CROP CLASSIFICATION IN UKRAINE USING SATELLITE OPTICAL AND SAR IMAGES

Nataliia Kussul, Sergii Skakun, Andrii Shelestov, Oleksii Kravchenko, Olga Kussul

Abstract: *This paper presents first results of the use of optical and synthetic-aperture radar (SAR) satellite images to crop classification in Ukraine. The study aims at optimizing SAR parameters to provide timely and economically efficient crop maps/area estimates for Ukrainian landscape. Integration of EO-1 and RADARSAT-2 is done for crop classification using support vector machine (SVM). Classification is carried out per-field. The results on using SAR data for summer crops classification look very promising enabling classification of major summer crops with 10-15% of commission and omission errors under a typical Ukrainian landscape.*

Keywords: *crop classification, SVM, satellite images, SAR multipolarization.*

ACM Classification Keywords: *I.4.8 [Image Processing and Computer Vision] Scene Analysis - Sensor Fusion.*

Introduction

Space Research Institute of NAS Ukraine and SSA Ukraine (SRI, Ukraine) is actively involved in the Joint Experiment for Crop Assessment and Monitoring (JECAM) activities of the Group on Earth Observations (GEO), and established two JECAM test sites in Ukraine in 2011 [Kussul et al, 2012]. One of the main problems being solved is crop identification and crop area estimation with the use of satellite optical and synthetic-aperture radar (SAR) images.

Recently, many studies have focused on the estimation of crop acreage and proportions at global scale using time-series of moderate resolution remote sensing images such as MODIS and SPOT-VEGETATION [Verbeiren et al, 2008; Fritz et al, 2008; Pan et al, 2012; Wu and Li, 2012; Vintrou et al, 2012]. The use of synthetic-aperture radar (SAR) images in combination with optical ones for crop acreage estimation and crop monitoring is discussed in [McNairn et al, 2009a,b; Leichtle et al, 2012; Blaes et al, 2005; Skriver et al, 2011; Hoekman et al, 2011]. As to classification algorithms, decision tree (DT) [McNairn et al, 2009a,b; Vintrou et al, 2012; Boryan et al, 2008], artificial neural networks (ANN) [Verbeiren et al, 2008; Fritz et al, 2008; Gallego et al, 2012; Skakun et al, 2007; Kussul et al, 2012], support vector machine (SVM) [Gallego et al, 2012; Kussul et al, 2012; Pal and Foody, 2012], and maximum likelihood (ML) [Pan et al, 2012; Wu and Liu, 2012; Skriver et al, 2011] have been recently the most widely used. In general, overall classification accuracy reported in the literature is 80% to 90% depending on the available remote sensing images, complexity of landscape and extent of the region.

In 2010, SRI completed an EC-JRC contract “Crop area estimation with satellite images in Ukraine” within the MARS and GEOLAND2 projects which showed particular difficulties in discriminating summer crops using satellite optical images [Gallego et al, 2012; Kussul et al, 2012]. This was due to cloud cover, not optimal dates of satellite image acquisition and inherent limits of optical data. Therefore, feasibility and use of satellite synthetic-aperture radar (SAR) multi-polarized images need to be exploited.

This problem is addressed within the SRI project of the SOAR-JECAM program to acquire quad-polarized RADARSAT-2 images. The project aims at optimizing SAR parameters to provide timely and economically efficient crop maps/area estimates for Ukrainian landscape [Kogan et al, 2013; Shelestov et al, 2013; Kussul et al, 2011; Kussul et al, 2010]. This paper discusses the results of integration of SAR and optical satellite images for crop classification in Ukraine.

Study area and data description

For exploring capabilities of satellite SAR imagery to discriminate summer crops in Ukraine, a test site of Vasylkiv county in Kyivska oblast was selected (Fig. 1). The test site incorporates all major summer crops (maize, soy beans, sunflower, sugar beet), and has total area of about 1,200 sq. km.

