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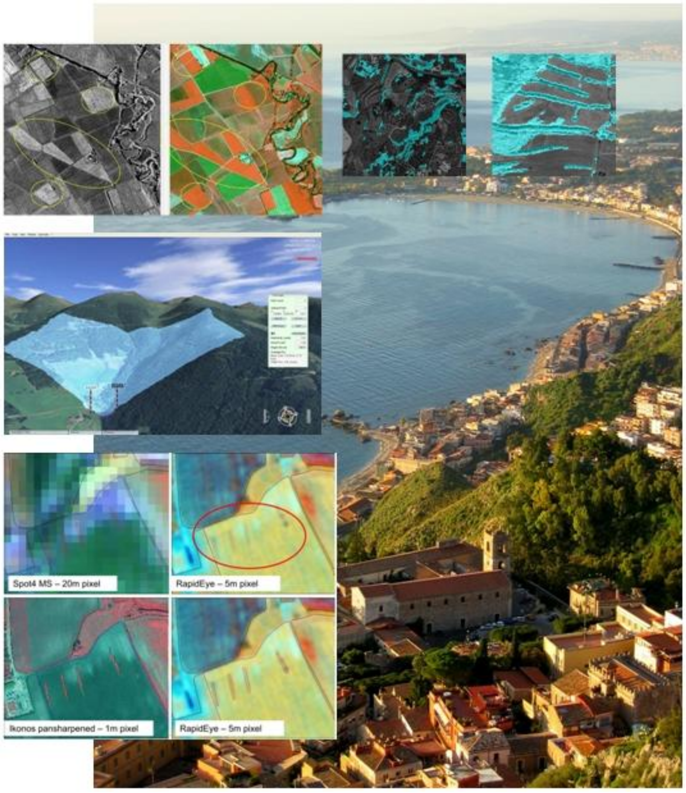
Geomatics in support of the Common Agricultural Policy

Proceedings of the 15th GeoCAP Annual Conference, 2009
Congress Centre, Taormina 18th-20th November 2009

Edited by: Beata Hejmanowska, Joanna Nowak, Vincenzo Angileri, Wim Devos, Hervé Kerdiles and Philippe Loudjani



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Conference Abstract

The 2009 Annual Conference was the 15th organised by GeoCAP action of the Joint Research Centre in ISPRA. It was jointly organised with the Italian Agenzia per le erogazioni in agricoltura (AGEA, coordinating organism of the Italian agricultural paying agencies).
The Conference covered the 2009 Control with Remote sensing campaign activities and ortho-imagery use in all the CAP management and control procedures. There has been a specific focus on the Land Parcel Identification Systems quality assessment process.

The conference was structured over three days – 18th to 20th November. The first day was mainly dedicated to future Common Agriculture Policy perspectives and futures challenges in Agriculture. The second was shared in technical parallel sessions addressing topics like: LPIS Quality Assurance and geodatabases features; new sensors, new software, and their use within the CAP; and Good Agriculture and Environmental Conditions (GAEC) control methods and implementing measures. The last day was dedicated to the review of the 2009 CwRS campaign and the preparation of the 2010 one.

The presentations were made available on line, and this publication represents the best presentations judged worthy of inclusion in a conference proceedings aimed at recording the state of the art of technology and practice of that time.

Acknowledgements

The editors of this publication, as well as all team members of the GeoCAP action, would like to express sincere thanks to Mr. Giancarlo Nanni (Director of AGEA) who accepted to host and support the conference. We would like also to thank all the persons from the Italian administration for both material and logistical support in the organisation of this successful and popular meeting in such an extraordinary location. We would like to particularly thank Mr. Maurizio Piomponi, Livio Rossi (AGEA) and Paolo Pizziol (JRC) for their deep involvement. We express our gratitude to the staff of the 'centro dei congressi' of Taormina through Mrs. Gabriella Calandrucci.

Finally, we are grateful to presenters for agreeing to submit their work as papers, as well as to the review committee for contributing their valuable time at the meeting to identifying those most suitable for publication.

Peer review process and committee

Up to the 11th Conference, GeoCAP had produced "proceedings" gathering the slides of all presentations made at the annual conference.
In 2006 however, it was decided to go one step better and to produce a restricted set of papers in a special JRC publication, selected by a peer review committee during the conference.

Since the 12th GeoCAP annual Conference held in Toulouse (France) in 2006, peer reviewed proceedings have been produced and published for each MARS conference.

To achieve credibility on these publications, a peer-review committee is assembled, mostly external to the JRC. This committee members organise themselves to attend the technical sessions of the conference, and decide upon the short list of presentations for publication.

The proceedings here are a result of that shortlist, and the conference organisers and the editors are grateful to the assistance provided in reviewing the presentations.

The Peer Review committee members were:

- Mr. Jacques DELINCÉ, Joint Research Centre, European Commission, Chairman of the Committee
- Mr. Kristian MILENOV Agency for sustainable development and euro integration, Bulgaria;
- Mr. Michel DEBORD, CCI Gers, France;
- Mr. Jack CREANER, Department Agriculture, Ireland;
- Ms Ruxandra BADEA, SC TRADSYM CONSULT SRL, Romania;
- Mr. Selim AKSOY, Bilkent University, Turkey;
- Mr. Ugo MINELLI, Cooprogetti Soc Coop, Italy;
- Mr. Fernando RUIZ, TRAGSATEC, Spain;
- Ms. Beata HEJMANOWSKA, Joint Research Centre, European Commission;

As a result of the proceedings selection, awards for the best presentation and best poster were assigned to:

***Best presentation**:* Fabio Slaviero; 3D data extraction techniques and validation methods, prior to the integration in the LPIS;

***Best poster**:* Alfred Hofmann; Implementation of a land registry system showing erosion risk on LPIS;

NEW SAR PROCESSING CAPABILITIES: COSMO-SKYMED VERY HIGH RESOLUTION DATA APPLIED TO AGRO-ENVIRONMENT ANALYSIS AND MONITORING

Filippo Britti [1], Roberto Ligi [1], Livio Rossi [1], Giulio Monaldi[1]

[1] AGEA-SIN: Italian Agency for Agriculture Subsidy Payments

KEY WORDS: SAR, VHR satellite, SAR data processing, CAP, Cross-Compliance, agro-environment, feature extraction, subsidy controls, parcels measurements

ABSTRACT

The new Very High Resolution (VHR) SAR data generation, increasing the advantages related to this technology, has renewed the technological expectations for using radar in agro-environmental analysis and monitoring.

In 2008-09 SIN-AGEA Research dept. addressed its interest to spaceborne SAR pre-operational feasibility in CAP CwRS, selecting several test areas from national Control samples, in agreement with JRC and with Italian Space Agency- ASI collaboration.

Several COSMO-SkyMed products were acquired and processed, such as Spotlight (1m), H-Image (3-5m) and Ping-Pong (10-15m multi-polarimetric), testing ortho-correction accuracies, co-registration and mosaicking capabilities, feature extraction possibility, considering different ancillary data, software to be used and processing-chains, always taking into account CwRS technical specifications and the comparison with traditional optical data.

The outputs include:

- Geometric accuracies and working times for different zones and resolutions
- Applicable Software
- Parcels measurement assessment
- Crop system detection capability through the comparison of both ground surveys and optical VHR
- Achievable operational scales
- SAR usability where cloud cover affects optical data
- Agro-environmental parameters and indicators extractions

1. INTRODUCTION: THE TELAER AIRBORNE EXPERIENCE

AGEA, the Italian Agency for Agriculture Subsidy Payments, started by the end of 2006 test campaigns of Very High Resolution (VHR) Synthetic Aperture Radar (SAR) data from its TELAER airborne system acquiring several lesson learnt on X-Band SAR, especially in thematic mapping capabilities and geomatic issues.

