ESTIMATION OF CROP EXTENT USING MULTI-TEMPORAL PALSAR DATA

Nada Milisavljević[1], Francesco Holecz[2], Isabelle Bloch[3], Damien Closson[1] and Francesco Collivignarelli[2]

[1]Department of Communication Information Systems & Sensors (CISS), Royal Military Academy, Brussels, Belgium; [2]Sarmap, Purasca, Switzerland; [3]Télécom Paris Tech, CNRS LTCI, Paris, France

ABSTRACT

The aim of the approach proposed in this paper is to determine a potential crop extent prior to the crop season, by determining regions that might change in time vs. those that surely do not change. We use multi-annual PALSAR-1 data since in dry conditions, L-band HH/HV data have a potential of distinguishing between bare soil and other classes. In addition, a more accurate map can be reached with multi-temporal data than using a single date. We work on HH and HV data sets separately and analyze the two outputs using ground-truth information. In a final phase, we combine these two outputs and compare the result with the ground-truth too, to test the usefulness of fusing the HH/HV information. This approach is the first step in our three-step procedure for estimation of cultivated area in small plot agriculture in Malawi. Validation results show that the proposed approach is promising.

Index Terms— multi-temporal data, PALSAR, crop extent estimation, fusion

1. INTRODUCTION

For food security purposes in Africa, it is important to estimate cultivated areas in small plot agriculture. To this end, multi-temporal high resolution SAR systems are sources of reliable and overall information [1-3], as an alternative to time and resource consuming classical field surveys and aerial photography, in addition to the demand of continuous monitoring. In our approach, a three-step procedure for estimation of cultivated area in small plot agriculture in Malawi is envisaged, where the crop extent prior to the crop season is the first step, the potential area at start of the crop season is the second step, while the third step consists in determining the crop growth extent during the rainfed crop season. Taking into account that various vegetation types grow during the rainy season, the key issue is to know what is really cultivated and not simply vegetated.

In this paper, we detail and further develop the first step, which is crucial when dealing with food security and agriculture in developing countries, where available land-cover map is either inaccurate, out of date or it does not even exist. Once derived, this global information, which should give a basis for deciding where to perform more detailed analysis, should be relevant for a longer period of time in normal situations, so it should not need to be updated annually.

The main goal of deriving the potential crop extent prior to the start of the rainy season is to provide a first information layer regarding the extent of the bare soil area where crop will potentially grow. Multi-temporal SAR data having resolution in the order of 15m should be sufficient to extract this type of information. In a next step, where potential cultivated area at start of season should be looked for, a very high resolution sensor is needed. The acquisition coverage of this very high resolution sensor (such as Cosmo-SkyMed with the resolution of 3m) can be limited thanks to the output of the first step, i.e., the one we discuss in this paper.

In dry conditions, L-band HH/HV data have a potential of distinguishing between bare soil and other classes (water, forest, etc). Therefore, in order to estimate crop extent, multi-annual PALSAR-1 [4] data are chosen, since we are interested in an average bare soil area, and not in small changes. Another reason for selecting these data lies in the fact that their archive, acquired by the Japanese Space Agency (JAXA), is consistent and can be processed in a multi-temporal way, which enables the speckle reduction, on the one hand, and, on the other hand, allows for the generation of a more accurate map (based on a multi-temporal classifier) than the one obtained using a single date.

2. APPROACH

Input data in estimating the crop extent are preprocessed multi-temporal PALSAR data in HH and HV polarization. The preprocessing phase consists of co-registration, multi-temporal speckle filtering, orbital correction, terrain geo-coding, radiometric calibration and normalization, and anisotropic non-linear diffusion filtering. Such a preprocessing allows us to work at pixel level.

