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Innovative Synthetic Aperture Radar Products for the Management of Land and Water

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Abstract—**The use of satellite data for land management optimization is extremely powerful in low-income countries, where in situ measurements require costly and time-consuming solutions. In this paper we present the innovative results of a pilot-project that used high resolution synthetic aperture radar (SAR) data for agriculture physical parameter retrieving. In particular, we present land use maps and a vegetation index evaluated at small scale, thank to the use of Cosmo-Skymed data.**

Synthetic Aperture Radar; agricolture; hydrologic modeling.

I. INTRODUCTION

In Sub-Saharan Africa, most of the population depends on agriculture [1]. The climate is characterized by extreme conditions, that strongly influence the land productivity. Hydrologic models can be very useful for facing these conditions and driving decisions on resource management. To this aim, the knowledge of the land characteristics (topography, land cover, eroded and vegetated areas, and so on) is crucial [2]. Remote sensing instruments can be a precious support for retrieving this information. In particular, with the launch in 2007 of the Cosmo-Skymed synthetic aperture radar (SAR) sensor, new opportunities for using SAR data in small-scale agriculture were born. The sensor, with spatial resolution of the order of few meters, acquire a huge amount of physical information, that could be used by farmers and decision makers for improving the land productivity.

The use of SAR data for agriculture applications has been so far limited by several factors: the limited spatial resolution, the absence of interpretation instruments, and, mainly in low-income countries, the cost of the images. In this paper we present a new approach devoted to remove the obstacles to the use of SAR data for agriculture in low-income countries, producing low-cost or no-cost products. The project had the non-secondary goal of involving students and volunteers in Europe and Africa, creating human and cultural exchanges.

A pilot project was developed in Burkina Faso, in the frame of a research project approved by the Italian Space Agency (ASI). A set of data was acquired on the Yatenga region, characterized by a semi-arid climate, with the alternation of a rainy (from June to October) and a dry season (from November to May). Burkina Faso is one of the poorest countries of Western Africa, where almost 80% of the population lives from agriculture and the semi-arid climate poses important challenges to farmers and cooperative of local people.

The project was developed with the cooperation of European and local partners, with the common goal of obtaining useful information for the land management. In this paper, in particular, we focus our attention on a processing chain devoted to produce value added maps with physical results easily readable for non-expert users [3]. The procedure is based on two steps: a multi-temporal filtering of the stack of SAR data for reducing the speckle and the definition of physical based indexes for land classification.

The paper is organized as follows: In Section 2 we present the data processing, that gave us the opportunity of creating a set of de-speckled data; in Section 3, we present the physical approach used for the creation of a vegetation index and the classification procedure. Section 4 is devoted to the result presentation. The final discussion is provided in Section 5.

II. DATA PROCESSING

A. Input Data Set

In the frame of a project selected in the Cosmo Skymed AO competition, a set of 15 X-band Cosmo-Skymed StripMap images, with 3m of resolution, was acquired from June, 12 of 2010 to December, 12 of 2011. The images are all HH polarized and acquired by the same nominal track. They cover an area of almost 40km x 40km in the Yatenga region, a Sahelian region in the North of the country, at the border with Mali.

SAR image interpretation is hampered by the presence of the speckle signal, whose reduction approaches are typically based on geometrical or spectral averages, with a consequent

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loss of the geometric resolution. As an example, the amplitude of a multi-looked image acquired on April, 28, 2011, at the end of the 2011 dry season, is presented in Fig. 1. The pixel spacing of the image, due to the average process is about 150m. In order to present the image characteristics at the resolution cell scale (about 3m), we present, in Fig. 2, a detail of the image, relative to Bidi, a small farmer village, at almost 20 km north of Ouahigouya, the capital of the Yatenga region. Fig. 2 shows the full resolution image of the village, along with the effect of the speckle signal, which is carrier of information on the surface roughness, but it is considered a noise if the mean value of homogeneous areas is required for physical parameter retrieval.