The TELAER airborne system includes two aircraft equipped by optical, multispectral and hyperspectral sensor and a X-Band SAR. Particularly, the SAR sensor works in the X-Band (the same of the SAR mounted on the COSMO-SkyMed satellites constellation or on TERRASAR-X) guaranteeing a ground resolution up to 0.5 mt. In agreement with Joint Research Center JRC (GeoCAP Unit), AGEA during the summer 2007 performed, through this technology, operational experimentations in order to test its capability in agriculture Controls with Remote Sensing (CwRS), including Cross-Compliance (agro-environmental measures) analysis on annual sample areas to be controlled.

Basically, good results in these applications were proven, when using adequate ancillary data (e.g. Digital Model of Elevation/Terrain/Surface) especially for fitting the official geometrical requirements [1]. The possibility of night, winter and persistent cloud cover acquisitions, gives to SAR systems clear advantages for territorial investigation, including agro-environmental monitoring, also allowing the best dealing with the time-windows necessity of information.

In summary, from the technical point of view, the experimentations of Telaer X-Band SAR flights, provided AGEA and JRC with the following knowledge of capability:

- On flat areas: thanks to the regular fields geometry and the relief absence very good compliance, both from the geometric and the thematic point of view, with the traditional use of optical VHR, dealing up to 90% of accuracy
- On flat - hilly areas: some geometrical problems and some detection concerns (e.g. the tree crowns can present major extension in canopy). Land use /eligibility capacity is around 80% of the checked test parcels
- On hilly areas: at complex morphology; here the usual DEM appears inadequate, creating on high gradient slopes/aspects, sometimes severe deformations. Correspondence is around 65% on less steep zones up to very few workable parcels on mountain.

Starting from these encouraging results, AGEA R&D Department was addressed to satellite SAR pre-operational feasibility in CwRS, selecting several test areas inside the 2008 annual Control samples.

Particularly, COSMO-SkyMed VHR SAR data were analyzed as:

- Possible replacement when optical data is affected by cloud cover (in total or partially)
- Possible tool for detection and monitoring of complex agronomic patterns (herbaceous or permanent crops)
- Multi-temporal information source in “coupled” crops detection (payment associated to specific crops)
- Possible support for Cross-Compliance policy, especially for detection of GAEC (Good Agricultural Environmental Conditions) infringements such as erosion, water stagnation, pastures maintaining, etc.
- Multi-temporal information source in rice areas (North Italy paddies), also aimed at using optical-SAR packages on international agronomic/food scenarios.

As additional investigation in renewable resources, a mapping analysis on woodland was done with the purpose of finding relationships to environmental safeguards and Kyoto parameters monitoring.

2. 2008-2009 COSMO-SKYMED VHR SAR EXPERIMENTATIONS

In 2008-09 new VHR X-Band SAR experimentations through the COSMO-SkyMed constellation was carried out by AGEA, in agreement with JRC and Italian Space Agency (ASI) like data provider, always focusing on agro-environmental scenarios, but shifting from airborne X-Band SAR to satellite, in order to evaluate the spaceborne VHR SAR capability to fit the DG AGRI-JRC specific requirements.

Figure 1 Selected AGEA samples for agriculture controls, targets of the COSMO-SkyMed VHR SAR test

A brief description of the activities is as follows:

- Evaluation on crop parcel discrimination by COSMO-SkyMed VHR SAR data, both in terms of agronomical land use and geometrical measurements, in absence of optical reference data. This test was aiming at cloud cover optical zones replacement for CwRS (Figure 1) by using COSMO-SkyMed Spotlight-2 (1mt spatial resolution) on portions of sample; all the investigated parcels were checked by ground surveys for the final analyses.
- COSMO-SkyMed detection capability on different typical agricultural patterns: (complex arable crop pattern and permanent olives, hazelnuts, chestnuts); VHR SAR data was compared with the same optical VHR on AGEA sample, evaluating the operational capability of VHR SAR in detecting and measuring the mentioned targets. Due to the limited COSMO-SkyMed Spotlight-2 frame size (10 by 10 Km) evaluations on the mosaicking performances of such data were carried on (4 adjacent frames at different dates and angles of CSK-SAR acquisitions to be merged as unique layer) being an important test for the future possible data exploitation (Figure 2-3).
- Crop detection possibility, including the phenological phases investigation and evaluation, as foreseen by CwRS activity, multi-temporal and multi-polarization tests were carried on where mixed winter and summer crops are present; different false colour composite RGB images were generated also at different resolution: Spotlight-2 (1mt), HImage (3mt - 5mt), PingPong (10mt - 15mt) with HH-HV (CH) or VV-VH (CV) or HH-VV (CO) polarization modes, through multitemporal interferometric or polarimetric series, aiming at defining the better polarization mode, resolution and temporal characterization for different targets
- Cross-Compliance (GAEC infringements detection) relationships using Winter 2009 COSMO-SkyMed to complete the multi-temporal monitoring of the areas, such as, for example, grass coverage on slopes to be maintained during winter for avoiding soil erosion.
- Due to the increasing importance of forestry monitoring (land change, legal/illegal logging, woodland burnt scars, forestry structures, Kyoto Protocol emissions rules, etc.) also SAR data is increasing as remote used tool, especially for tropical/wet zones monitoring; for this reason COSMO-SkyMed VHR SAR data detection capability was evaluated on forestry landscape, on different areas in Italy (natural and semi-natural); tests with different resolutions and polarizations provided the technical Community with new solutions in Forest Monitoring.

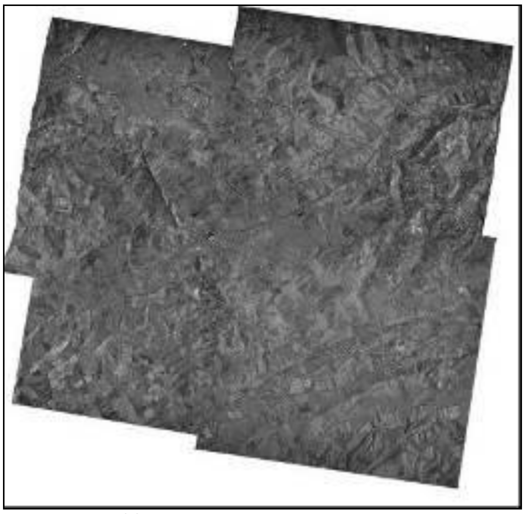

Figure 2 *Mosaic of four COSMO-SkyMed Spotlight-2 images acquired over the Macerata (IT) area. The acquisition dates are: 01/11/2008-04/11/2008-17/11/2008-31/01/2009, two different angle of incident were chosen: 49.81° e 54.66°. Thanks to the optimized post-processing applications the radiometry was cross-balanced and all the geometric distortions attenuated*

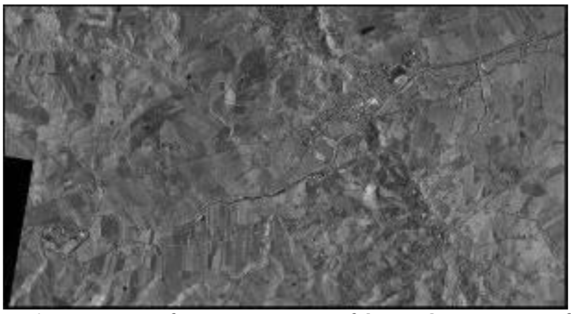

Figure 3 *Zoom of Figure 2 over one of the overlapping areas of the mosaic. As it is possible to note, thanks the apllied post-processing all the seamlines are indistinguishable*

Figure 4 *Coherent MultiTemporal false colour composite RGB done over the Macerata area realized through a COSMO-SkyMed Spotlight-2 interferometric couple; highlighted the changes on the water level of the reservoir (a) and on the ditches status [RED: SAR detected amplitude of the first acquisition (17/11/2008), GREEN: SAR detected amplitude of the second (05/02/2009), BLUE: interferometric coherence]*

For all the tests above described ground surveys, with geometric and thematic ground truths, were carried out with the aim to define cost / benefits and performance statistics, to be used for any future activity and planning with COSMO and in general with VHR SAR data.