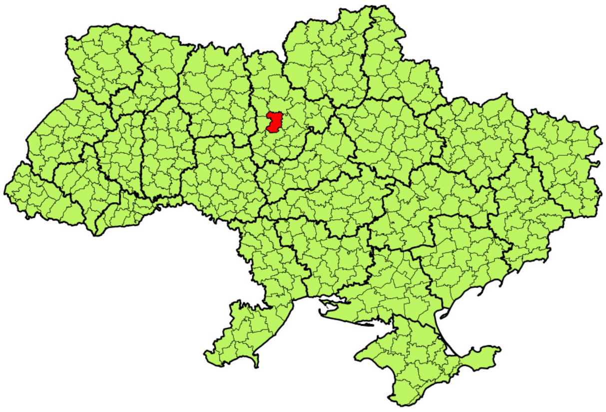
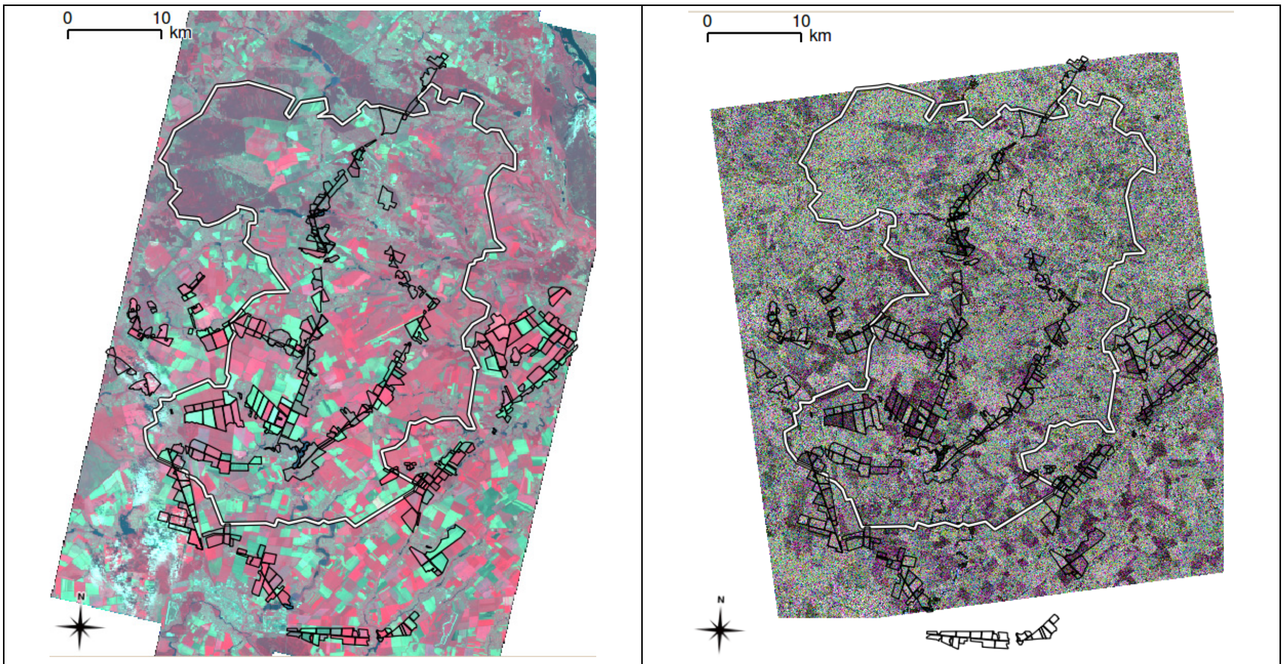


Figure 1. The Vasylkiv county test site shown in red

The first RADARSAT-2 images over one of the test-site were acquired on 27 and 30 July 2012. Optical images from EO-1 satellite were acquired on 28 July 2012 as well. Ground observations to support satellite images were carried out on 4 August 2012 to collect in situ measurements (Fig. 2). In total, information on 271 fields was collected. The following crop types were present (Table 1): maize, soy beans, sunflower, sugar beet, harvested winter and spring crops, and minor crops like buckwheat.



(a) (b)

Figure 2. Boundaries of observed crop fields outlined in black over EO-1 VNIR image (a) and RADARSAT 2 quad-pol images (b). The test site area is shown in white. EO-1 Data are courtesy of the NASA Earth Observing One (EO-1) mission operated by the Goddard Space Flight Center, 2012. RADARSAT-2 Data and Products © MacDonald, Dettwiler and Associates Ltd.(2012) - All Rights Reserved. RADARSAT is an official trademark of the Canadian Space Agency.

