot 10^3$ m (referred to as medium resolution). Then, the maps of changes are segmented using thresholds that are selected sufficiently high in order to reduce the number of false alarms and, at the same time, not too high in order to detect most of the occurring tillage change events. Presently, the provisionally adopted thresholds are: $th_{HR} = 3$ dB and $th_{MR} = 2$ dB at 100 m and $5 \cdot 10^3$ m, respectively. The advantage of using the VH channel is that VH signal is extremely sensitive to surface roughness, though it is marginally affected by the disturbing “flashing field” phenomenon [11-12]. The final step consists of selecting among the identified VH changes those due to roughness changes only. To do so, a multiscale approach is beneficial because tillage practices have an important impact at point scale, whereas their effect can be disregarded at a medium resolution scale. As a result, tillage practices generate a contrast between backscatter observed at “field” and medium scale. This is the contrast that is finally identified by the algorithm. It is worth noting that the VH change (ΔVH in dB) can be positive or negative. Table 1 summarizes the events associated to the multiscale thresholding of VH and their interpretation in terms of tillage/no-tillage change identification. Events 2 and 4 correspond to VH changes due to tillage practices.

The output product is a tillage change binary mask at approximately 100 m resolution, which can be cumulated to produce a tillage change map every 2-3 months. The flowchart reported in Figure 1 summarizes the proposed tillage change detection algorithm.

2.1. Case study

A case study to illustrate the approach is provided by a time series of S-1 and optical SPOT5 images acquired from April to beginning of November 2015 over the Apulian Tavoliere site. The SPOT5 images were acquired every 5 days in the framework of the SPOT5-Take5 ESA-CNES experiment [spot-take5.org/client/#/home].

Table 1. Thresholding of VH backscatter changes at High (ΔVH_{HR}) and Medium Resolution (ΔVH_{MR}).

Event	Thresholding	Reason of Change
1	$-th_{HR} < \Delta VH_{HR} < th_{HR}$	no change
2	$\Delta VH_{HR} > th_{HR}$ AND $-th_{MR} < \Delta VH_{MR} < th_{MR}$	roughness change likely due to ploughing
3	$\Delta VH_{HR} > th_{HR}$ AND $\Delta VH_{MR} > th_{MR}$	soil moisture change likely due precipitation
4	$\Delta VH_{HR} < -th_{HR}$ AND $-th_{MR} < \Delta VH_{MR} < th_{MR}$	roughness change probably due to seedbed preparation after ploughing

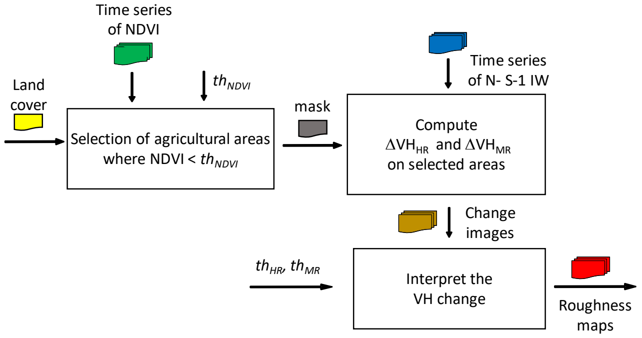

Figure 1. Flowchart of the tillage change detection algorithm.

In the Apulian Tavoliere, it is located the Segezia experimental farm, for which detailed information on agricultural practices carried out in 2015 are known. The farm stretches over an area of approximately 2x2 km [14], and the analysis has been focused on two fields, namely field F01 and F11. In 2015, field F01 was cropped with wheat, while field F11 with oat. Both fields were harvested at mid-June.

NDVI time series for both fields are shown in Figure 2. It can be observed that NDVI is below 0.25 from June 22 onward (i.e. after harvesting).

Figure 3 shows the S-1A VH time series observed at $\sim 100\,m$ resolution over field F01 (red line) and field F11 (blue line); in addition the S-1A VH backscatter averaged at medium resolution (black line) is also reported. After harvesting, both field F01 and F11 show a VH backscatter lower than -20 dB. Then, between July 6 and July 18 (see the vertical lines on Figure 3) an important VH backscatter change (larger than 3 dB) is observed. A second minor increase, due to a precipitation event, is observed between July 18 and August 11. On the same figure and in the same period, the VH time series estimated at medium resolution shows a fairly smooth behavior as compared to that estimated at field scale. In particular, between July 6 to July 18, the VH change is significantly lower than 2 dB.