All the obtained results are explained in detail in this paper.

Geomatic Performances Assessment: in order to assess both the COSMO-SkyMed VHR SAR data geomatic accuracy and the behaviour of the measured deviation, the analysis carried on was focused on the definition of the geometrical mismatch and how it is affected by the two major causes of error:

- Inaccuracy of the digital model of Elevation/Terrain/Surface used during the ortho-correction
- Orbital data and acquisition parameters (looking direction above all)

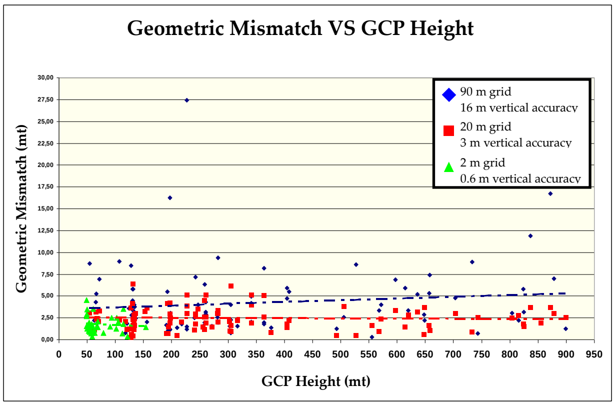

Figure 5 *Plot of the geometric mismatch measured versus the height of the GCP used during the assessment for different digital model used for the ortho-correction*

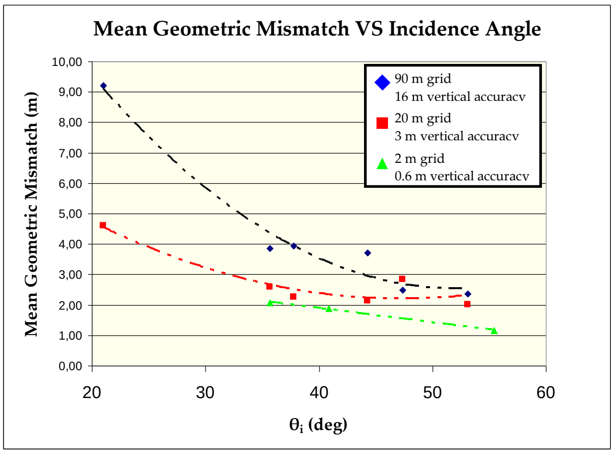

Figure 6 *Plot of the geometric mismatch measured versus the incidence angle implemented during the acquisition for different digital model used during the ortho-correction*

As the above figures explain (Figure 5-6), the geometrical mismatch behaviour is clearly in line with our expectations. In fact, even if the influence of DEM precision is more limited for spaceborne SAR with respect to the airborne one (mainly due to the distance from the ground target), the improvement brought by a more accurate digital model is clear. Concerning to the acquisition parameters contribute, as expected, wider incidence angles guarantee a better accuracy of the ortho-rectified image: the improvement on the measured precision goes from 45% (2 m grid) to 70% (90 m grid). Finally, by an accurate selection of the acquisition parameters (for example: an angle of incidence ranging 30°-40°, good trade-off also from the distortions point of view (lay-over, foreshortening, shadowing,…) and the use of a digital model of 20m grid without using GCP during the ortho-rectification procedure has shown an output of 3m of RSME with Spotlight-2 (1m) data.

Aiming at assessing the COSMO-SkyMed capabilities also in wide targets, an additional test based on the parcels measurement (area and perimeter) was carried on. The used methodology was based on the technique developed by the GeoCAP Unit of JRC and it is briefly explained in [3-4].

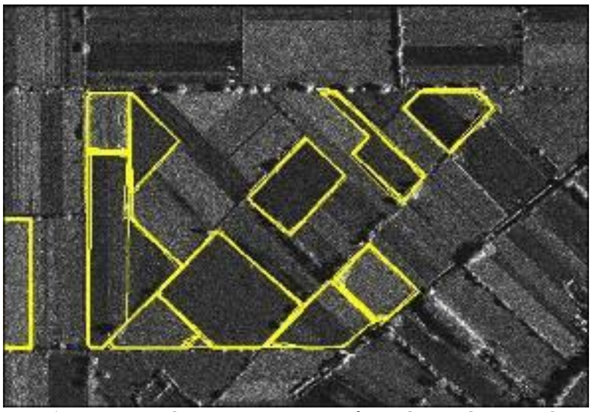

Figure 7 *Parcels measurements, performed twice by several interpreter, over the Fucino area through COSMO-SkyMed Spotlight-2 data*

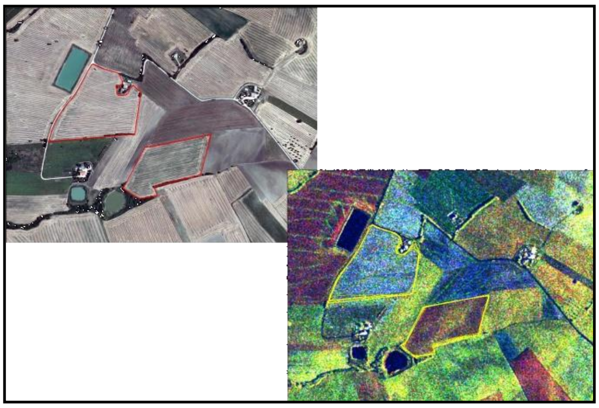

Figure 8 *Parcels measurements over the Macerata area through Coherent MultiTemporal false colour composite RGB (RED: SAR detected amplitude of the first acquisition (17/11/2008); GREEN: SAR detected amplitude of the second acquisition (27/12/2008) ; BLUE: interferometric coherence)*

Two different scenarios were investigated:

- Fucino : flat plain area near L'Aquila (IT) characterized by intensive crops (Figure 7)
- Macerata : hilly area in the centre of Italy with complex agricultural activities (Figure 8)

Three different analysis were carried on:

i. Single SAR image (SAR) with reference optical data
ii. Single SAR image (SAR) without reference optical data
iii. Coherent Multitemporal false colour composite SAR image (RGB-SAR) with reference optical data

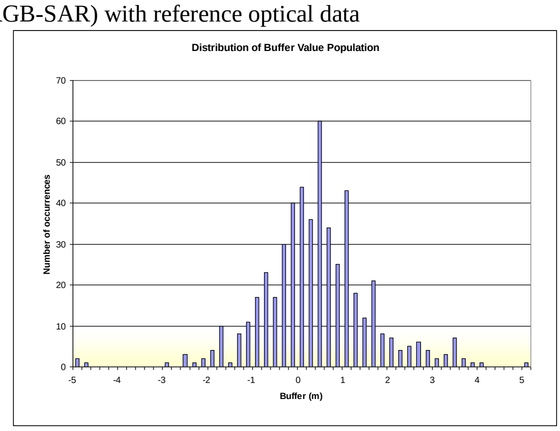

Figure 9 *Parcels measurement assessment: distribution of buffer value population*

As the above figure shows (Figure 9), encouraging results came from parcels measurement assessment. Good accuracy (especially for flat areas) was measured. Multitemporal analysis enhanced the features recoginition but, due to the multilook (necessary step to compute the interferometric coherence map), the reduction of GSD (Ground Sampling Distance) seems to slightly make the accuracy worse.

