POTENTIAL OF TERRASAR-X STRIPMAP DATA IN EARLY AND RAPID AGRICULTURAL CROPS MAPPING

Malbork Test Area (Poland)   54°N / 19°E

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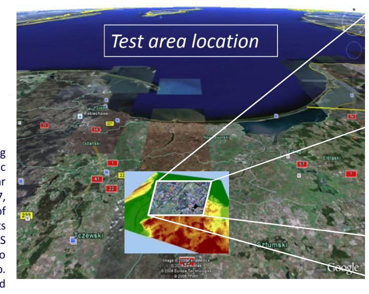
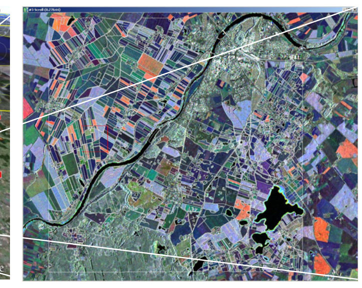




Materials

TerraSAR-X images were programmed via Science Server of DLR on the basis of system scheduling and available configuration at given day in 11-days interval. Strip Map mode at single and dual polarizations configuration were chosen. The area of interest (AOI) 20x20 km large is located in Northern Poland (about 54 deg. N) in typically agricultural region, partially on ideally flat alluvial soils (west part) and postglacial moraines (east part) with moderate relief. The acquisitions started on 25th of April 2008 when the winter crops (rape, cereals, …) were developed over the ground but the spring crops were just emerged or not yet sown. All images were taken on descending pass and pre-processed to **EEC** (Enhanced Earth Corrected) product variant using precise orbit parameters (**SCIEntific**). All products were ordered in **RE** (Radiometrically Enhanced) resolution variant giving less speckle constraints. Two strips, R013 and R007, having different looking angles were chosen. Incidence angle at the scene centre for R013 Near_strip is about 42 degrees and 31 degrees for R007 strip respectively. This difference of about 11 degrees could be examined as an additional potential discriminative factor of crops classes for different surface roughness situations resulting from crops development stages. For both strips the images were acquired in VV polarization. For R013 strip in dual-pol mode, second polarimetric component was cross-pol channel VH. Geometric and radiometric characteristics of both swaths are specified in the tab.1. The time sequence of collected data is listed in the tab.2.

Table.1.Parameters of TerraSAR-X StripMap data. Parameter	stripNear_013 Dual VV/VH	stripNear_007 Single VV
Nominal Slant Range Resolution:	1 m	1 m
Nominal Azimuth Resolution:	6 m	3 m
Ground Range Resolution:	7.7 m	6.3 m
Azimuth Resolution:	7.6 m	6.2 m
Azimuth Looks:	1.3	2.2
Range Looks:	4.5	2.7
Row Spacing Units:	3.5 m	2.75 m
Column Spacing Units:	3.5 m	2.75 m
Image Resampling Method:	Cubic Convolution	
Map Projection	UTM	
Radiometric Correction	Calibrated	
Image Data Depth	16 bits	
Pixel Value ID	Radar Brightness (Beta Nought)	

Date	Time	Polarization Mode	Polarization Channels	Incidence angles: Min. / Max.	Beam	Product type/ Projection / Resolution variant
2008-04-25	4:58 UTC	Dual	VV/VH	41.9-42.9	StripNear_013R	EEC/UTM/RE
2008-05-17	4:58 UTC	Dual	VV/VH	41.9-42.9	StripNear_013R	EEC/UTM/RE
2008-05-22	5:07 UTC	Single	VV	29.7-32.4	Strip_007R	EEC/UTM/RE
2008-06-02	5:07 UTC	Single	VV	29.7-32.4	Strip_007R	EEC/UTM/RE
2008-06-08	4:58 UTC	Dual	VV/VH	41.9-42.9	StripNear_013R	EEC/UTM/RE
2008-06-19	4:58 UTC	Dual	VV/VH	41.9-42.9	StripNear_013R	EEC/UTM/RE
2008-06-24	5:08 UTC	Single	VV	29.7-32.4	Strip_007R	EEC/UTM/RE
2008-06-30	4:58 UTC	Dual	VV/VH	41.9-42.9	StripNear_013R	EEC/UTM/RE
2008-07-22	4:58 UTC	Dual	VV/VH	41.9-42.9	StripNear_013R	EEC/UTM/RE
2008-08-13	4:58 UTC	Dual	VV/VH	41.9-42.9	StripNear_013R	EEC/UTM/RE
2008-08-29	5:07UTC	Single	VV	29.7-32.4	Strip_007R	EEC/UTM/RE