Table 1. Ground survey statistics

Crop	Fields observed, %	Total area (ha), %
Maize	63 (23.2%)	6264 (29.5 %)
Soy beans	46 (17.0%)	3553 (16.7 %)
Sunflower	19 (7.0%)	1722 (8.1 %)
Sugar beet	12 (4.4%)	1130 (5.3 %)
Winter and spring crops (already harvested)	79 (29.2 %)	6184 (29.1 %)
Non agricultural land and minor crops	52 (19.2 %)	2369 (11.2 %)
Total	271 (100 %)	21222 (100 %)

Classification method

SAR images were classified using a per-field classification approach. Many previous studies have shown that efficiency of SAR classification can be improved using per-field approach due to the presence of speckle at the pixel level [Blaes et al, 2005]. For each field, a median value of backscatter coefficient was estimated for each polarization (VV, VH, HV, and HH), and was used as an input to classification algorithm. Classification was done using the SVM classifier.

Support vector machine (SVM) became popular for solving problems in classification, regression, and novelty detection [Bishop, 2006]. An important property of support vector machines is that the determination of the model parameters corresponds to a convex optimization problem, and so any local solution is also a global optimum. The SVM is a decision machine and, unlike ANNs, does not provide posterior probabilities. Also, processing new datasets could be resource consuming comparing to the ANNs.

Classification results

Collected data was used for preliminary analysis of the discriminating power of optical, SAR and a combination of them both by visual interpretation and supervised classification. In contrast to optical images visual interpretation of SAR images allows distinguishing maize, soy beans and combined sunflower & sugar beet crops due to different canopy architecture and different scattering processes. Sugar beet and sunflower could not be discriminated.

Numerical analysis was performed using a Support Vector Machine (SVM) classifier. Classification accuracies, commission and omission errors were estimated using a five-fold cross-validation procedure. Special care has been taken to prevent over-fitting of cross-validation procedure due to spatial correlation in collected data. Three different data sets were examined: combined EO-1 and RADARSAT-2, EO-1 only and RADARSAT-2 only data (Table 2).

Total accuracies appear similar in all datasets because they are heavily influenced by winter and spring crop class that is classified equally well by optical and SAR data.

The difference between datasets lies in per crop classification errors. All summer crops are better classified using SAR data rather then optical data. The most profound effect is observed on soy beans that is the second major summer crop after maize in the given area. Using SAR data instead of optical allows decreasing omission error for soybeans from 34% to 13% while maintaining similar level of commission error.

Combined dataset shows gradual decrease of errors for most crops 5% to 10%. Sunflower + sugar beet class is the most beneficial as combined data allows decreasing classification errors in 1.5-2 times in comparison with optical or SAR data alone. This result is explained by complementary roles of SAR and optical data for discriminating sunflower at flowering phenological stages.

Table 2. Total accuracy, commission (CE) and omission (OE) classification errors

Crop	**EO1 + R2**		**EO1**		**R2**	
Total accuracy	**91.4 %**		**84.8 %**		**88.9 %**	
	CE, %	**OE, %**	**CE, %**	**OE, %**	**CE, %**	**OE, %**
Maize	11.8 %	4.8 %	17.6 %	11.1 %	13.6 %	9.5 %
Soy beans	6.1 %	18.4 %	7.4 %	34.2 %	10.8 %	13.2 %
Sunflower + sugar beet	20.0 %	23.1 %	39.3 %	34.6 %	28.0 %	30.8 %
Winter + spring	2.8 %	1.4 %	6.7 %	1.4%	2.9 %	4.2 %

Conclusions

The first results on using SAR data for summer crops classification look very promising enabling classification of major summer crops with 10-15% of commission and omission errors under a typical Ukrainian landscape. Further research is required to ensure robustness of proposed approach on larger areas. Additional efforts should be put on investigation of possibility to substitute quad-polarization SAR data with cheaper wide swath dual-polarization data available from RADARSAT-2 and the upcoming Sentinel-1 satellites.

Bibliography

[Bishop, 2006] C. Bishop. Pattern Recognition and Machine Learning, Springer, New York, USA, 2006.

[Blaes et al, 2005] X. Blaes, L. Vanhalleb, and P. Defourny. Efficiency of crop identification based on optical and SAR image time series. Remote Sens. of Env., 96, pp. 352–365, 2005.