Land use/cover detection and agro-environmental parameters extraction: COSMO-SkyMed Land use/cover detection and agro-environmental parameters extraction were assessed through several analysis carried on over sites affected by cloud cover and in comparison with VHR optical data, where cultivation and environment conditions were different.

Results as follow:

- COSMO-SkyMed VHR SAR data interpretation test shows good thematic capabilities, reaching the same outputs of TELAER X-Band Airborne SAR (1m) for both land use mapping and GAEC infringements on agricultural parcels (assessment via CwRS official results); all not coupled declared cultivation were mapped and the cultivation groups of coupled crops (associated payment for each specific cultivation), through the joined analysis of multitemporal COSMO-SkyMed VHR SAR data series (Optical HR data as additional reference) were quite well identified but, as expected, an increase on the number of the uncertainty was noticed
- Through COSMO-SkyMed Spotlight-2 all the agricultural and cultivated parcels and their field boundaries were identified, and, in some cases, depending on the ancillary information, also the belonging crop groups; good single tree structures counting capabilities (olive, citrus trees …) were also assessed
- Good identification capabilities of winter and summer crops within the same agricultural pattern was noticed thanks to the clear differences in backscattering measured with respect to the various types of cultivation sensed and compared with HR optical data and in situ surveys. As expected, due to the acquisition geometry and the direction of view of the sensor, the analysis was easier over flat agricultural areas with respect to the hillsides. Concerning permanent crops, COSMO-SkyMed Spotlight-2 data shows good identification capability while, as expected, diversification of species and variety of permanent crops was impossible due to the absence of spectral signature; the main limitation is related to the fact that the SAR response of same crop structure (altitude, spekle, backscattering) can identify same crop groups, even if belonging to different species (e.g. young maize and sorghum). Soil erosion and creeping, due to their geometric roughness on soil, are instead more evident by SAR, such as in water stagnation detection, due to the levels of low/null backscattering on those areas;

Obviously, a better maintenance of the agricultural plantation guarantees a better detection thanks to the enhancement of the geometric and backscattering features of the area

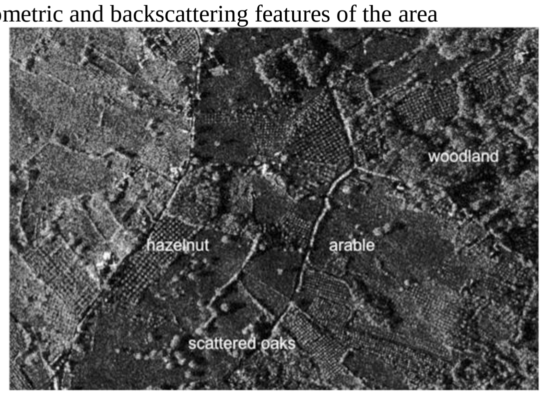

Figure 10 *COSMO-SkyMed Spotlight-2 image (05/09/2008) over the Avellino agricultural area. Example of land-cover features extraction: single trees, hazel groves, sowable and wooded areas*

Figure 11 *Summer crops analysis over the Pavia area: comparison within COSMO-SkyMed Spotlight-2 (30/09/2008) and VHR optical data (04/07/2008); highlighted the differences of the various types of cultivation*

Multi-temporal analysis: Together with the classical multi-temporal monitoring activity based on the differences within SAR detected amplitude of subsequent images acquired over the same area of interest, or on RGB false colour composite generation by different data, a newer approach of survey was assessed. Going deeper, the developed technique is based on the interferometric coherence maps, additional layers generated through interferometric processing of couple of collected SAR images using the same acquisition characteristics, i.e. same incidence angle, polarization, orbit and look direction. The main purpose of this product consists on the characterization of the enlightened area from the temporal point of view. Particularly, being the Synthetic Aperture Radar an active sensor, it is possible to compare, pixel by pixel, the amplitude and the phase of the echo received during the first and the second acquisition. If the target did not change its structural characteristics (shape and dimension above all) within the two acquisitions, the two signals received (from the first and the second passage) will be comparable (coherent), otherwise there will be a difference (both within the amplitudes and the phases) proportional to the level of change noticed by the sensor. In this way, any stable target (like building, bare soil or rocks, asphalted roads,…) will have a high level of coherence and, on the other hand, all the unstable targets (agricultural areas, forests, water bodies, dirty roads crossed,…) will show a low level of coherence. Coupling this information together with the two backscattering maps (or the SAR detected-amplitude maps) different false colour RGB composites can be created, as follow:

- *ILU (Interferometric Land Use Image)* : Interferometric Coherence on Red channel, the mean and the absolute difference of the two SAR detected amplitude maps respectively on Green and Blue Channel (Figure 12-14)
- *MTC (Coherent Multi-Temporal Image)* : The backscattering map coming from the first acquisition (Master image) on Red Channel, while on Green the backscattering map of the second image (Slave image) and the Interferometric Coherence on Blue channel (Figure 4-13)

Through these products all the agro-environmental changes occurred over the test areas were quickly identified, allowing the photo-interpretation team to focus only on the altered zones, both using SAR and HR optical image or, if required, directly in situ surveys.

Particularly, coupling these data with HR optical images (or multi-temporal series) very accurate land change information may be extracted, optimizing all the positive characteristics of both sensor. In fact, combining the spectral information of VHR optical data with certainty of acquisition of Radar a guarantee of acquisition during the desired temporal window can be provided. Integrating SAR data (backscattering maps and RGB products) with optical and external ancillary data (like in situ surveys) into a GIS platform a precise description of all the variations occurred appears available, allowing a more accurate classification and easier to be checked.

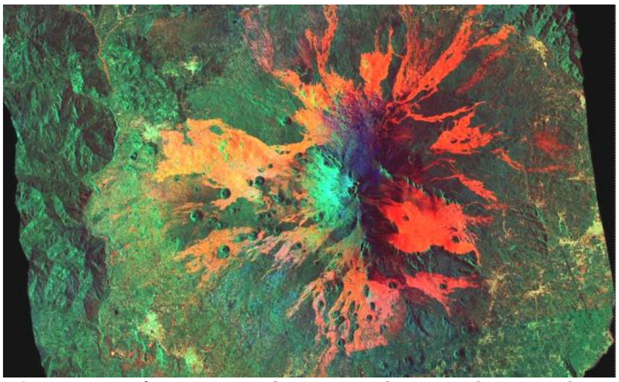

Figure 12 *Interferometric Land Use image done over the Etna volcano (COSMO-SkyMed HImage interferometric couple: 14/04/2008-08/05/2208). In red the solidified old lava flows.*

Forestry: In order to understand COSMO-SkyMed data capabilities in forestry thematic mapping activities, two different areas of interest were selected – Pavia (flat area in Lombardia region with artificial tree plantations) and Pollino Natural Park in Basilicata Region (hilly-mountainous area characterized by natural coppice). Three different acquisition mode were chosen:

- Spotlight-2 (very high resolution (1m) mode with limited swath (10 Km x 10 Km));
- HImage (high resolution (3m) with large swath (40 Km x 40 Km
- Ping-Pong(medium-low resolution (10m) with large swath (30 Km x 30 Km)).

In forestry analysis the geometric features of the examined natural or planted woodlands provided the VHR SAR capability, both in mapping and for monitoring, always through a GIS solution; the lack of spectral signatures does not permit the usual classifications, while the trees altitude, density in canopy, crown structures seem the better parameters for woodland distinction; good results were outlined observing experimental timber farms, both by single SAR passage (amplitude) and by multi-temporal synthesis in RGB.