Methods

The main aim of the methodological procedure was to create the subsets of data which enable to extract maximum of information in the shortest multitemporal dataset. As all registered single and dual polarization bands were delivered in EEC precise geometry, with sub-pixel overlaying accuracy, deGrandi multitemporal filtering was applied for each strip (R007 and R013 separately). Within this multitemporal filtering an optimum weighting filter is introduced to balance differences in reflectivity between images at different times. The filtering was done with SARScape software. For stronger speckle filtering smaller values of number of looks were chosen: 1.3 looks for R013 dual-pol VV/VH strip and 2.2 looks for R007 single-pol VV strip. DeGrandi filtering was followed next by moderate smooth filter - median 5x5. The images still representing intensity were next converted from 32-bits values (real-float) to 8-bit values with very slight histogram stretching on the right side: 0.15 % for VH bands and 0.30 % for VV bands in both modes. For more precise crops distinguishing an agricultural/non-agricultural areas mask was created. It is justified because use of remote sensing techniques for crops mapping and control in the framework of CAP/CwRS campaigns can be supported by LPIS database (Land Parcel Identification System) which exists in almost all EU countries.

The following subsets of collected images were analyzed separately:
- ✓TSX R013 VV/VH - time series from longest to shortest
- ✓TSX R013 VV only - time series from longest to shortest
- ✓TSX R007 VV - time series
- ✓IKONOS + TSX R013 VV/VH - shortest time series.

The same analysis was done for the same time series of R013 dual-pol acquisitions but neglecting cross-polarisation component VH. The results could give us an indication on the use VV polarisation only, at the same incidence angle of about 42 degrees (R013 or R014 strips) but in single polarisation mode. This option seems to be interesting from two points of view: better spatial resolution what is important for the regions of small size of parcels (like most regions in Poland) and larger imaging swath (30 km instead of 15 km) what is more comfortable for national administrations defining AOC (Areas Of Control) for each yearly CwRS campaign.

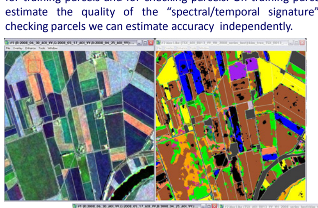
The first steps in time series image analysis were calculations of Jeffries-Matusita Distance (JMD) - class separability measure. It is a commonly used, besides of Transformed Divergence, standardized statistical measure of class similarity based on their spectral or temporal signatures defined on reference parcels (ground truth). The values of JMD measure go from 0 to 2.00 and can be divided into 4 classes with following suggestions:

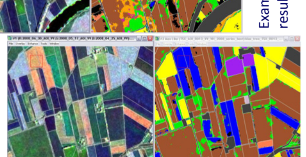
0-1 – very bad separability: classes have to be absolutely merged,
1-1.8 – bad separability: classes rather have to be merged,
1.8-1.9 – good separability: good results of classification expected,
1.9-2.0 – very good separability.

The analysis of class separability lead to their redefinition and the "per pixel" classification was made using maximum likelihood classifier on the "spectral/temporal" signatures extracted from **all** reference parcels. For each classification routine the same high probability level of 0.9 was set up in the classifier parameters set. The last step in classification procedure was calculation of Confusion Matrix and Kappa Index of Agreement. Kappa index expressing the agreement between observed coincidence and expected coincidence is considered as substantial in the range 0.61-0.80 and almost perfect in the range 0.81-1.0.