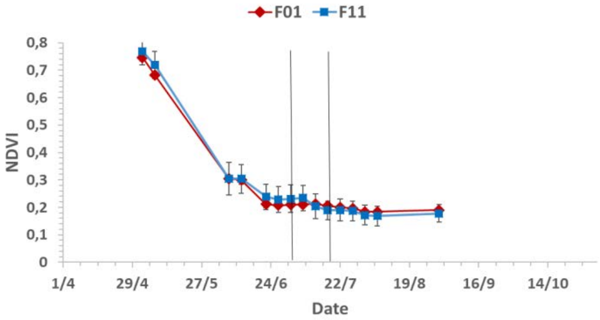

Figure 2. Temporal behaviour of SPOT-5 NDVI in 2015 over the F01 and F11 fields of the Segezia farm.

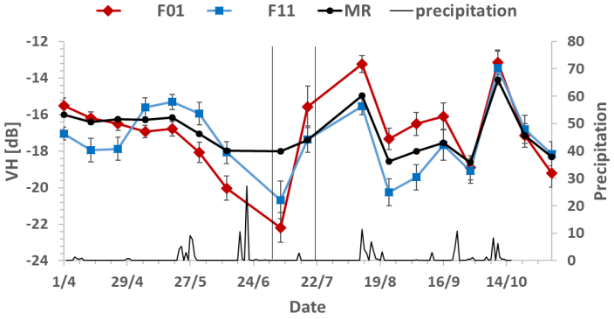

Figure 3. Temporal behaviour of VH S-1A at ~100 m resolution over fields F01 (red line) and F11 (blue line) of the Segezia farm. The VH temporal behavior at medium resolution (MR) (black thick line) and the precipitations (black thin line) are also reported.

Therefore, the identified abrupt VH change can be attributed to tillage changes, which is confirmed by in situ data. It is worth mentioning, that on Figure 3, the VH increase observed between July 18 and August 11 takes place both at high and medium resolution, hence implying that it is likely due to moisture changes (as indeed it is the case).

2.2 A map of roughness changes at farm scale

Figure 4 shows the Segezia farm (border in yellow) imaged by the SPOT5 and S-1A systems. Figures 4a and 4b are SPOT5 false color composite images (i.e. R=NIR, G=Red, B=Green) acquired on July 7 and 17 (~10m resolution), respectively. Figures 4c and 4d are S-1A VH images acquired on July 6 and 18 (~100 m resolution). Fields F01 and F11 are circled in red and blue, respectively. On the optical images, vegetated fields appear in red, bare fields are light cyan. The fieldworks determine a change of the colour from light to dark cyan, due to a small decrease of the NIR reflectance component. On the S-1A VH image the ploughed fields become brighter indicating a significant increase of VH backscatter. The tillage change map derived at farm scale by using the proposed algorithm is reported in Figure 4e.

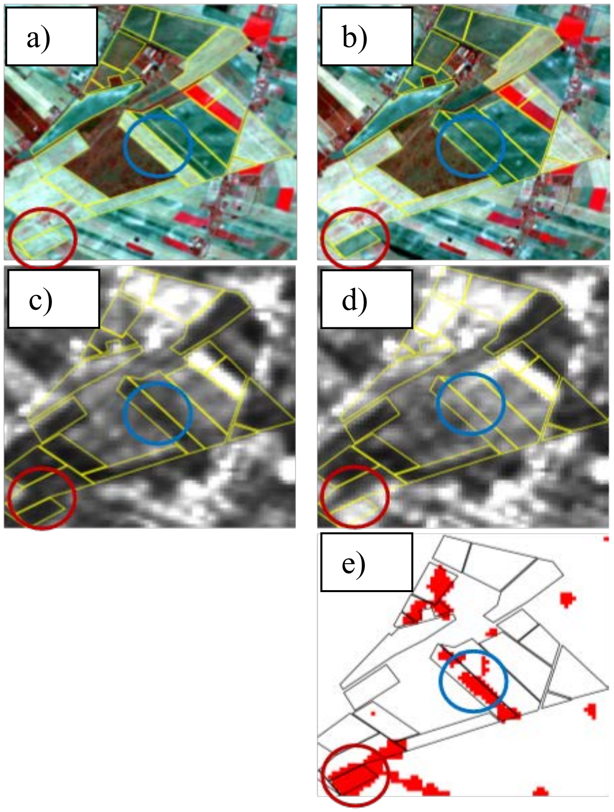

Figure 4. The Segezia farm (Apulian Tavoliere) on the SPOT5 and S-1A VH images. The fields F01 and F11 are highlighted in red and blue. a): SPOT5 on July 07; and b) July 17. c): S-1 VH on July 06; and d) July 18. e): VH change on July 6-18.