Concerning forestry information extraction, COSMO shows good results in flat areas with smoothed morphology with respect to hilly-mountainous zones. Particularly, land-change monitoring appears suitable in order to quickly detect variations occurred over the forested zones (clear cuts, fires, etc. …)

The analysis done over Pollino area leads to note that:

- Single VHR SAR images allow to map forestry areas and extract single trees, both isolated and surrounded by scrub in case of big dimensions.
- Single forestry and agro-environmental target counting capabilities. Obviously the better is the status of the plantation the better it will be its visibility (so allowing a tailored selection of all allotments having a bad maintenance)
- Clear cuts appear clearer using multitemporal false colour composite RGB (ILU or MTC) (Figure 13).
- Very good results come from river beds and alluvial fans monitoring through the analysis of interferometric coherence maps. Clear potentialities in soil or deposit movements were noticed, even concerning useful parameters extraction for Civil Protection (Figure 14).

Large and growing interest in Cosmo and in general in new SAR data appears for tropical area mapping monitoring; these applications must be inserted into LUCF projects (land use change in forestry) and in UNFCCC (UN Framework Convention on Climate Change), due to Cosmo intrinsic capability of: cloud cover penetration, large swath and suitable high resolution for operational mapping scale.

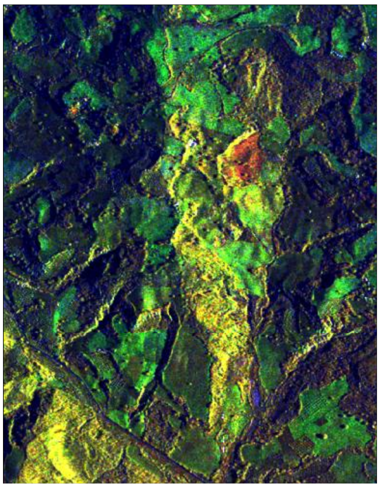

Figure 13 *Coherent Multitemporal image over the Pollino area (COSMO-SkyMed Spotlight-2 interferometric couple: 08/12/2008-09/03/2009); In red a forest parcel cut*

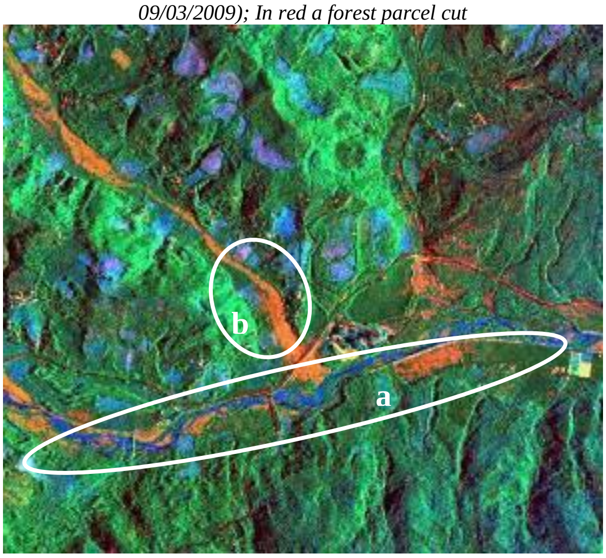

Figure 14 *ILU done over the Pollino area ((COSMO-SkyMed Spotlight-2 interferometric couple: 08/12/2008-09/03/2009); Changes on the river path are in blue due to the high differences on the backscattering values over the flooded or dried areas within the two acquisition (a). The dried river-bed appears in red because, being characterized by rocks, has a high level of coherence (b).*

At last, according to what is written above, the integration of COSMO-SkyMed data with VHR/HR Optical data for land monitoring activities, annual or seasonal, particularly for agricultural and agro-environmental analysis, represents an effective solution. Concerning traditional agronomic features (hedge trees, rows, stonewalls, ponds, etc.) mapping and updating, COSMO data may guarantee very good results, enabling to fit the Cross-Compliance monitoring recommendations; in the end and obviously, when cloud cover affects optical data, both partially and in total, VHR SAR data appears as the unique RS instrument to be used in this kind of projects.

3. CONCLUSIONS

AGEA, besides the mandatory projects of CwRS and the national Agricultural System and GIS maintaining and continuous updating, is fully involved in Research and Development activities aiming at enhancing the complete agronomic and territorial monitoring. All the performed studies and tests were focused on typical Agency duty, but due to its

"in house" large amount of data set (Remote Sensing Systems, cadastral and topographic maps; historical airborne and satellite ortho-imagery, historical ground surveys, digital thematic layers at national/local level) AGEA wants to contribute and develop new and sustainable agro-environmental solutions to be shared with other Agencies and EU partners, always in agreement with official Institutions. The described experimentations and performed tests must be inserted in this scenario, aiming at introducing these systems into the management and control chain of CwRS and IACS.
Work results were already shown to GeoCAP unit of JRC which demonstrated its interest in continuing the experimentation with SAR data, integrated with existing and available Remote Sensing and Territorial data set.

4. REFERENCES AND SELECTED BIBLIOGRAPHY

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LPIS PORTUGAL – QUALITY ASSURANCE STRATEGY

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KEY WORDS: LPIS, GIS, information system, quality assurance, PDCA cycle, Reference Parcel (RP)

ABSTRACT
The paper presents the Portuguese strategy defined to implement the PDCA cycle methodology in the LPIS quality assurance procedures, as an internal process of monitoring the quality of the LPIS.

1. INTRODUCTION

Since the beginning of LPIS in 1995, IFAP, the Portuguese paying agency, has been concerned with the quality of the system, but one can consider that the first step to implement a quality assurance process started in 2004 with the reengineering of the LPIS data base.

In this reengineering project implementation, IFAP tried to follow some quality standards, for example, while defining systematic procedures to the system development and errors reporting.

After the first phase of the LPIS reengineering project, the Portuguese authorities understood the need to improve the subsidies management model and decided to widen the upgrade effort to others business areas in IFAP.
In April 2006, the iDIGITAL project was created with two main objectives:

- ✓ Reengineering the subsidies management model in IFAP integrated in the e-governance policy.
- ✓ Improve the customer's satisfaction by increasing the IFAP information transparency.

The authorities established that the iDIGITAL project should prepare IFAP for the certification of quality (ISO 9001:2000).
In this framework, three main principles were adopted at the LPIS business process level:

- ✓ Document what to do; normative documents, documents of specification of requirements, documents of software acceptance had been produced
- ✓ Do what is documented
- ✓ Register what is done; register of the update actions in the LPIS (accesses, type of update and historical management); new system of document management guided by processes was implemented.

2. QUALITY ASSURANCE STRATEGY

"Quality assurance, refers to planned and systematic production processes that provide confidence in a product's suitability for its intended purpose. "

http://en.wikipedia.org/wiki/Quality_assurance

One of the most popular methodologies to determine quality assurance is the PDCA cycle.
The PDCA cycle methodology consists in four steps:

- ✓ PLAN
- ✓ DO
- ✓ CHECK
- ✓ ACT

The PDCA is considered an effective method for monitoring quality assurance because it analyses existing conditions and methods used to provide the product or costumers service.
The goal is to ensure that excellence is inherent in every component of the process.
In addition, if the PDCA cycle is repeated throughout the lifetime of the product or service, it helps to improve the company's internal efficiency.
In the LPIS specific case the "confidence in the product" is to provide accurate information for the farmers, the administrative crosschecks, the on-the-spot controls and other related entities or systems and also to provide a good service for the farmers to update and access their information.

3. PDCA CYCLE APPLIED IN LPIS-PORTUGAL

The application of the PDCA methodology in IFAP is in an initial phase, one cannot yet consider that it is applied as part of the routine of the LPIS business process.

Following it will be detailed the Portuguese approach to the use of PDCA cycle:

3.1. <u>CHECK</u>

"Measure the new processes and compare the results against the expected results to ascertain any differences."