Results

Main crops covering major part of the test site are: Cereals (including winter wheat, spring wheat, winter barley, spring barley, oat, triticale), sugar-beet, rape, grasslands and peas. Incidentally some other crops and land cover types were found on the area: potato, rutabaga, fallow, maize, orchards, gardens, wastelands, spruce and willow (energetic crop). First analyzed parameter was JMD for all pairs of crops and for all collected data series. This analyses show that grasslands and cereals are always confused regardless the number of images and polarization used. First analysed data chain (R013 VV/VH) shows that the highest number of pairs of classes (164/171) of maxima separability is reached just after or during the cereals harvesting (13.08.). The classes which still remain confused are different cereals (winter and spring wheat, spring and winter barley, triticale) and grasslands. Almost the same average class separability, but at smaller pairs number (160/171) can be reached using shorter time series. Last TSX acquisition is done on 22.07., when all crops are fully developed, cereals are in the beginning of stage of maturity. This subset can be considered as fulfilling the requirements to control the parcels before the harvest. But like the results show, almost the same class separations (156/171pairs), with practically the same average separability can be reached using the images registered just until 30.06., it means much before the harvest. Shorter time series e.g. 17.05-30.06. should not be rather considered as sufficient for classification purposes. Worse results in JMD values were achieved without VH component for R013 series, and the worst for the single-pol , R007 time series. Adding Ikonos image at the start of the season improves slightly crops separability but it has no major importance for separation grasslands from winter cereals. The analyses of separability gave us an indication for class merging and aggregation. For all classes mentioned below in the tables the ML classifications were made, "producers" and "users" accuracies and Kappa index of agreement as well were calculated twice: for training parcels and for checking parcels. On training parcels we can estimate the quality of the "spectral/temporal signature" and on checking parcels we can estimate accuracy independently.



