MULTI-TEMPORAL QUAD-POLARIMETRIC CHANGE MATRIX FOR AGRICULTURAL FIELDS MONITORING

Cristian Silva[1]*, Armando Marino*[1]*, Juan M. Lopez-Sanchez*[2] *and Iain Cameron*[3]

[1]University of Stirling, Scotland, United Kingdom
[2]University of Alicante, IUII, Alicante, Spain
[3]Environment systems Ltd, Aberystwyth, United Kingdom

ABSTRACT

In this work, a new way to extract temporal polarimetric information from a stack of co-registered images is presented. This method considers not only polarimetric evolution of consecutive acquisitions but also includes polarimetric changes between every image with respect to the rest of images in the stack.

The methodology is tested for different crop types exploiting C-band quad-polarimetric RADARSAT-2 data over rice fields in Seville, South-West of Spain and the Indian Head in Canada as part of the Agrisar 2009 campaign.

1. INTRODUCTION

Traditionally, the extraction of polarimetric observables is done from the covariance or coherency matrices either at pixel or at parcel level. This process is repeated for each image acquired and the polarimetric observables are plotted as time varying variables.

The proposed methodology uses a polarimetric change detector as the core of its operation. It is based on the analysis of a pair of co-registered acquisitions by optimizing the pixel-wise difference of their covariance matrices.

The optimization process uses the diagonalization of this difference matrix as described in [1,2], to find the set of unitary vectors that causes the largest polarimetric change between the pair of images.

The output provides information about the type and intensity of the scattering mechanisms that were added and/or removed from one image to the other. This can also be seen as finding the scattering mechanisms that increased and decreased between images.

The scattering mechanisms are represented as RGB composites where each element of the eigenvector takes a colour and the contrast of the image is modulated through its associated eigenvalue.

The methodology is initially applied to observe the temporal evolution of one crop type and subsequently the potential for further applications is introduced including usefulness for crop type mapping an crop parameters retrieval.

2. TEST SITE AND DATASETS

The methodology is applied to the rice fields located near Seville, in the south of Spain. Ground truth for six parcels was gathered for the season running from May to October of 2014, including phenological evolution, height of plants and length of the leaves, among others.

The satellite data used is composed of 16 C-band quad polarimetric Radarsat-2 Images acquired with three different incidence angles during the 2014 season, covering all the campaign.

2.1. Interpretation of crop evolution based on polarimetric changes

The crop evolution can be described as a continuous change of the crop morphological parameters, including changes in the plant's height, leaves size and the plant's density and orientation, among others.

Since the change detection procedure compares pairs of images to find polarimetric changes between them (e.g. scattering mechanisms added and removed in the scene), we can associate the polarimetric changes with the changes in morphological parameters that drive the crop evolution. Previous work introducing this concept has been presented in [3].

2.2. Multitemporal change matrix

Since the information about the crop evolution is obtained from the analysis of pairs of images, it is possible not only to evaluate changes from consecutive images (as traditionally done) but is also possible to see the difference of an image with respect to all the other images in the stack. This process identifies the change of the scattering mechanisms throughout the season.

The information can be represented by a square matrix, where each element of the diagonal represents one of the acquisitions. The off-diagonal elements correspond to the evaluation of polarimetric changes between images.

The upper triangular part represents the increase in scattering mechanisms between a given pair of analysed images and the lower triangular part represents the corresponding decrease. It is worth noticing that the unitary vector that represents a scattering mechanism is again represented as an RGB composite using its associated eigenvalue to modulate the contrast.

The result of this process is shown in the figure 1. The figures (a) and (b) represent the change matrix for two different parcels and figure (c) represents a change matrix obtained from averaging the change matrices of the six parcels where ground truth is known.

A remarkable characteristic of the matrix is that its colours and intensity provide information of the scattering mechanisms during the season and they can be interpreted as a conventional RGB composite, that is, red for double bounce, green for volume and blue for surface scattering.

It can be seen from figure 1(a) and 1(c) that these change matrices have minor differences corresponding to the normal differences in the parcel's evolution. However, the general patterns as well as the colours and intensity are preserved. The parcel (b) on the other hand, presents atypical evolution of scattering mechanisms.

It is important to notice that because the matrix contains separately increase and decrease in time of each scattering mechanism, the analysis of parcel evolution can be done for each mechanism separately. This results in being able to compare for instance if the double bounce in a parcel due to the plants emergence above the water level is delayed in time with respect to a reference parcel.

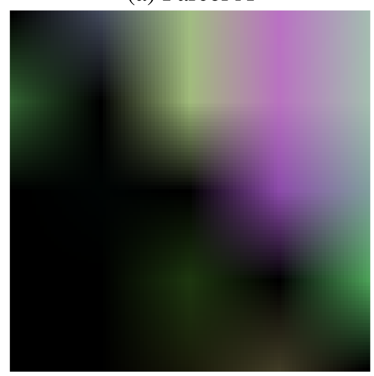
The purpose of obtaining an average change matrix as in the figure 1(c) is to obtain a reference of a rice parcel such that one can compare any parcel against this reference and analyse that parcel's evolution during the season, even if no ground truth is known for that parcel.

Furthermore, since each row and column of the matrix is associated to a day of the year, the change matrix immediately tells the scattering mechanism present at any given moment during the season (it can also be associated to a ground truth variable e.g. phenological stage at a particular day).