In October 2006 the results of the EC audit mission brought up the necessity of establishing an immediate strategy to assure the quality of the Portuguese LPIS.
For the purpose of this presentation, it was assumed that the audit mission findings were the results that had to be considered for the next step of the PDCA cycle (Act).

3.2. ACT

"Analyze the differences to determine their cause. Determine where to apply changes that will include improvement."

At the ACT step the results of the audit mission were analyzed in order to identify where to apply changes in the LPIS.
Three issues were identified and reviewed:

- The concept of Reference Parcel
- The register of the maximum eligible area
- The LPIS Update procedures

3.3. PLAN

"Establish the objectives and processes necessary to deliver results in accordance with the expected output."

The objectives and processes defined to implement were:

1. The creation of a new concept: Sub Parcel
2. To improve the LPIS update procedures

3.4. DO

"Implement the new processes. Often on a small scale if possible."

1. The creation of a new concept: Sub Parcel

The objective of the creation of the new concept of sub-parcel was defined in sequence of the review of the concept of reference parcel.
The main reason for the creation of the sub-parcels new level of information was to give the administration the possibility to update the information registered in the LPIS, reducing the changes in the unique ID of the reference parcels.
IFAP decided to keep the Portuguese reference parcel concept based on the farmer's block in order to maintain the stability of the RP unique ID, considering that this attribute relates the LPIS with other information of the IACS system, and it can be associated with multi-annual compromises and historical information.

Sub Parcel	The area delimited geographically with an unique identification as registered in the LPIS whose limits are inside or coincident with the reference parcel, representing a unique land cover.

Reference Parcel	Sub Parcel
• Farmer Block	• Land cover
• Used to relate LPIS with IACS and other systems	• Used for maximum eligible area calculation
• More stable (close to the reality that farmer's know)	• More flexible (close to the land cover reality)

To achieve the creation of the sub-parcel concept, IFAP developed new tools on the LPIS software to identify the limits of the land cover areas within the reference parcel.
These new tools were implemented by the end of 2007.

2. To improve the LPIS update procedures

The second objective was to improve the LPIS update procedures in the following five initiatives:

- Improving the quality of the farmer's surveys
- Integrating other official information
- Improving the process of integration of the control results
- Implementing systematic photo-interpretation
- Improving the regularity of the imagery updates

The first bullet is the improvement of the quality of the farmer's surveys that are realized in regional services all over the year, which involved the following actions:
-To place the LPIS on-line for the aid applications to allow the farmer to confirm the correctness of the LPIS information before he submits the application and to proceed to the update when necessary.
-To promote training actions to certificate new update operators and to carry out training for the operators who already work in the system, in order to review the old procedures and learn about the new ones. The idea is to promote these actions annually to bring the operators up to date with the procedures of the LPIS.
-To establish an annual plan of follow up visits to the regional offices in order to clarify the doubts of the regional staff and to evaluate the quality of the service provided to the farmer.
In what concerns about the improvement of the quality of the farmer's surveys, IFAP worked hard to put the LPIS available on-line in the aid applications software, developed e-learning and b-learning training actions to improve the skills of the regional staff and made some technical visits to the regional offices.
The second bullet was the integration of other official information. IFAP integrated into the LPIS system information provided by Estradas de Portugal, S.A., which is the company that manages the roads in Portugal, representing all the roads constructed in Portugal in the last 10 years.
The third initiative foreseen in the plan was the improvement of the process of integration of the control results.
IFAP developed a procedure in the LPIS to integrate the control results in packages of information and is implementing a link between the LPIS and the control system in order to make it possible to update the LPIS at the very moment a control result for each farmer is loaded into the control system. This possibility will reduce very significantly the availability of the control result for the farmer at the LPIS.
The systematic photo-interpretation was the fourth initiative defined in the plan and intends to assure that the administration proceed to a quality control of the parcels that present greater risk, to guarantee the correctness in the register of the maximum eligible area.
IFAP defined a first phase for the photo-interpretation, based on the 2005/2006 imagery, which included almost 1 million parcels that were applied for SPS in the 2006, 2007 and 2008 campaigns. This task was initiated in August 2007 and was concluded in April 2009.
In 2009 another systematic photo-interpretation, based on the 2009 orthophotos, is being done. For this process 280.000 parcels were selected considering a risk criteria based on the parcels applied in the single application for the 2009 campaign that were not updated in the last 4 years and were located in the NUT regions were the controls detected more problems with the reference parcel identification.
To improve the regularity of the imagery updates, foreseen in the fifth and last initiative, IFAP signed a protocol with the Portuguese Geographic Institute, which establishes the production of an annual flight and orthophoto for the continental Portuguese territory.

4. CONCLUSIONS

The objective was to present the strategy that was defined to improve the quality of the LPIS in Portugal, using an approach to the PDCA cycle.

Although IFAP considers that the PDCA methodology is not yet completely applied as an inherent component of the LPIS business process, it believes that some steps have been taken.

But the most important idea to take home is that IFAP will only know if the objectives were effectively achieved when a new check step will be made to measure the results reached and evaluate the need of new changes.

The continuous improvement has to be understood as an iterative process, and the quality assurance methodology should be part of the routine of the LPIS.

DIGITALGLOBE'S ADVANCED SATELLITE CONSTELLATION, 8-BAND HIGH-RESOLUTION IMAGERY & COLLECTION OPTIMISATION BY EUROPEAN SPACE IMAGING, MEMBER OF THE WORLDVIEW GLOBAL ALLIANCE.

A Joint Paper from Maher Khoury (1) & George Ellis (2)

(1) Regional Sales Director, DigitalGlobe (2) Director of Operations, European Space Imaging

KEY WORDS: High Resolution Satellite Imagery, Multispectral, Resolution, Accuracy, Collection Capability, Real-Time, Direct Access Facility, Optimized Collection

ABSTRACT

The paper expands on the features and benefits of DigitalGlobe's advanced satellite constellation, including collection capability, accuracy, agility, the use of high-resolution 8-band multispectral imagery, and how the process of collection is optimized through regional direct access by European Space Imaging, members of the WorldView Global Alliance.

1. INTRODUCTION

On October 13th, 1999, The New York Times hailed the first successful launch of a commercial high-resolution imaging satellite as one of the most significant developments in the history of the space age. More than 10 years have passed since then, with satellite imagery being adopted across governments, businesses, organizations and individuals, providing value that ultimately changes the way we make decisions.

DigitalGlobe's advanced satellite constellation showcases the latest improvements to high-resolution imagery capture from space, including high-resolution 8-band multispectral imagery, control moment gyros for enhanced agility and the benefits of regional direct access for optimized imagery collections.

2. DIGITAL GLOBE'S ADVANCED SATELLITE CONSTELLATION

DigitalGlobe's constellation of high-resolution satellites offers incredible accuracy, agility and collection capacity, imaging more of the world in the finest level of detail. The constellation collects more than 500 million km2 of high resolution imagery per year – building and refreshing the most comprehensive and up to date image library in the world, containing more than 1billion km2 of accessible imagery, of which a third is less than one year old.

The QuickBird satellite is the first in a constellation of spacecraft that DigitalGlobe operates. Launched on October 18th, 2001 it continues to collect 60 cm panchromatic and 2.44 m multispectral high-resolution imagery at nadir.

WorldView-1, launched September of 2007, has a hight-capacity, panchromatic imaging system featuring half-meter resolution imagery. Operating at an altitude of 496 kilometres, WorldView-1 has an average revisit time of 1.7 days and is capable of collecting up to 750,000 square kilometres (290,000 square miles) per day of half-meter imagery.