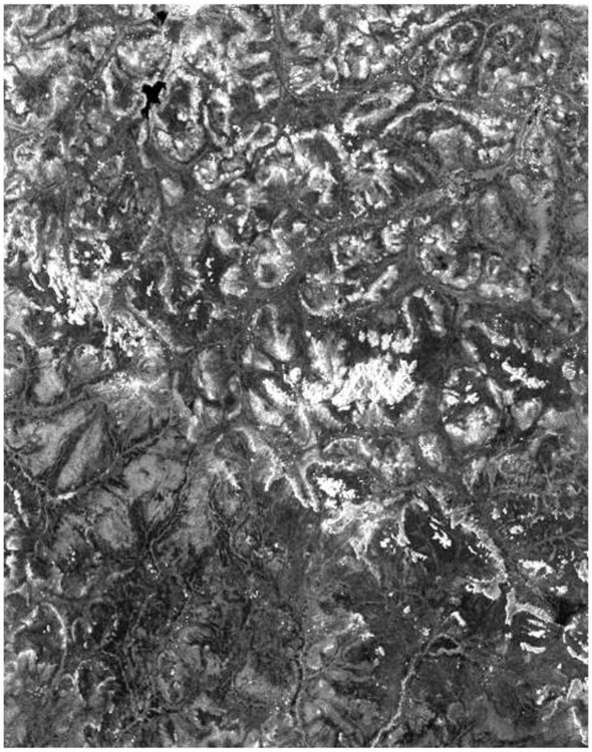

Figure 1. Example of SLC image of the Bidi area. Pixel spacing is 150m, the area is about 40km x 40km.

Thank to the availability of a set of multi-temporal data relative to the same area, we performed a temporal filtering with the goal of reducing the speckle, preserving the geometrical resolution. The idea behind the approach is that, the speckle characteristics are constant in time if only the soil moisture of the soils change. In addition, if we acquire images at different time and with slightly different look angles, we expect that the speckle relative to the same areas will be significantly uncorrelated. Therefore, the speckle can be estimated by temporal averages and subtracted by the acquired images, with the consequent production of a set of SAR de-speckled images at full resolution.

In Fig. 3 we present the filtered image, where we can better recognize homogeneous areas. The road structures, the Bidi village and areas characterized by different mean reflectivity can be clearly identified and the obtained result can be segmented for classification purposes. The reflectivity of the area is strongly dependent by the soil moisture and the land cover, as clearly appears by the acquisitions performed during the rainy season. The difference in reflectivity are due to the backscattering enhancement phenomenon in vegetated area, suggesting a classification algorithm for defining the land cover in the observed area.

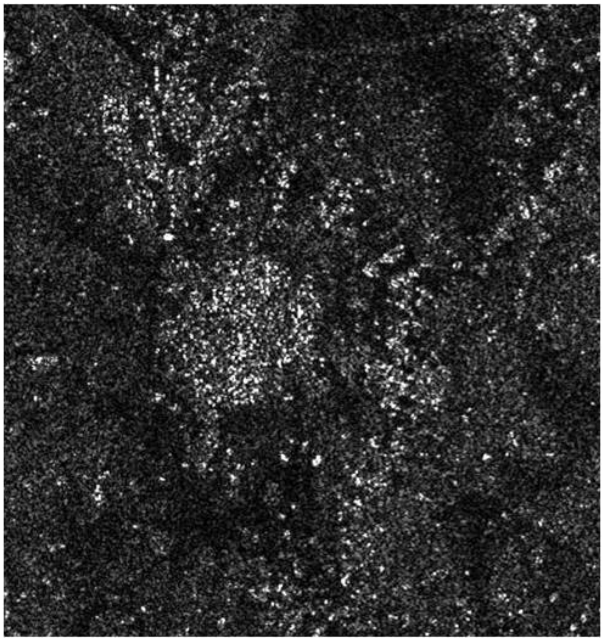

Figure 2. Example of SLC image of the Bidi area. Pixel spacing is 3m, the area is about 800 m x 800m

