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SAR multi-frequency observations of vegetation in agricultural and mountain areas

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Abstract

In this paper, the potential of space-borne Synthetic Aperture Radar (SAR) sensors combined with optical ones has been exploited by analyzing datasets collected on two vegetated areas in Italy, by using COSMO-SkyMed X-band and Sentinel-1 C-band SAR, PRISMA hyperspectral and Sentinel-2 multispectral imagery, combined with field measurements acquired with spectroradiometers. On the mountain area in Alto Adige, a biomass estimation approach was developed by combining Sentinel-1 SAR and spectroradiometer hyperspectral data. On Val d'Elsa area in Tuscany, COSMO-SkyMed StripMap HIMAGE and Sentinel-1 Interferometric Wide swath mode SAR data have been integrated with Sentinel-2 imagery for improving the classification of agricultural crops. Convolutional Neural Networks (CNN) have been used for the classification of agricultural areas using these three sensors.

1 Introduction

Agricultural activities are facing severe challenges due to the progressive reduction of land devoted to cultivation, industrial pollution, increasing urbanization, dumps and so on. In the meantime, human population is increasing and its alimentary needs will necessarily increase. As a consequence, research efforts aimed to the increase of resources, protection of the environment, and maximization of the final yield will play a considerable role in agriculture development.

The focus of the paper concerns the use of satellite data (optical and microwave) for monitoring vegetation cover and water status along with soil moisture temporal evolutions, in order to improve the knowledge of the water cycle in agricultural and mountain areas. Both local and regional monitoring are carried out in order to investigate different spatial scales.

The monitoring of natural surfaces with Synthetic Aperture Radar (SAR) sensors, and in particular with COSMO-SkyMed (CSK, at X-band) and Sentinel-1 (S-1, at C-band), could exploit the synergy between these two frequencies and with optical sensors, making possible the collection of information on different types of vegetation, their biomass and water conditions. Moreover, in case of scarce vegetation cover, especially at C-band, the soil moisture conditions can also be investigated. The synergy between C- and X-band is essential for this purpose, since C-band backscatter shows a noticeable sensitivity to the soil water content, even in case of vegetated surfaces [1], whereas X-band signal shows an evident sensitivity to crop geometry and biomass [2,3].

The integration of C- and X-band data collected from S-1 and CSK systems together with optical data collected from hyperspectral sensors on some test areas in Italy has been exploited, in order to estimate the main geophysical parameters of soil and vegetation, such as soil moisture and vegetation biomass. This work is part of the research project ALGORITMI, funded by ASI [4].

2 Results

An assessment of the sensitivity of the SAR signal to the soil and vegetation parameters was carried out on two test sites in Italy: a pasture-land in the Alpine region of Val Mazia, Alto Adige, at 1500 m a.s.l., and an agricultural area in Val D'Elsa, Tuscany.

Over Val Mazia a retrieval approach based on the Support Vector Machine (SVM) methodology, which was already tested in this area using C-band data from ENVISAT ASAR data, was carried out. Biomass estimation approach was developed by combining S-1 SAR and spectroradiometer hyperspectral data. Hyperspectral bands were resampled to match those of ASI's PRISMA mission. Feature selection was applied to hyperspectral bands to determine which are the most sensitive frequencies to biomass estimation, based on genetic algorithm. A total of 52 bands were selected out of the 239 available: 8 in the visible range, 3 red edge, 9 in the NIR range, and 32 in the SWIR range. These bands were added to the information extracted from the SAR data. SVM regression model was fed with all collected inputs and validated for the testing dataset, using the selected bands only and all the featuresValidation was done by comparing predicted values with field samples from 2017, 2018, and 2019 campaigns in the meadow-land. In table 1, the main statistical parameters (R^2, RMSE and MAE) are shown for simulation1.