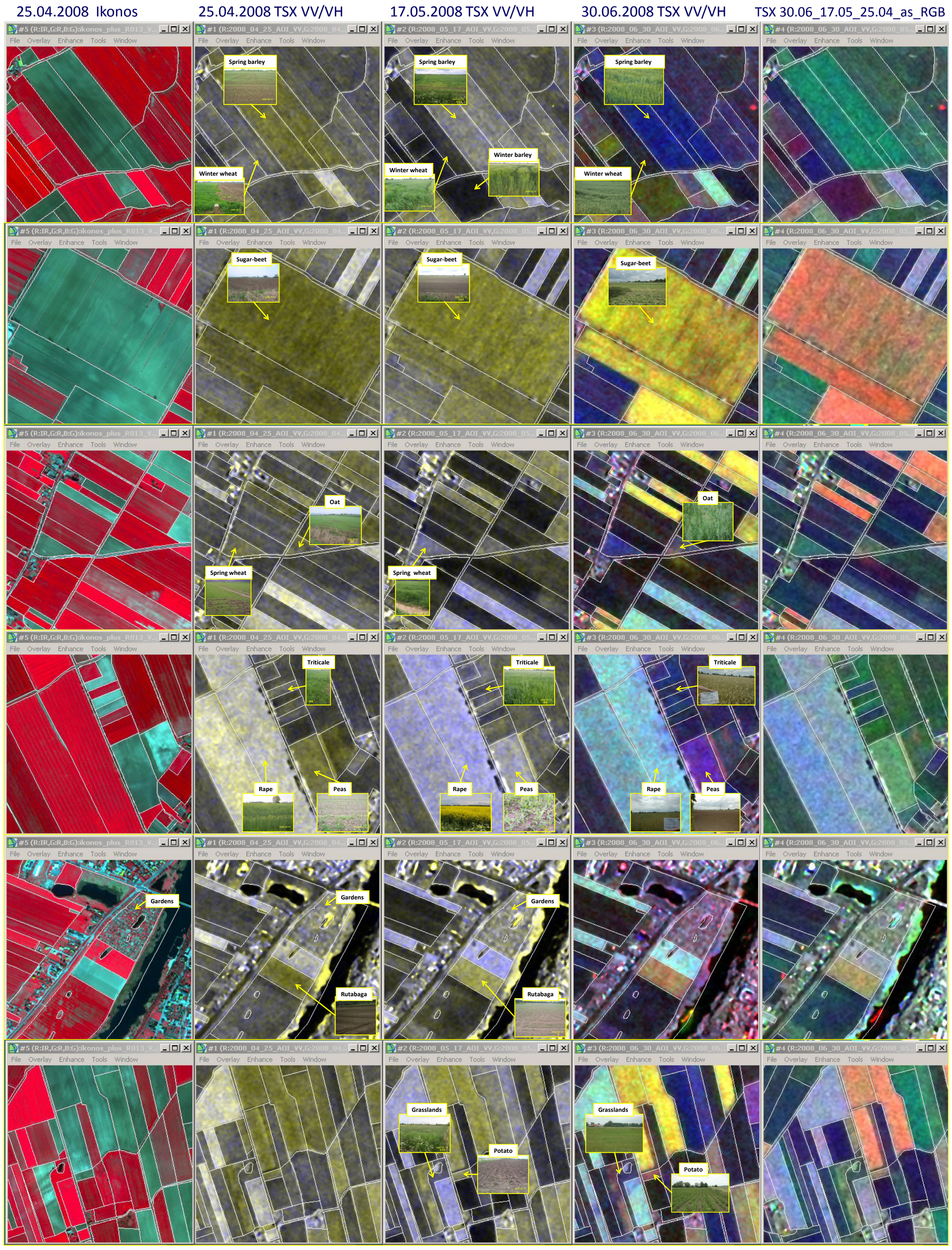


Examples of classification results

Abstract

This poster presents the methodology and first results of early agricultural crops mapping achieved with TerraSAR-X StripMap images acquired at single and dual polarization mode, during spring and summer 2008 over test siteMalbork in Northern Poland. Two types of images in time sequence were ordered and acquired: stripNear_013R, VV/VH and strip_007R, VV, both in Radiometric Enhancement resolution variant. The first TSX observations and Rapid Field Visits started at the moment just after spring cereals have been emerging over the soil but not yet influencing radar backscattered signal coming from soil. Two short-time TSX series were analyzed from crops identification's point of view regarding differences of: viewing angles between strips R013 and R007, radiometric and speckle characteristics of VV channel in single and dual pol. mode, significance of cross polarization component. The development stages and variability (evolution) in time of plants' parts were documented in order to analyze their influence on power of backscattering ("spectral" signature). The methodology of data analyses was subordinated to CwRS requirements demanding the maximum reliability and accuracy in crops mapping before the harvest. In this perspective TSX dataset was supported by optical IKONOS image taken the same day as the first TXS image (25.04.2008) and two input dataset were created for automatic classification purposes: 1) TSX images only, 2) TSX plus multispectral IKONOS data. The results show that it was possible to identify and classify correctly main crop groups occured on the test site as needed by CwRS campaign using short time series of TSX images acquired in dual polarisation mode on R013 strip. Additional input of optical Ikonos data in green, red and near infrared bands permitted to discriminate better spring crops including spring cereals. Unfortunately grasslands were strongly confused with other classes.

25.04.2008 Ikonos | 25.04.2008 TSX VV/VH | 17.05.2008 TSX VV/VH | 30.06.2008 TSX VV/VH | TSX 30.06_17.05_25.04_as_RGB



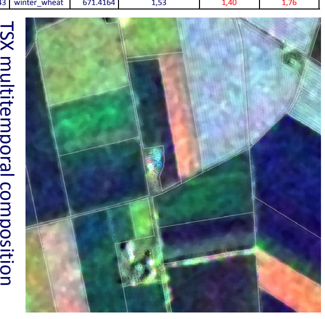
Jeffries – Matusita Distance (JMD) – class separability measures

	R013_VV_VH 2008-04-25 2008-06-30	R013_VV_VH 2008-05-17 2008-06-30	R013_VV_VH 2008-04-25 2008-07-22	R013_VV_VH 2008-04-25 2008-08-13
Average	1,96	1,92	1,98	1,99
Min	1,22	0,86	1,33	1,50
Max	2,00	2,00	2,00	2,00
Number of pairs classes of maxima separability				
	156 /171	142/171	160/171	164/171

	R013_VV 2008-04-25 2008-06-30	R013_VV 2008-04-25 2008-07-22	R013_VV 2008-04-25 2008-08-13	R013_VV 2008-05-17 2008-06-30
Average	1,86	1,91	1,94	1,58
Min	0,83	0,88	1,08	0,24
Max	2,00	2,00	2,00	2,00
Number of pairs classes of maxima separability				
	109/171	133/171	144/171	51/171