[Boryan et al, 2008] C. Boryan, M. Craig, and M. Lindsay. Deriving Essential Dates of AWiFS and MODIS Data for the Identification of Corn and Soybean Fields in the U.S. Heartland. In: Pecora 17 – The Future of Land Imaging. Going Operational, Denver, USA, 2008.

[Fritz et al, 2008] S. Fritz, M. Massart, I. Savin, J. Gallego, and F. Rembold. The use of MODIS data to derive acreage estimations for larger fields: A case study in the south-western Rostov region of Russia. Int. J. of Appl. Earth Observ. Geoinf., vol. 10, no. 4, pp. 453–466, 2008.

[Gallego et al, 2012] J. Gallego, A. Kravchenko, N. Kussul, S. Skakun, A. Shelestov, and Y. Grypych,. Efficiency Assessment of Different Approaches to Crop Classification Based on Satellite and Ground Observations. J. of Automation and Inf. Sci., vol. 44, no. 5, pp. 67–80, 2012.

[Hoekman et al, 2011] D.H. Hoekman, M.A.M. Vissers, T.N. Tran. Unsupervised Full-Polarimetric SAR Data Segmentation as a Tool for Classification of Agricultural Areas,. IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens., vol. 4, no. 2, pp. 402–411, 2011.

[Kogan et al, 2013] F. Kogan, N. Kussul, T. Adamenko, S. Skakun, O. Kravchenko, O. Kryvobok, A. Shelestov, A. Kolotii, O. Kussul and A. Lavrenyuk. Winter wheat yield forecasting in Ukraine based on Earth observation, meteorological data and biophysical models. Int. J. Appl. Earth Observ. Geoinf., vol. 23, pp. 192–203, 2013.

[Kussul et al, 2010] N. Kussul, A. Shelestov, S. Skakun, O. Kravchenko. High performance Intelligent Computations for Environmental and Disaster Monitoring. In: Intelligent Data Processing in Global Monitoring for Environment and Security (Krassimir Markov, Vitalii Velychko editors), I T H E A, Sofia, pp. 64-92, 2010.

[Kussul et al, 2011] N. Kussul, S. Skakun, O. Kravchenko. Environmental Risk Assessment Using Geospatial Data and Intelligent Methods. Int. J. "Information Technologies & Knowledge", Vol.5, Number 2, pp. 129-140, 2011.

[Kussul et al, 2012] N. Kussul, A. Shelestov, S. Skakun, O. Kravchenko, B. Moloshnii. Crop state and area estimation in Ukraine based on remote and in-situ observations. Int. J. on Information Models and Analyses, vol. 1, no. 3, pp. 251-259, 2012.

[Kussul et al, 2012] N. Kussul, S. Skakun, A. Shelestov, O. Kravchenko, J. F. Gallego, and O. Kussul. Crop area estimation in Ukraine using satellite data within the MARS project. In: 2012 IEEE Int. Geoscience and Remote Sensing Symposium, 22-27 July 2012, Munich, Germany, pp. 3756–3759, 2012.

[Leichtle et al, 2012] T. Leichtle, A. Schmitt, A. Roth, and M. Schardt. On the capability of different SAR polarization combinations for agricultural monitoring. In: 2012 IEEE Int. Geoscience and Remote Sensing Symposium, 22-27 July 2012, Munich, Germany, pp. 3752–3755, 2012.

[McNairn et al, 2009a] H. McNairn, J. Shang, C. Champagne, and X. Jiao. TerraSAR-X and RADARSAT-2 for crop classification and acreage estimation. In: 2009 IEEE International Geoscience and Remote Sensing Symposium, IGARSS 2009, vol.2, pp. II-898–II-901, 12-17 July 2009.

[McNairn et al, 2009b] H. McNairn, C. Champagne, J. Shang, S. Holmstrom, and G. Reichert. Integration of optical and Synthetic Aperture Radar (SAR) imagery for delivering operational annual crop inventories. ISPRS J. of Photogramm. and Remote Sens., 64(5), pp. 434–449, 2009.

[Pal and Foody, 2012] M. Pal, and G.M. Foody. Evaluation of SVM, RVM and SMLR for Accurate Image Classification With Limited Ground Data. IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens., vol. 5, no. 5, pp. 1344–1355, 2012.