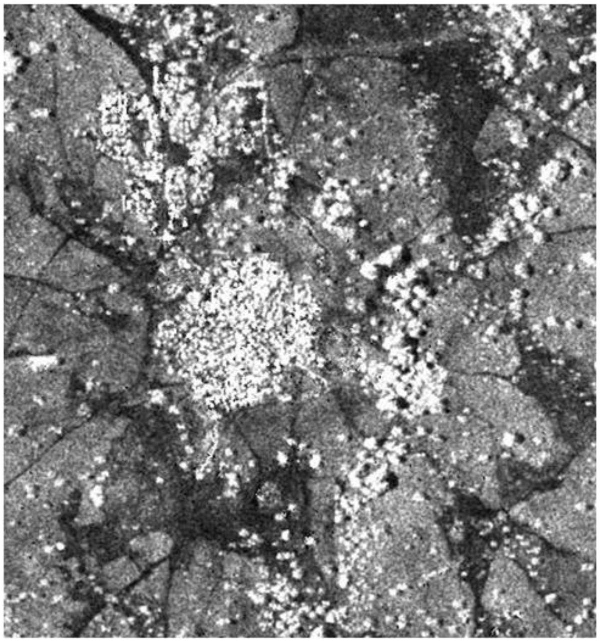

Figure 3. Multi-temporal filtered image. Pixel spacing is 3m, the area is about 800 m x 800m

III. VEGETATION INDEX DEFINITION

Fig. 3 provides a lot of physical information, whose extraction requires expert users. In order to obtain new products for potential application purposes, we need to relate the observed signal response to the physical phenomena that we expect to find in the area. In this paper we propose a classification index, based on the intensity changes both in amplitude and phase. The physical principles over which the index is based are:

1. The backscattering enhancement in vegetated areas
2. The quick loss of coherence with time

Such principles allow the discrimination of areas where the crops is growing, by processing the amplitude and phase images. In particular, we expect that in cultivated areas, the signal during the dry season will be formed only by the land backscattering. The expected soil moisture will be very low, so that the back-scattered signal is expected to be weak. When the rain starts and the soil absorbs water, the reflectivity index grow up. In addition, the presence of the crop creates volumetric scattering, with a consequent further increasing of the backscattering.

In presence of trees or evergreen areas, the return is significantly higher with respect to the dry soil response, so that the corresponding areas are always characterized by a response higher with respect to the mean value. Also in urban areas, the backscattering signal is expected to be high due to the multiple reflections that occur both in the dry and in the rainy season. The presence of water give rise to a weak signal, because all the incident signal is reflected in specular direction.

The above cited considerations suggested to compare the signal intensity of all the acquired images with the intensity of an acquisition made at the end of the dry season, when the water content of the terrain is almost null in almost all the observed area. In Fig. 4, we provide an interpretative tool for reading of images where on a blue band is loaded the dry season image and in the green band the tested data.

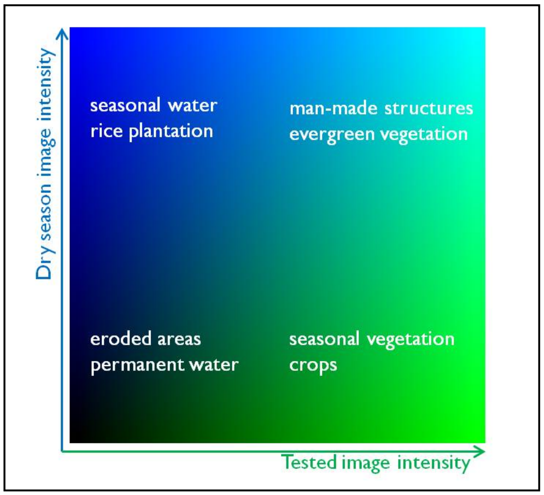

Figure 4. Interpretation tool.

Note that dark areas are representative of permanent water, with a weak signal in all the year, whilst blue areas represent catchments that completely dry due to the absence of rain, causing an increasing of the terrain backscattering in the april image.

A further discrimination principle can be provided by the fact that the coherence between two signals acquired at different times is expected to be higher almost anywhere in natural areas. Only permanent scatterers, as urban structures, preserve the coherence for long time. These considerations led us to test the set of acquired images, by using as a reference image the image acquired the 28 of April, 2011, at the end of the dry season, when almost no vegetation is present in the whole observed area.

Therefore, we created RGB images where, in the red band is loaded the coherence between the tested and the reference images, in the green band the intensity of the tested image and in the blue band the intensity of the reference image. A first example of the obtained result is shown in Fig. 5.