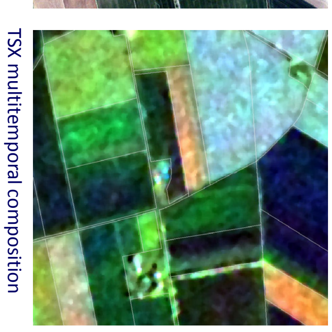
TSX_R007_VV 2008-05-22 2008-08-29
1,78
0,72
2,00
Number of pairs classes of maxima separability
84/171

Class pairs (examples extracted from large calculation reports)					ikonos_plus TSX R013_VV_VH 2008-04-25 2008-06-30	ikonos_plus TSX R013_VV_VH 2008-05-17 2008-06-30	ikonos_plus TSX R013_VV_VH 2008-04-25 2008-08-13
				Average	1,99	1,97	1,99
				Min	1,53	1,27	1,72
				Max	2,00	2,00	2,00
				Number of pairs classes of maxima separability			
Name	Area [ha]	Name	Area [ha]		166/171	160/171	169/171
gardens	7.6771	orchards	3.4165		1,80	1,27	1,96
grasslands	33.9117	orchards	3.4165		1,93	1,80	1,97
grasslands	33.9117	triticale	18.5343		1,85	1,69	1,92
grasslands	33.9117	winter_wheat	671.4164		1,59	1,42	1,72
spring_barley	77.1775	spring_wheat	3.7375		1,72	1,64	1,92
spruce	1.9110	orchards	3.4165		1,92	1,69	1,99
Triticale	18.5343	winter_wheat	671.4164		1,53	1,40	1,76



TSX multitemporal composition 3.5x3.5m

Ikonos pansharpened 1x1m



TSX multitemporal composition fused with Ikonos panchro through highpass filtering 1x1m.

Confusion matrices

Training parcels		TSX_R013 VV_VH 2008-04-25 2008-06-30		TSX_R013 VV_VH 2008-05-17 2008-06-30		TSX_R013 VV_VH 2008-04-25 2008-07-22		TSX_R013 VV_VH 2008-04-25 2008-08-13	
	Overall Accuracy	89.8647%		87.6863%		92.3347%		92.6229%	
	Kappa Coeff.	0.8360		0.8031		0.8730		0.8781	
		Prod. Acc.	User Acc.	Prod. Acc.	User Acc.	Prod. Acc.	User Acc.	Prod. Acc.	User Acc.
fallow		99.80	68.16	98.98	48.50	99.80	84.58	99.80	98.79
gardens		83.17	77.96	59.62	67.37	91.75	80.03	94.00	88.70
grasslan ds		78.61	26.48	71.90	24.34	81.98	26.95	84.31	27.10
maize		96.21	61.67	95.53	46.49	96.64	77.83	97.58	94.41
orchards		51.61	1.04	19.35	0.18	51.61	1.40	51.61	1.84
peas		96.45	98.38	95.54	98.65	96.87	98.36	97.35	98.30
potato		98.33	72.97	98.57	56.10	99.52	89.89	99.52	89.70
rape		97.00	99.16	95.56	99.26	97.60	99.05	97.89	99.01
rutabaga		96.22	90.01	94.82	79.17	97.72	96.16	98.22	96.77
sugar-beet		94.98	95.92	90.34	96.18	96.63	96.09	97.53	95.89
willow		99.21	96.19	98.17	56.99	100.00	90.09	100.00	99.48
wastelands		99.50	84.81	98.02	33.56	99.50	84.81	99.50	97.10
spruce		40.00	0.02	20.00	0.01	80.00	0.65	80.00	2.86
cereals		86.21	99.29	84.58	99.29	89.55	99.32	89.63	99.41