There are different ways of classifying these preprocessed multi-temporal SAR data. Our intention is to

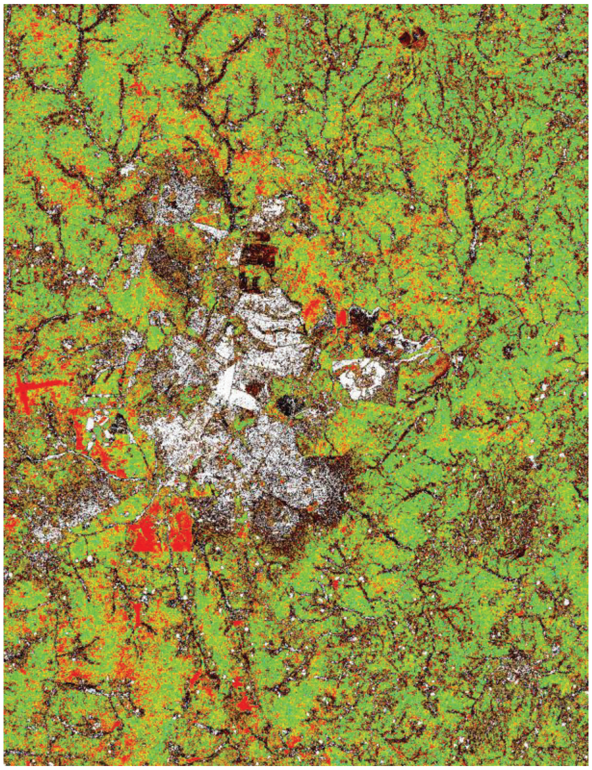

Fig. 1. An example of the HV image classification result

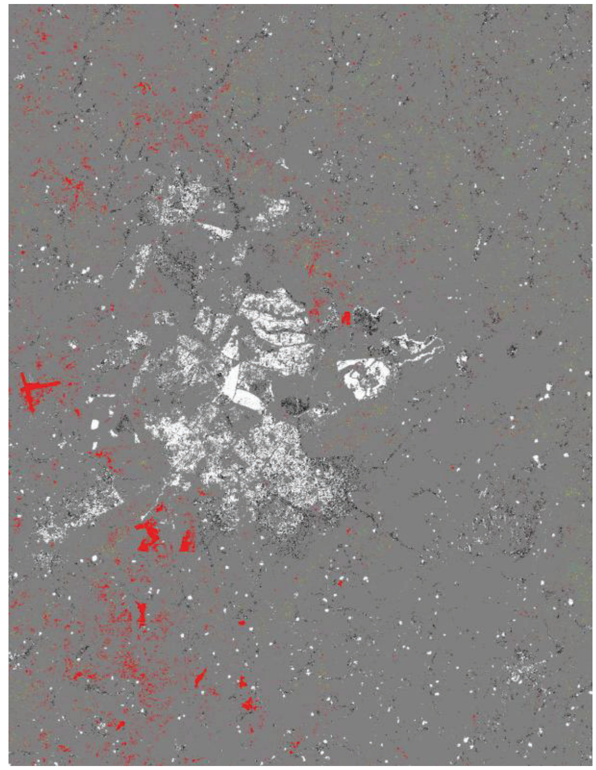

Fig. 2. comparison of the HV classification results

develop an approach that could be reused in other regions, where we might not have information about the existing land-cover classes. Therefore, we opt for an unsupervised classification method, meaning that we can either analyze the multi-temporal signatures of pixels or regions and perform classification based on the similarity of signatures, or perform classification on each image separately and then combine the classification results. We choose the latter in order to cover situations where the data are not radiometrically calibrated or where we have only a few multi-temporal images. It is crucial here to determine which pixels change in time (as a potential bare soil) and which pixels do not change in time (so they can be used as a mask that covers the regions that are not interesting for further steps of our three-step method). Thus, we have to apply such an unsupervised classification algorithm to each image of the multi-temporal data set that preserves the grayscale information so that the classes from one image can be compared with the classes of another image and that the decision whether the class changed or not is meaningful. Based on this, our final choice is an algorithm using the Principal Components Transform (PCT) and median cut [5]. In brief, this algorithm looks for the most discriminative information based on which it divides the image into a preset number of classes, taking into account the colour/grayscale values.

At this step of the global approach, our goal is to be sure that none of the pixels that might change in time is excluded from further steps (masked as stable), while misclassifying stable pixels as changing ones is not critical at this point and will be further corrected in the two following steps. Due to that, we proceed as follows. Once pixels of each image are classified into n classes, labeled 1, 2, … , n, they are compared and as soon as a pixel changes its label, it is marked as 0, i.e., a potential bare soil. Only if the pixel preserves its class label in all images, that is its final label too.