A larger map of tillage changes taking place between July 6 and 18 is shown in Figure 5. The map identifies a number of areas (red spots) of various dimensions, which are predicted as ploughed fields. Red areas do not appear on the northeastern and southeastern part image likely because these areas are either forested or cropped with vineyard and olive groves.

3. VALIDATION AND TEST SITES

The proposed algorithm will be extensively validated and, eventually, improved particularly with respect the tuning of thresholds both for NDVI and ΔVH.

Ground data will be collected over three European sites and used to evaluate the accuracy of tillage change identification in terms of percentage of events correctly recognized.

The test sites (Figure 6) are: the Apulian Tavoliere in the Puglia region (Italy); the Castile and León region (Spain) and the Lamasquère site in the Occitanie region (France). The three sites are intensively cultivated with winter and summer crops and a high number of fields are tilled.

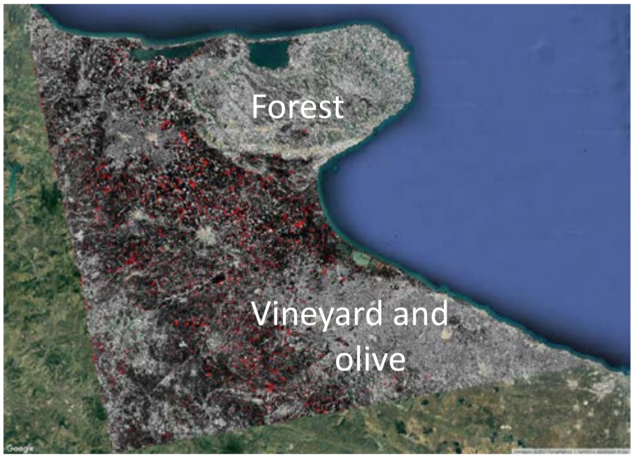

Figure 5. Soil tillage change map derived from VH S1 images referred to July 6-18, 2015 period. Red areas are predicted to be ploughed fields.

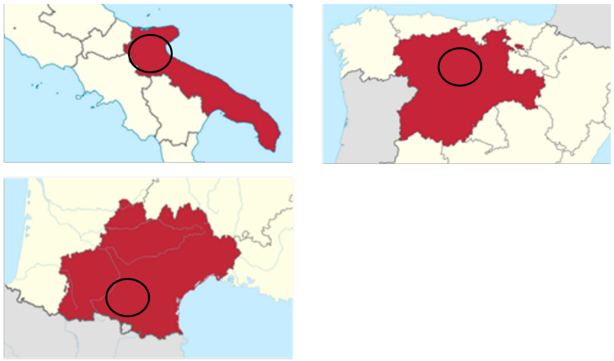

Figure 6. Test sites of agricultural fields (inside the black circles) selected for the tillage change detection. Top left: Apulian Tavoliere (Italy). Top right: Castile and Leon (Spain). Bottom left: Lamasquère in Occitanie (France).

Over the Apulian Tavoliere area 450 fields have been already surveyed in 2017 and tillage changes recorded. Per each field, the collected data include information such as geographical coordinates, dates and type of tillage (e.g. ploughing, disk harrowing, rolling), presence of residues, etc.). Similar activities are in progress over the other sites and all the data will be stored in a common repository.

Concerning satellite data, both S-1 (IW- GRD products) and S-2 (MSI-L2A products) acquisitions are continuously collected over these sites since March 2017.

5. SUMMARY

A new classification algorithm detecting soil tillage changes from S-1 and S-2 data has been illustrated and initially assessed at farm scale. The algorithm produces tillage change binary masks at $\sim 100m$ resolution. The proposed methodology consists of a multiscale temporal change detection applied to S-1A VH images collected over bare or scarcely vegetated surfaces, which are identified by means of S-2 NDVI. A case study at farm scale located on the Apulian Tavoliere in 2015, has been illustrated. An extensive ground data collection is in progress over three European sites and the data will be used for validating and improving the algorithm.

6. ACKNOWLEDGEMENTS

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