Training parcels		TSX_R013_VV 2008-04-25_2008-06-30		TSX_R013_VV 2008-05-17_2008-06-30		TSX_R013_VV 2008-04-25_2008-07-22		TSX_R013_VV 2008-04-25_2008-08-13	
	Overall Accuracy	68.7388%		50.4315%		75.9055%		80.2450%	
	Kappa Coeff.	0.5645		0.3605		0.6494		0.7036	
		Prod. Acc.	User Acc.	Prod. Acc.	User Acc.	Prod. Acc.	User Acc.	Prod. Acc.	User Acc.
fallow		96.73	41.93	91.62	28.54	97.34	45.99	97.34	47.08
gardens		50.83	37.38	25.94	18.25	67.23	54.89	76.54	62.96
grasslan ds		62.43	15.37	57.99	16.80	73.13	13.22	73.49	14.18
maize		89.68	34.10	88.50	33.49	93.85	42.91	94.78	46.31
orchards		16.13	0.08	0.00	0.00	19.35	0.13	45.16	0.29
peas		80.71	90.14	53.89	22.67	88.84	92.97	94.38	96.59
potato		95.00	22.68	95.48	18.92	96.90	35.33	97.14	41.80
rape		86.36	99.55	56.24	98.01	92.19	99.51	92.81	99.47
rutabaga		89.48	72.48	76.92	8.01	91.10	88.45	93.19	89.10
sugar-beet		70.56	99.42	24.86	98.81	80.61	99.21	87.68	98.89
willow		93.98	10.85	91.10	9.20	98.95	10.16	99.74	22.57
wastelands		97.03	15.43	92.57	5.89	97.52	25.52	97.03	34.81
spruce		20.00	0.00	40.00	0.01	60.00	0.11	80.00	0.18
cereals		60.52	99.18	51.10	99.28	67.63	99.22	73.31	99.32

Training parcels		ikonos_plus_R013V V_VH 2008-04-25 2008-06-30		ikonos_plus_R013V V_VH 2008-05-17 2008-06-30		ikonos_plus_R013 VV_VH 2008-04-25 2008-08-13	
	Overall Accuracy	94.4837%		93.2734%		96.0417%	
	Kappa Coeff.	0.9072		0.8879		0.9326	
		Prod. Acc.	User Acc.	Prod. Acc.	User Acc.	Prod. Acc.	User Acc.
fallow		99.59	92.23	98.98	89.96	99.80	98.59
gardens		89.83	78.06	76.91	68.09	95.90	87.88
grasslan ds		90.77	50.51	89.15	51.14	92.35	53.94
maize		97.45	79.27	97.02	75.63	97.82	97.89
orchards		67.74	1.24	38.71	0.38	64.52	2.45
peas		97.62	97.66	96.54	98.02	98.21	97.33
potato		98.81	96.51	98.57	94.31	99.05	97.88
rape		96.98	99.13	96.14	99.30	97.80	99.00
rutabaga		96.85	92.46	95.97	86.73	98.16	98.87
sugar-beet		96.64	97.39	95.58	97.70	97.94	97.64
willow		99.74	99.22	98.69	97.42	99.74	99.74
wastelands		99.50	92.63	99.01	61.54	99.50	100.00
spruce		40.00	0.06	40.00	0.04	80.00	5.97
cereals		93.16	99.42	91.98	99.51	95.03	99.48

Checking parcels		TSX_R013 VV_VH 2008-04-25 2008-06-30		TSX_R013 VV_VH 2008-05-17 2008-06-30		TSX_R013 VV_VH 2008-04-25 2008-07-22		TSX_R013 VV_VH 2008-04-25 2008-08-13	
	Overall Accuracy	95.3636%		95.8071%		93.5325%		95.4829%	
	Kappa Coeff.	0.9048		0.9135		0.8699		0.9071	
		Prod. Acc.	User Acc.	Prod. Acc.	User Acc.	Prod. Acc.	User Acc.	Prod. Acc.	User Acc.
grasslands		94.95	46.52	92.63	33.13	95.29	47.17	96.61	48.90
peas		98.34	95.37	97.07	94.80	98.95	94.94	99.38	95.05
rape		97.91	98.09	96.98	98.50	98.16	97.85	98.38	97.71
sugar-beet		97.18	94.47	94.96	95.70	97.50	94.06	97.80	93.38
cereals		94.45	99.72	92.42	99.65	94.49	99.71	94.83	99.77