Since we have both HH and HV data sets, we perform the above procedure to each of the sets and analyze the two outputs using ground-truth information. In a final phase, we combine these two outputs and compare the result with the ground-truth as well, to test the usefulness of fusing the HH/HV information at this step.

3. RESULTS

The test site is a relatively flat region of Malawi, around Lilongwe, its capital. We have ten ALOS PALSAR intensity data (so, ten HH and ten HV images) acquired from 2007 to 2010. Since the dry season prior to the start of the rainy season in Malawi is from June to October [6], the multi-annual PALSAR data that cover that period of the year are selected. Based on the information from field, we choose to classify each image in eight classes. (However, note that in order to be more general, we have repeated the whole procedure for ten and for twelve classes, and there was no

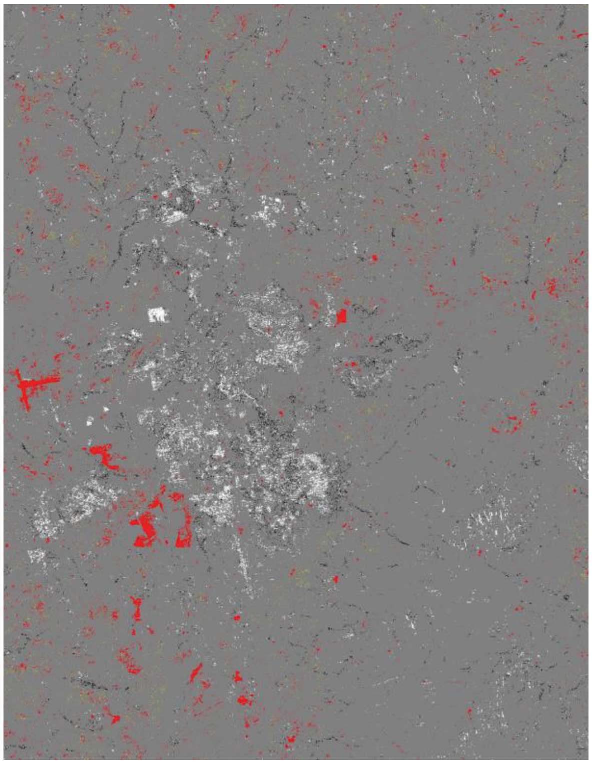

Fig. 3. Comparison of the HH classification results

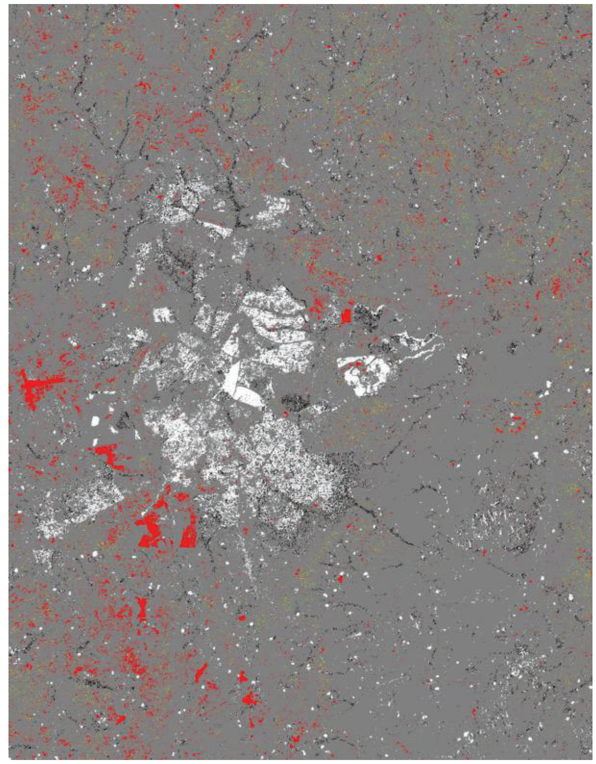

Fig. 4. Combination of the HH and HV results

significant change in the final result.) An example of the classified image is given in Fig. 1. The result of comparing the classification results for the HV data set is given in Fig. 2, and for the HH data set, it is shown in Fig. 3. Finally, a combination of the results of the HV and HH data sets is given in Fig. 4. (Label 0 is in gray in the images.) This combination is based on the idea that if the HH and HV results label differently the pixel, its neighborhood is analyzed in HH and HV results and of the two labels, the one that is more present is chosen.