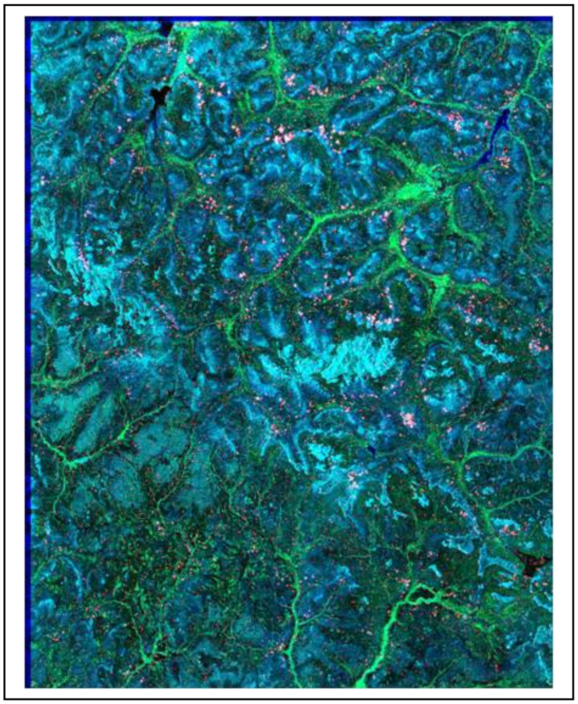

Figure 5. False color image. Green band represent the intensity of the acquisition taken the 12 of June, 2012.

Fig. 5 represent the RGB composition relative to the 12 of June, 2010, at the beginning of the rainy season. In that year, the rain started to fall at the end of May, so that a first growth of the vegetation can be observed close to the water reticulate. Note that the white spots represent the villages of the area.

In Fig. 6, we present the same result relative to the 15 of August, 2010, after 2 months of rain. The presence of vegetation is significantly increased, in correspondence of cultivated fields.

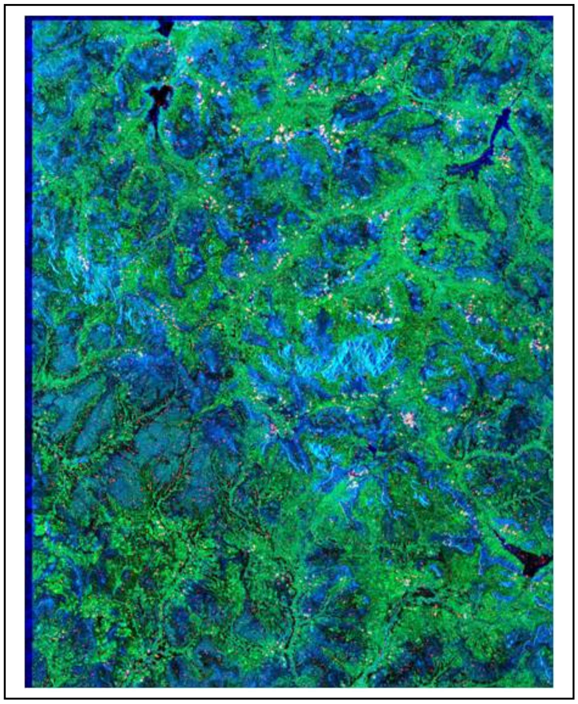

Figure 6. False color image. Green band represent the intensity of the acquisition taken the 12 of June, 2012.

The last example we present is relative to the 27 of March, 2011, when almost all the available surface water is finished, and the vegetation in the area is almost absent. The exception is provided by the cultivations guaranteed by the greatest dams of the region, able to store the water during the dry season.