Checking parcels		TSX_R013_VV 2008-04-25 2008-06-30		TSX_R013_VV 2008-05-17 2008-06-30		TSX_R013_VV 2008-04-25 2008-07-22		TSX_R013_VV 2008-04-25 2008-08-13	
	Overall Accuracy	86.0660%		90.3515%		79.9958%		87.7207%	
	Kappa Coeff.	0.7430		0.8139		0.6495		0.7704	
		Prod. Acc.	User Acc.	Prod. Acc.	User Acc.	Prod. Acc.	User Acc.	Prod. Acc.	User Acc.
grasslands		95.06	21.89	88.55	16.34	95.42	21.68	95.16	27.47
peas		94.55	94.72	90.17	78.90	95.59	94.66	96.98	94.55
rape		93.95	97.80	91.12	98.19	95.53	98.05	96.51	97.84
sugar-beet		85.85	97.64	65.28	98.52	91.08	98.01	93.26	97.37
cereals		83.63	99.71	78.30	99.63	84.95	99.68	88.16	99.67

Checking parcels		ikonos_plus_R013 VV_VH 2008-04-25 2008-06-30		ikonos_plus_R013V V_VH 2008-05-17 2008-06-30		ikonos_plus_R013 VV_VH 2008-04-25 2008-08-13	
	Overall Accuracy	96.2409%		95.2015%		96.8666%	
	Kappa Coeff.	0.9219		0.9015		0.9344	
		Prod. Acc.	User Acc.	Prod. Acc.	User Acc.	Prod. Acc.	User Acc.
grasslands		94,53	59,45	92,53	45,62	96,18	65,86
peas		98,55	99,05	98,00	99,30	99,12	99,27
rape		98,12	98,13	97,50	98,43	98,46	97,91
sugar-beet		97,77	95,97	97,04	96,95	98,19	95,46
cereals		95,58	99,72	94,41	99,68	96,28	99,76

Conclusions

Short time series of TSX StripMap images acquired at large incidence angle (about 40-43°) in dual-pol mode has been useful for identification of typical crops occured on the AOI. The TSX acquisitions made before or during cereals harvesting can shorter the period of inspections and supported by ONE VHR optical image can give the material not only for crop identification but also for parcels area measurements according to CwRS rules. This method could be recommended for the regions of difficult optical imagery acquisitions caused by high cloudiness and with small crops variability. An important aspect of TSX image interpretation and classification is quite large spectral signature of cereals resulting probably from plants variable density and biomass on different parcels to control. This could be further studied in the perspective of detection of percels „overfertilized". (GAEC)

Image	Training parcels: Overall Accuracy	Training parcels: Kappa Coefficient	Checking parcels: Overall Accuracy	Checking parcels: Kappa Coefficient
TSX_R013_VV_VH 2008-04-25_2008-06-30	89.8647%	0.8360	95.3636%	0.9048
TSX_R013_VV_VH 2008-05-17_2008-06-30	87.6863%	0.8031	93.5325%	0.8699
TSX_R013_VV_VH 2008-04-25_2008-07-22	92.3347%	0.873	95.4829%	0.9071
TSX_R013_VV_VH 2008-04-25_2008-08-13	92.6229%	0.8781	95.8071%	0.9135
TSX_R013_VV 2008-04-25_2008-06-30	68.7388%	0.5645	86.0660%	0.7430
TSX_R013_VV 2008-05-17_2008-06-30	50.4315%	0.3605	79.9958%	0.6495
TSX_R013_VV 2008-04-25_2008-07-22	75.9055%	0.6494	87.7207%	0.7704
TSX_R013_VV 2008-04-25_2008-08-13	80.2450%	0.7036	90.3515%	0.8139
TSX_R007_VV 2008-05-22_2008-08-29	23.7334%	0.1878	69.2948%	0.5114
ikonos_plus_R013_VV_VH_2008-04-25_2008-06-30	94.4837%	0.9072	96.2409%	0.9219
ikonos_plus_R013_VV_VH_2008-05-17_2008-06-30	93.2734%	0.8879	95.2015%	0.9015
ikonos_plus_R013_VV_VH_2008-04-25_2008-08-13	96.0417%	0.9326	96.8666%	0.9344

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