[Pan et al, 2012] Y. Pan, L. Li, J. Zhang, S. Liang, X. Zhu, and D. Sulla-Menashe. Winter wheat area estimation from MODIS-EVI time series data using the Crop Proportion Phenology Index. Remote Sens. of Env., vol. 119, pp. 232–242, 2012.

[Shelestov et al, 2013] A.Yu. Shelestov, A.N. Kravchenko, S.V Skakun., S.V. Voloshin, and N.N. Kussul. Geospatial information system for agricultural monitoring. Cybern. Syst. Anal., vol. 49, no. 1, pp 124–132, 2013.

[Skakun et al, 2007] S. Skakun, E. Nasuro, A. Lavrenyuk, and O. Kussul. Analysis of Applicability of Neural Networks for Classification of Satellite Data. J. of Automation and Inf. Sci., vol. 39, no. 3, pp. 37–50, 2007.

[Skriver et al, 2011] H. Skriver, F. Mattia, G. Satalino, A. Balenzano, V. R. Pauwels, N. E. Verhoest, and M. Davidson. Crop classification using short-revisit multitemporal SAR data. IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens., vol. 4, no. 2, pp. 423-431, 2011.

[Verbeiren et al, 2008] S. Verbeiren, H. Eerens, I. Piccard, I. Bauwens, and J. Van Orshoven. Sub-pixel classification of SPOT-VEGETATION time series for the assessment of regional crop areas in Belgium. Int. J. of Appl. Earth Observ. Geoinf., vol. 10, no. 4, pp. 486–497, 2008.

[Vintrou et al, 2012] E. Vintrou, A. Desbrosse, A. Bégué, S. Traoré, C. Baron, and D. Lo Seen. Crop area mapping in West Africa using landscape stratification of MODIS time series and comparison with existing global land products. Int. J. of Appl. Earth Observ. Geoinf., vol. 14, no. 1, pp. 83–93, 2012.

[Wu and Liu, 2012] B. Wu, and Q. Li. Crop planting and type proportion method for crop acreage estimation of complex agricultural landscapes. Int. J. of Appl. Earth Observ. Geoinf., vol. 16, pp. 101–112, 2012.

Acknowledgement

The paper is published with partial support by the project ITHEA XXI of the ITHEA ISS (www.ithea.org) and ADUIS (www.aduis.com.ua).

Authors' Information

Nataliia Kussul – *Deputy Director, Head of Department of Space Information Technologies and Systems, Space Research Institute NASU-SSAU, Glushkov Prospekt 40, build. 4/1, Kyiv 03680, Ukraine; e-mail: inform@ikd.kiev.ua*

Major Fields of Scientific Research: Grid computing, Sensor Web, Earth observation, satellite data processing, risk analysis.

Sergii Skakun *– Head of Laboratory for Satellite Monitoring, Space Research Institute NASU-SSAU, Glushkov Prospekt 40, build. 4/1, Kyiv 03680, Ukraine; e-mail: serhiy.skakun@ikd.kiev.ua*

Major Fields of Scientific Research: Grid computing, Sensor Web, Earth observation, satellite data processing, risk analysis.

Andrii Shelestov – *Head of Department of Software Engineering, National University of Life and Environmental Sciences of Ukraine, Heroyiv Oborony st., 15, Kyiv-03041, Ukraine; e-mail: andrii.shelestov@gmail.com*

Major Fields of Scientific Research: Grid computing, distributes systems, system architecture design, Earth observation, satellite data processing.

Oleksii Kravchenko *– Senior Scientist, Space Research Institute NASU-SSAU, Glushkov Prospekt 40, build. 4/1, Kyiv 03680, Ukraine; e-mail: oleksiy.kravchenko@gmail.com*

Major Fields of Scientific Research: Earth observation, satellite data processing, machine learning.

Olga Kussul *– Assistant Professor, Physics & Technology Institute of the National Technical University of Ukraine "Kiev Polytechnic Institute", 37 Prospect Peremogy, Kyiv 03056, Ukraine; e-mail: olgakussul@gmail.com*

Major Fields of Scientific Research: trust management in distributed and heterogeneous systems, satellite data processing.