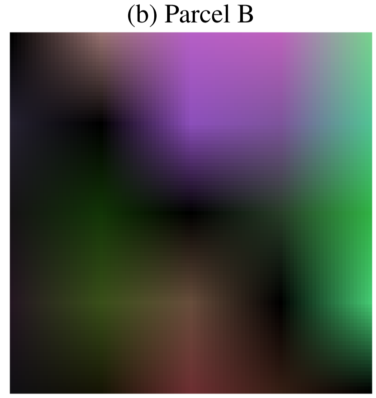
An initial method tested to analyse differences between parcel's evolution is by determining the distance between the Frobenius norm of each parcel's change matrix with respect to that of the other parcels as shown in figure 1(d).

As an interesting result, the distance of the Parcels B and F (not shown here due to lack of space) compared to the other parcels and the average parcels is the largest. This can be seen analysing their change matrices, as the evolution was delayed. It can also be confirmed when looking at the yield from ground data of these parcels.

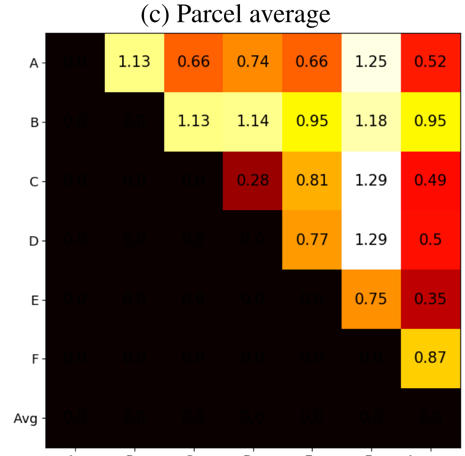
(a) Parcel A



(b) Parcel B

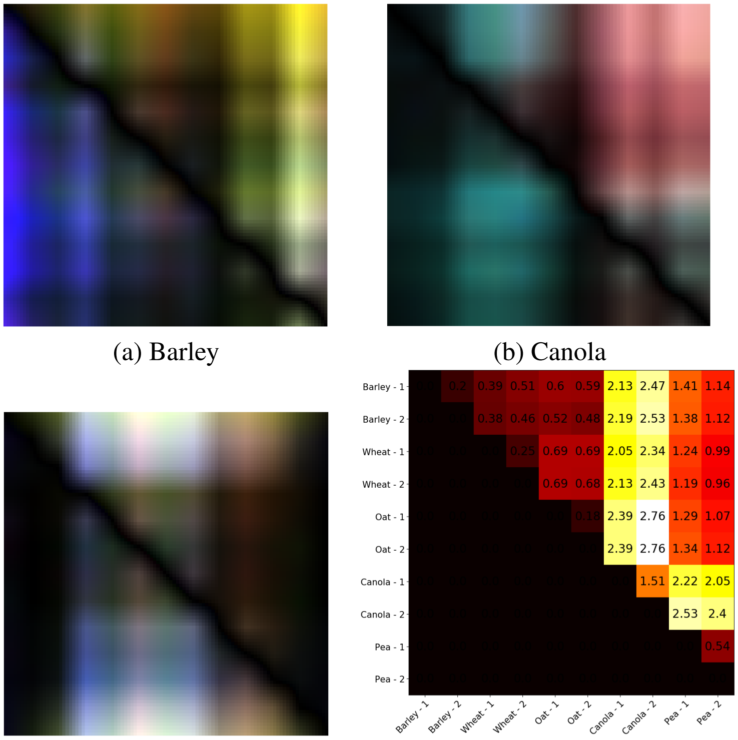


(c) Parcel average



(d) Heatmap of Frobenius distances between the change matrices of 6 rice fields

Fig. 1. RGB composite of the rice fields change matrices. RADARSAT-2 quad-pol data season of 2014



(a) Barley

(b) Canola

(c) Pea

(d) Distance between crops

Fig. 2. Change matrices for different crop types. The abnormal bright and dark rows and columns in (a), (b) and (c) are a consequence of the incidence angle. Figure (d) presents a Heatmap of Frobenius distances between the change matrices of different crop types

2.3. Change matrix for different crop types

The same methodology was applied to several crops including cereals such as barley, oats and wheat and other crop types such as canola, and field peas. The crops are located in the Indian head in Canada, where ground truth was gathered as part of the Agrisar 2009 campaign. A stack of 10 Radarsat-2 quad pol images was analysed, and the resulting change matrices are shown in the figure 2

It is possible to see by visual inspection how different the resulting matrices are for each of these three crop types and to that of the rice crop presented in figure 1. These differences, described by the colours that represent the scattering mechanisms, the contrast of the image and the times when specific events occur, can be used as a feature for crop type classification.

As a basic preliminary test, again the Frobenius distance between 10 different crops is shown in figure the 2(d).

It can be seen how the distance between the cereal crops (Barley, Oats, Wheat) is shorter compared to that of the canola or field peas. Similarly, distances from and to canola and peas are separable between them.

2.4. Further applications

The following applications are being implemented but not included here due to lack of space:

- Extraction of the information contained in the matrix provides new features for crop type mapping applications.
- Initial results confirmed the correlation of the volume scattering mechanism contained within the matrix and the phenological stage provided by the ground truth. Further experiments are being developed to also corroborate correlation with the leaf area index.
- The effect of the incidence angle during the season can be clearly seen using the change matrix, explaining which scattering mechanism is affected at what point in time. This can be used to analyse incidence angle normalization techniques over agricultural fields.
- The matrix size increases with every new acquisition. Therefore, real time monitoring can be achieved by extracting information from the matrix when new data is obtained.

3. ACKNOWLEDGEMENT

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4. REFERENCES

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