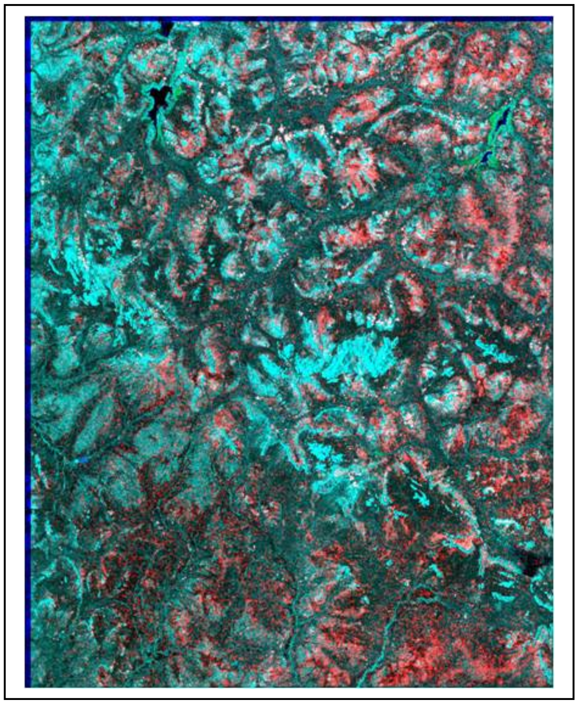

Figure 7. Multi-temporal filtered image

The presented false color images suggest the possibility of creating different indexes related to the crop growth in the observed region. As an example, we defined a global vegetation index as the percentage of pixels covered by vegetation in a given date. The corresponding index can be evaluated during the rainy and dry season and it is shown in Fig. 4.

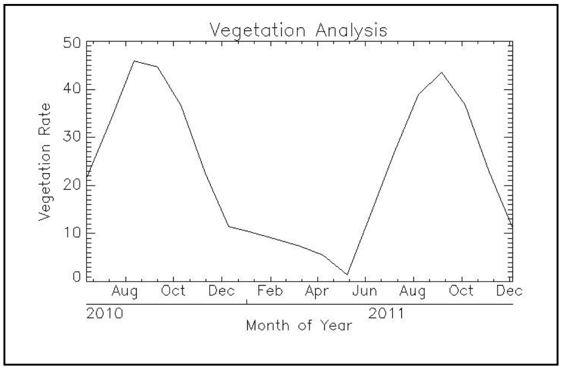

Figure 8. Vegetation index as a function of time

Most of the presented products would be better interpreted if related with the slope information. To this aim, during the project, a digital elevation model was extracted by a couple of images with a temporal interval of one day. The images were acquired during the dry season, when the temporal decorrelation is expected to be much lower than in the wet season. The importance of a digital elevation model is due to the fact that in that area, it would not be easy to obtain a similar product. In Fig. 9 we present the obtained result and we compare it with the most reliable of the available dem, obtained by the SRTM mission, see Fig. 10. Of course, thank to the high resolution of CosmoSkymed, the spatial resolution is significantly higher, obtaining new details.

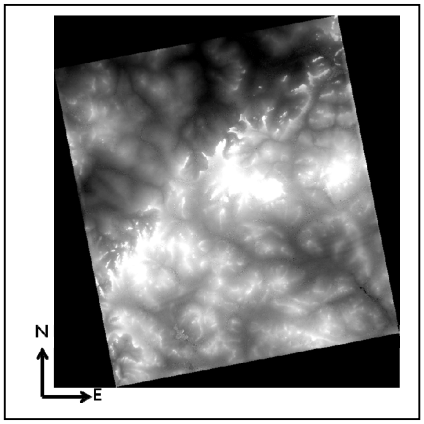

Figure 9. Digital elevation model extracted from SAR images

In addition, the digital elevation model can be used for improving the readability of the data, by superimposing the obtained classified images onto the DEM, as presented in Fig. 9.

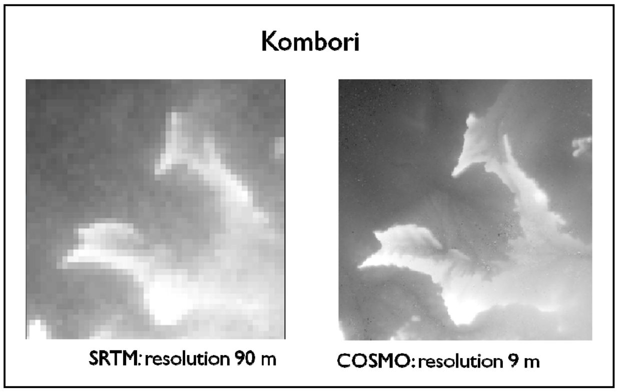

Figure 10. Comparison between SRTM and CosmoSkymed dems: a detail.

In Figure 11 we present the index superimposed on the digital elevation mode, so that the erosive processes and the vegetation indexes could be related to the topography of the observed area.