In order to validate the obtained results, we use the ground-truth information consisting of 432 points that correspond to regions that do not change in time (buildings, water …) and 328 points that belong to arable land. For HV result (Fig. 2), 203 points that do not change in time are correctly classified (having label other than 0), while 328 points that change in time are correctly labeled as 0. In the HH case (Fig. 3), 91 points that belong to regions that do not change in time are well classified, and 319 are correctly classified in case of arable land. Finally, the combination result (Fig. 4) classified well 244 points that do not change in time and all 328 points of arable land.

4. DISCUSSION AND CONCLUSION

The aim of the approach proposed here is to determine a potential crop extent prior to the crop season, by determining regions that might change in time vs. those that surely do not change. This approach represents the first step in our three-step procedure for estimation of cultivated area in small plot agriculture in Malawi. Thus, the mask obtained in this first step will be further used in the next steps of the global approach for estimating cultivated areas using data that would observe only the region that might change in time in order to find which parts of this region will be cultivated. Therefore, our goal regarding this first step is to make sure that none of the zones where crops might grow is excluded from further analysis, and to mask only the zones where crops will certainly not grow. The validation results where the correct classification of arable land is maximized reflect this goal. Consequently, the usefulness of a multi-temporal approach for classifying SAR images in agricultural areas is proven as well.

The fact that not all regions that do not change in time are labeled as such is not critical and it is related to the fact that the analysis is performed prior to the crop season, so further limitations of the region labeled as a potential crop extent should be reached during the following steps of the analysis, where the data during the crop season will be collected and processed for that region.

As the work presented here is performed on the pixel level, there is a potential interest of a spatial regularization, which will be analyzed in detail in future.

Finally, the validation results suggest that HV data might be sufficient at this step of the analysis, but this aspect will be further analyzed and tested using other data sets, since our intention is to develop an approach that could be reused in other regions.

5. ACKNOWLEDGEMENTS

The Japanese Space Agency is acknowledged for the provision of the ALOS PALSAR-1data.

This work has been done in the scope of the SPARE-SAFE project launched by the Belgian Ministry of Defense.

6. REFERENCES

[1] D. Bargiel and S. Herrmann, "Multi-Temporal Land-Cover Classification of Agricultural Areas in Two European Regions with High Resolution Spotlight TerraSAR-X Data", Remote Sensing 3, pp. 859-877, 2011.

[2] F. Holecz et al, "Synergetic use of multi-temporal ALOS PALSAR and ENVISAT ASAR data for topographic/land cover mapping and monitoring at national scale in Africa", IEEE International Geoscience and Remote Sensing Symposium (IGARSS) 2009, Cape Town, South Africa, pp. II-5 – II-8, 2009.

[3] V.Krylov and J. Zerubia, "High resolution SAR image classification",Technical report 7108, INRIA Sophia Antipolis, France, 2009.

[4] A. Rosenqvist, M. Shimada, and M. Watanabe, "ALOS PALSAR: Technical outline and mission concepts", 4th International Symposium on Retrieval of Bio- and Geophysical Parameters from SAR data for Land Applications, Innsbruck, Austria, 2004.

[5] Umbaugh, S.E. "Digital Image Processing and Analysis: Human and Computer Vision Applications with CVIPtools, Second Edition", CRC Press, Taylor & Francis Group, Boca Raton, USA, 2010.

[6] United States Agency International Development (USAID) - Famine Early Warning Systems Network (FEWS Net), "Malawi Food Security Update" [cited May 30 2012], Available from: http://www.fews.net/docs/Publications/Malawi_FSU_March_2010_final.pdf