WorldView-2 is DigitalGlobe's second next-generation satellite, launched on October 2009 it has more than tripled DigitalGlobe's multispectral collection capacity, brought intraday revisit and added 8-band capability. Like WorldView-1, WorldView-2 is equipped with state of the art geolocation accuracy capabilities and will be only the second commercial spacecraft (after WorldView-1) equipped with control moment gyros, which enable increased agility, rapid targeting and efficient in-track stereo collection.

Feature	QuickBird	WorldView-1	WorldView-2
Operational Altitude	450 km	496 km	770 km
Weight Class	1100 kg (2400 lb)	2,500 kg (5500 lb)	2,800 kg (6200 lb)
Spectral Characteristic	Pan + 4 MS	PAN	Pan + 8 MS
Panchromatic Resolution (nadir)	60 cm (0.6 m)	50 cm (0.5 m)	46 cm (0.46 m)*
Multispectral Resolution (nadir)	2.4 meters	N/A	1.84 meters*
Accuracy Specification**	24M CE90	6.5M CE90	6.5M CE90
Measured Accuracy** (133 samples)	16.4M CE90	4.1M CE90	TBD
Swatch Width	16.5 km	17.6 km	16.4 km
Average Revisit at 40˚N latitude	2.4 days at 1m GSD 5.9 days at 20˚ off-nadir	1.7 days at 1m GSD 5.9 days at 20˚ off-nadir	1.1 days at 1m GSD 3.7 days at 20˚ off-nadir
Monoscopic Area Coverage	1x	4.5x per satellite	
Single-Pass Stereoscopic C overage	Single Scene (<10˚ off-nadir)	2 x 2 Scenes (<30˚ off nadir) 1 x 10 Scenes (<30˚ off nadir)	
Attitude Control Actuators	Reaction Wheels	Control Moment Gyros (CMGs)	
Onboard Storage	137 Gbits (2^37 bits)	2199 Gbits (2^41 bits)	
WideBand Data Download Rate	320 Mbps total 280 Mbps effective	800 Mbps total 697 Mbps effective	
Rapid Delivery Options	Virtual Ground Terminal (VGT)	Direct Downlink, VGT	

*Distribution and use of imagery at better than .50m GSD and 2.0M GSD multispectral is subject to prior approval by the U.S. Government
**At nadir, excluding terrain effects

3. WORLDVIEW-2

WorldView-2, launched October 2009, is the first highresolution 8-band multispectral commercial satellite. Operating at an altitude of 770 kilometres, WorldView-2 provides 46 cm* panchromatic resolution and 1.84 meter* multispectral resolution.

Agility

WorldView-1 and WorldView-2 are the first commercial satellites to have control moment gyroscopes (CMGs). This high-performance technology provides acceleration up to 10X that of other attitude control actuators and improves both manoeuvring and targeting capability. With the CMGs, slew time is reduced from over 35 seconds to only 10 seconds to cover 200km. This means WorldView-2 can rapidly swing precisely from one target to another, allowing extensive imaging of many targets, as well as stereo, in a single orbital pass.

Better Collection & Faster Revisit

With its improved agility, WorldView-2 acts like a paintbrush, sweeping back and forth to collect very large areas of multispectral imagery in a single pass. WorldView-2 alone has a multispectral collection capacity of over 500,000 sq km per day, tripling the multispectral collection capacity of our constellation. And the combination of WorldView-2's increased agility and high altitude enables it to typically revisit any place on earth in 1.1 days. When added to our constellation, revisit time drops below one day and never exceeds two days, providing the most same-day passes of any commercial high-resolution satellite constellation.

4. HIGH RESOLUTION 8 SPECTRAL BANDS

Complementing the large-scale collection capacity is WorldView-2's high spatial and spectral resolution. It is able to capture 46 cm* panchromatic imagery, and is the first commercial satellite to provide 1.84 m* resolution, 8-band multispectral imagery. The high spatial resolution enables the discrimination of fine details, like vehicles, shallow reefs and even individual trees in an orchard, and the high spectral resolution provides detailed information on such diverse areas as the quality of the road surfaces, the depth of the ocean, and the health of plants. The additional spectral bands will also enable WorldView-2 to more accurately present the world as the human eye perceives it, creating a more realistic "true colour" view of the world.

WorldView-1

The WorldView-1 satellite carries a panchromatic only instrument to produce basic black and white imagery for government and commercial customers who do not require colour information. The spectral response band includes both visible and near infrared light for maximum sensitivity. The estimated spectral radiance response, expressed as output counts per unit radiance as a function of wavelength, normalized to unity at the peak response wavelength is shown in figure 1.

WorldView-2

The WorldView-2 satellite carries an imaging instrument containing a high-resolution panchromatic band with a reduced infrared and blue response and eight lower spatial resolution spectral bands. The multispectral bands are capable of providing excellent colour accuracy and bands for a number of unique applications. The four primary multispectral bands include traditional blue, green, red and near-infrared bands, similar but not identical to the QuickBird satellite. Four additional bands include a shorter wavelength blue band, centred at approximately 425 nm, called the coastal band for its applications in water colour studies; a yellow band centred at approximately 605 nm; a red edge band centred strategically at approximately 725 nm at the onset of the high reflectivity portion of vegetation response; and an additional, longer wavelength near infrared band, centred at approximately 950 nm, which is sensitive to atmospheric water vapour.

The spectral responses of the bands are shown in Figure 2, individually normalized as in Figure 1. Table 1 gives the nominal upper and lower edges and centre wavelengths for each band for both WorldView-1 and WorldView-2.

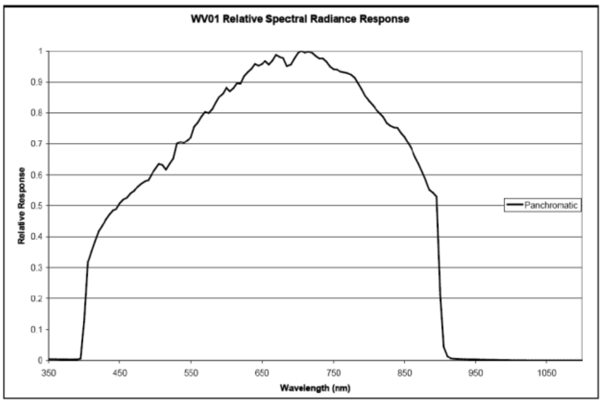


Figure 1. Spectral Response of the WorldView-1 panchromatic imager.

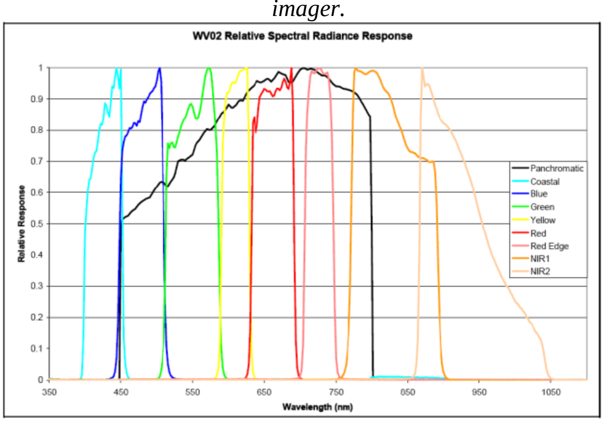


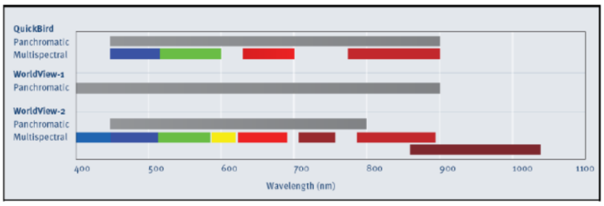
Figure 2. Spectral Response of the WorldView-2 panchromatic and multispectral imager.