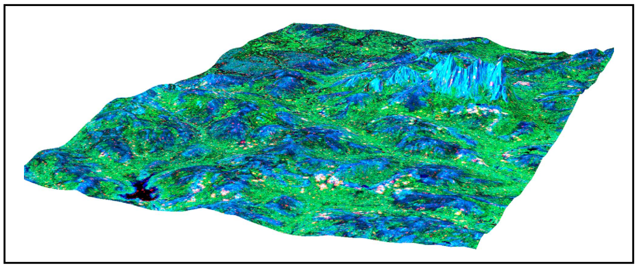

Figure 11. 3D vegetation map

Further products can be generated, without losing geometrical resolution. As instance, we compared the intensities of the SAR responses after the multi-time analysis, by loading the intensity of the July, 14, August, 15 and April, 28 on the RGB bands. The result is provided in Figure 12. Such an analysis provides a classification map, where eroded areas can, characterized by a weak return in any period of the year, can be clearly distinguished from seasonal water, represented in blue in the presented map.

IV. CONCLUSIONS

In this paper we presented a new approach for using high resolution data in low-income countries for monitoring of water, eroded areas and vegetation. The dynamics of the vegetation represents an integrated response to a variety of environmental processes: their study represents a way for describing and understanding complex ecosystems. Many studies on the vegetation indexes and their possible uses are available in literature [4]. In the peculiar context of developing country, where the ground monitoring systems are extremely insufficient, the potentialities of remote monitoring are particularly relevant.Innovative products have been generated, to be used for land management purposes. The project was developed with a continuous interaction with the beneficiaries, that were involved also in the calibration and interpretation of the results.

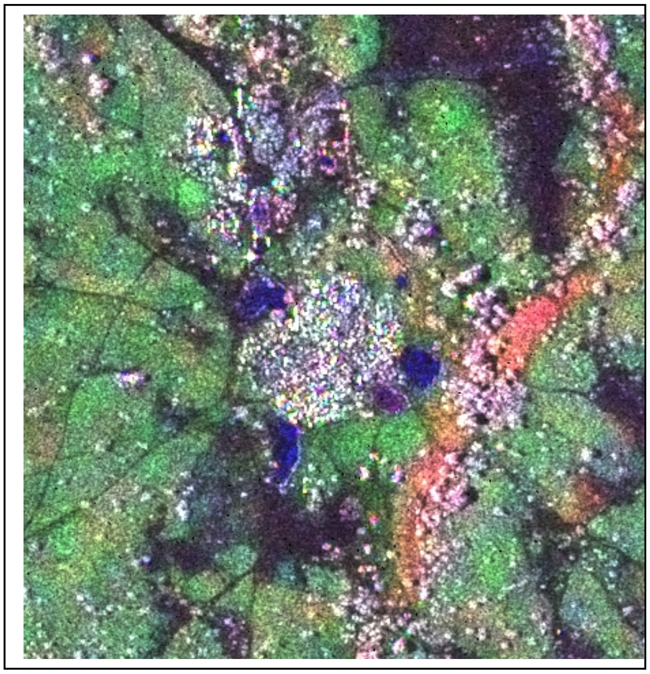

Figure 12. Detail of the RGB map. Red, Green and Blue channels are loaded with July, August and April images, respectively

REFERENCES

[1] FAO, The State of Food and Agricolture 2010-2011, FAO, Rome, 2011.

[2] Koussoubé Y. 2010, “ Hydrogéologie des séries sédimentaires de la dépression piézométrique du Gondo, (Bassin du Sourou) – Burkina Faso / Mali”, *Thèse de Doctorat, UPMC Sorbonne Universités*, 2010.

[3] Di Martino, G., Iodice, A.; Riccio, D.; Ruello, G.; Zinno, I.; Ciervo, F.; Papa, M.N.; Koussoube, Y., “Use of High Resolution Satellite Images for the Calibration of Hydro-geological Models in Semi-Arid Regions: A Case Study”, *IEEE Global Humanitarian Technology Conference 2011*, pp. 171-175, Seattle, 2011.

[4] McVicar, T.R. and Jupp, D.L.B. (1998) The current and potential operational uses of remote sensing to aid decisions on Drought Exceptional Circumstances in Australia: A Review. *Agricultural Systems*. 57 (3), 399- 468.