	R^2	RMSE (kg/ha)
Tested 239 bands	0.779	739
Tested 52 bands	0.792	681.2

Table 1. R2, RMSE, from prediction models based on differ training datasets

On Val d'Elsa area, CSK StripMap HIMAGE and S-1 Interferometric Wide (IW) swath mode SAR data have been integrated with Sentinel-2 (S-2) optical imagery for improving the classification of agricultural crops. Convolutional Neural Networks (CNN) have been used for the classification of agricultural areas using these three sensors. The results obtained from S-2 images show, as expected, the best accuracy (99.73%). However, the availability of optical images is significantly affected by clouds, cloud shadowing, rainfall and night-time. On the contrary, SAR images are independent from weather and sunlight, as well as available on a regular basis. The multi-temporal sequence of CSK imagery provides a valid alternative, scoring an accuracy of 94.56% and outperforming the result achieved with S-1 (85.16%). In figure 1, the ground truth is compared with the classification maps obtained with CNN method using CSK and S-1.

3 Conclusions

SAR and optical data have been integrated to obtain accurate classification maps and vegetation biomass estimates. Machine Learning methods have been tested for both classification and biomass estimation by means of multi-sensor multi-temporal data from CSK, S-2, S-1, and spectroradiometers. SVM applied to meadows fields in Mazia Valley provided accuracy estimates of dry biomass with R^2=0.79, RMSE=681 (kg/ha), with little differences between regression models using all the bands, and a reduced number, proving sensitivity analysis relevance. CSK data represent a valid alternative to S-2 data for classification purposes, wherever the latter are not available. 1-dimensional CNN (1d-CNN) have been trained and validated for the classification of agricultural areas. The classification accuracy with S-2 data is 99.73%, whereas 94.56% with CSK and 85.16% with S-1.

4 Acknowledgements

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5 References

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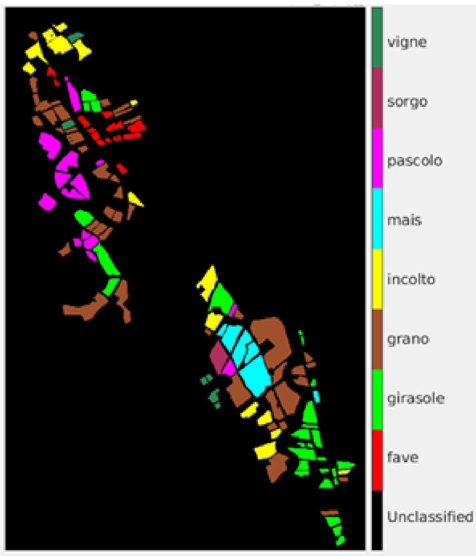
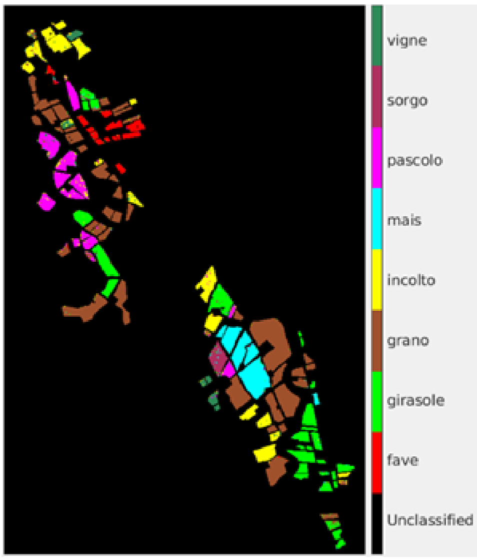
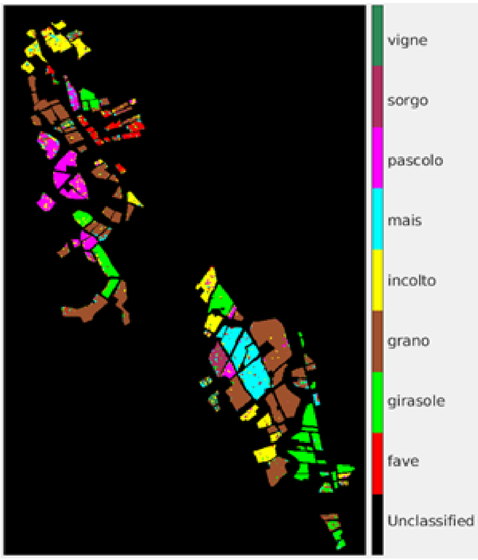


(a)



(b)



(c)

Figure 1. Comparison of (a) ground truth reference map with classification maps obtained using (b) CSK and (c) S-1.