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FROM SPACE TO LAND MANAGEMENT

remote sensing technologies supporting sustainable development and natural resource management

UNIVERSITÀ DEGLI STUDI FIRENZE

Session Remote sensing application in agriculture
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Bracco Classroom - Chairman: Mario Gomarasca

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Image Segments Vs Cadastral Maps: Effects in Monitoring Rice by Remote Sensing

IIntroduction

Nowadays remote sensing techniques are widely used in agricultural applications due to the high availability of free pre-processed dataset, leading to the development of monitoring services (web or standalone).
The management and monitoring of agricultural areas by Regional and European Administration is currently based on a sub-division of territory in cadastral parcels, which however do not necessarily define homogeneous surfaces. In this condition, the spectral signal belonging to the same parcel aggregated to generate a single average temporal profile for the whole parcel, doesn't match the real management of parcels. In fact, many parcels are internally divided in sub-parcels, possibly farmed differently in terms of crop type or timing of operation or both. Signal aggregation, in these situations, generates an unreliable average spectrum inconsistent with real conditions of the sub-parcels.
The focus of this work was to investigate differences between these two approaches, comparing maps of average spectral behaviour generated by aggregation of signal at cadastral level and the one generated by aggregation based on a segmentation algorithm able to identify sub-parcels average behaviour based on NDVI (Normalized Difference Vegetation Index) and NDWI (Normalized Difference Water Index).

Materials and Methods
This work was based on twenty-two optical satellite images representing at-surface reflectances from ESA (European Space Agency) Sentinel-2 Level 2A (S2) and NASA (National Aeronautics and Space Administration) Landsat-8 C1 Level 2 (L8) collections, jointly used. The L8 dataset was resampled at a geometrical resolution of 10 m to be consistent to the S2 one. A study area of 8.7·103 ha in Piemonte Region, mainly devoted to rice cultivation, has been investigated along the 2016 crop season deriving NDVI [1] and NDWI [2].

$$NDVI = \frac{\rho NIR - \rho RED}{\rho NIR + \rho RED} \qquad [1]$$

$$NDWI = \frac{\rho GREEN - \rho NIR}{\rho GREEN + \rho NIR} \qquad [2]$$

Where ρ NIR, ρ RED, ρ GREEN are reflectances respectively for Near Infrared, Red and Green bands.
Monitoring of rice managed areas allows to easily identify a typical feature of this crop: the pre-seeding flooding step in which rice fields are submerged. So, as NDVI is suitable for monitoring vegetative vigour of plants, NDWI generated with ρ NIR and ρ GREEN is more suitable detecting water surfaces like the pre-seeding submerged fields. Subsequently to detect homogeneous portions of parcels in terms of vegetative vigor variations during the season, a region-based segmentation method has been performed on the NDVI series into the free software Orfeo ToolBox (OTB). Then, for each index, a single multitemporal profile has been generated for each cadastral parcel and then compared with the segment-based profile one. Using as input a time series of NDVI for the 2016 season, pixel variation in the series has been aggregated in a mean value: if difference between adjacent pixels was under a threshold of 0.1 a homogeneous sub-parcel was created. A mean-shift algorithm with a spatial radius of five pixels and a range radius of 0.1 has been used to generate an homogeneous minimum region size of twenty-five pixels (0.25 ha, minimal area able to be measured with geometric resolution of L8 and S2 ensuring the radiometric homogeneity of the central pixels). Range radius identifies the spectral difference between pixels.

The Mean Absolute Error (MAE) for each index has been aggregated as showed in [3]:

$$MAE = \left(\Sigma \mid SM_i - PM_i \mid \right) / n \qquad [3]$$

Where SM_i is the generic index mean value for the segmented polygon, PM_i is the generic index mean value for parcel and n is the number of images. To better describe parcels and segmented polygons features, the Shape Index (SI, [4]) has been calculated in SAGA GIS.

$$SI = P / (2 * (p * A)^{0.5}) \quad [4]$$

Where P is the polygon perimeter and A is the area.

Successively, to detect where and when differences between SM_i and the PM_i are located, the signal aggregation maps have been tested with a spatial and temporal investigation for MAE. Spatial investigation lead to the computation for each time level in the series generating an average value of $MAE_{x,y}(t)$. As result, temporal profile for $MAE_{x,y}(t)$ identifies when (which date) maximum differences concentrate. The temporal analysis of $MAE_{t(}x,y)$ along temporal profile of each pixel generate as result a map of MAEt(x,y) that shows where maximum differences concentrate.

Results and Discussions

Comparison between SM_i and the PM_i maps for the year 2016 proves that this method is more reliable in monitoring and detecting differences between any sub-parcel behavior. In fact, number of homogeneous surface portions increases from 5787 (number of cadastral parcels) to more than 8000 (homogeneous segmented polygons). Moreover, specific features like mean values for area and SI, change respectively from 9594.38 m2 and 1.71 for cadastral polygons to 6823.49 m2 and 1.84 for segmented ones. It was observed that as the SI increases the shapes change from the perfect plane isotropy to the highest anisotropy in which a dimension is bigger than the other one. Focusing on segmented polygons, mean SI value shows that more anisotropic polygons have been generated identifying parcel edges in which the average index (NDVI or NDWI) behaviour is sensitively different from the central part of the same parcel. Regarding to $MAE_{x,y}(t)$, the maximum differences (0.07 for NDVI and 0.11 for NDWI) are respectively detected on the 19/04/2016 (start of growing season) and 21/05/2016 (first flooding step) underlining that within the same cadastral parcel, farming operations, flooding step and plants development occurred in different times.

Map of $MAE_t(x,y)$, otherwise, makes possible to detect unfarmed surfaces where the value is the highest because SM_i was able to identify terrain features not included in PM_i as headlands and service roads areas where the spectral behaviour is completely different. Moreover, map of $MAE_t(x,y)$ highlighted sub-parcels where differences between many rice cultivars (and related different farming techniques) in the same cadastral parcel are located.

Conclusions

As result of this methodology it is possible to identify homogeneous surfaces usable to obtain unique information related to macro-phenology and water content of crops and fields at single sub-parcel scale. Regarding $MAE_{x,y}(t)$, this was helpful to detect that maximum differences in time are concentrated at the start of growing season (mid-April for NDVI, mid-May for NDWI) underlining differences in sub-parcels management. Moreover this could be helpful, jointly to $MAE_t(x,y)$, to detect sub-parcels involved by dry seeding techniques, characterized by different spectral behaviour. The calculation of SI on the SM_i allowed to identify some terrain infrastructure (headlands, service roads) eventually not mapped by cadastral cartography, permitting their exclusion from the computations directly related to crops phenology.

These steps must be mandatory in a processing workflow oriented to the development of a reliable monitoring service, constantly updated (because based on regularly acquired images) and not based on cadastral data, often obsolete and not related to the real state of the areas, usable by Regional Administrators, farmers, and European agriculture managers.

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