Band Name	Center Wavelength (nm)	Minimum Lower Band Edge (nm)	Maximum Upper Band Edge (nm)
Panchromatic WV1	650	400	900
Panchromatic WV2	625	450	800
MS1 (NIR 1)	835	770	895
MS2 (Red)	660	630	690
MS3 (Green)	545	510	580
MS4 (Blue)	480	450	510
MS5 (Red Edge)	725	705	745
MS6 (Yellow)	605	585	625
MS7 (Coastal)	425	400	450
MS8 (NIR 2)	950	860	1040

Table 1. WorldView-1 and 2 Spectral Band Edges and centre Wavelengths

Use of the 8 bands

WorldView-2 is the first commercial high-resolution satellite to provide 8 spectral sensors in the visible to near-infrared range. Each sensor is narrowly focused on a particular range of the electromagnetic spectrum that is sensitive to a particular feature on the ground, or a property of the atmosphere. Together they are designed to improve the segmentation and classification of land and aquatic features beyond any other space-based remote sensing platform.



The Role of each Spectral Band

Coastal Blue (400-450 nm)
New band
• Absorbed by chlorophyll in healthy plants and aids in conducting vegetative analysis.
• Least absorbed by water, and will be very useful in bathymetric studies.
• Substantially influenced by atmospheric scattering and has the potential to improve atmospheric correction techniques

Blue (450-510 nm)
• Identical to QuickBird
• Readily absorbed by chlorophyll in plants
• Provides good penetration of water
• Less affected by atmospheric scattering and • absorption compared to the Coastal Blue band

Green (510-580 nm)
• Narrower than the green band on QuickBird
• Able to focus more precisely on the peak reflectance of healthy vegetation
• Ideal for calculating plant vigour
• Very helpful in discriminating between types of plant material when used in conjunction with the Yellow band

Yellow (585-625 nm)
New band
• Very important for feature classification
• Detects the "yellowness" of particular vegetation, both on land and in the water

Red (630-690 nm)
• Narrower than the red band on QuickBird and shifted to longer wavelengths
• Better focused on the absorption of red light by chlorophyll in healthy plant materials
• One of the most important bands for vegetation discrimination
• Very useful in classifying bare soils, roads, and geological features.

Red-Edge (705-745 nm)
New band
• Centred strategically at the onset of the high reflectivity portion of vegetation response
• Very valuable in measuring plant health and aiding in the classification of vegetation

NIR1 (770-895 nm)
• Narrower than the NIR1 band on QuickBird
• to provide more separation between it and the Red-Edge sensor
• Very effective for the estimation of moisture content and plant biomass
• Effectively separates water bodies from vegetation, identifies types of vegetation and also discriminates between soil types

NIR2 (860-1040 nm)
New band
• Overlaps the NIR1 band but is less affected by atmospheric influence
• Enables broader vegetation analysis and biomass studies

Feature Classification

The growth in agriculture, increased urbanization and natural processes all contribute to the changing nature of land use and land cover around the globe. Remote sensing has been identified as a critical tool in understanding changes on a large and small scale, and currently several satellites are being employed to monitor and study the globe. With 8 tightly focused spectral sensors ranging from visible to near infrared, combined with 1.8 meter spatial resolution, WorldView-2 will bring a high degree of detail to this classification process, enabling a finer level of discrimination and improving decision-making in both the public and private sector.

Land Use/Land Cover Classification and Feature Extraction

Land Use/Land Cover (LULC) classification can be seen on a continuum, starting with a basic estimation of land cover through broad categories, like farmland, and urban areas, to feature extraction, like road networks, buildings, and trees. A typical classification system might segment urban areas in the following manner:

Level 1	Level 2	Level 3	Level 4
• Urban or built-up	• Residential	• Single-family Units • Multi-family Units • Group Quarters • Residential Hotels • Mobile Home Units • Transient Lodgings	• Single Story Units • Two or more Story units

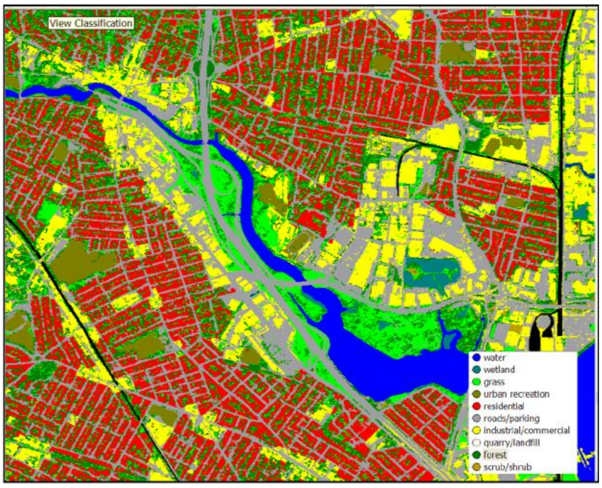
Current satellite-based remote sensing techniques are most effective at classifying LULC on a large scale. Lower resolution multispectral satellites like Landsat are very effective at mapping LULC at the first two levels, by identifying the spectral signature of a particular type of feature, and broadly classifying areas that contain that spectral pattern.

Mexico City, WorldView-2 collected on Feb 2010

With spatial resolutions of 15-30 m, Landsat can classify forests, grasslands and urban development's using the different spectral reflectance of each type of land cover. However, finer details cannot be reliably differentiated at these resolutions.
Higher resolution multispectral satellites with traditional visible to near infrared (VNIR) bands are increasingly able to discern fine scale features. With spatial resolutions of 0.5-1 meter, these satellites have consistently demonstrated the ability to classify features at the third level, for example, discriminating between grasses vs. trees in an orchard, segmenting urban areas by housing types, and discriminating between paved and unpaved roads.

In order to effectively classify LULC beyond the third level, analysts have investigated airborne hyper-spectral sensors, which have spatial resolutions in the 4-5 m range. Even with a decrease in spatial resolution over the highest resolution satellite imagery, the increased spectral fidelity has enabled them to extract fourth level features, like roof types and road conditions.

The increased spectral fidelity of WorldView-2, combined with very high spatial resolution, will provide the additional data necessary to address the feature classification challenge. A pilot study conducted for DigitalGlobe has demonstrated an overall improvement in classification accuracies when comparing traditional VNIR multispectral imagery with simulated WorldView-2 8-band imagery. In some critical areas the improvements are dramatic, highlighting the importance of the additional bands in the classification of specific features. For example, when looking at land classes, WorldView-2 is expected to deliver a 10-30% improvement in accuracy compared with traditional VNIR imagery overall. Specifically, the ability to accurately classify roads was shown to improve from around 55% to over 80%. Similar improvements were demonstrated when segmenting cultivated fields from other forms of vegetation. These dramatic improvements are due to the increased sensitivity to plant material and soil types provided by the addition of the Red-Edge, Yellow and NIR2 bands.



Land use classification using WorldView-2

In contrast, the classification of water bodies is expected to improve from 85-90% with traditional VNIR imagery to between 95-98% with WorldView-2. This suggests that while traditional VNIR multispectral imagery is very capable at classifying water types, the additional spectral bands of WorldView-2 will provide an incremental improvement in this area as well.

Automated Feature Extraction

Increasingly, scientists are experimenting with techniques for automating feature extraction, including neural net, machine vision and object oriented approaches. These methodologies rely not only on the spectral signal of individual pixels, but how pixels with a similar spectral signal are grouped together into recognizable features and how computer algorithms are refined to more accurately extract these features. For example, an asphalt road and asphalt roof shingles may have virtually identical spectral signatures, but by factoring in the shape of the cluster of pixels – long and narrow, or small and rectangular – an automated classification system can distinguish between the two. These various techniques are dependent on the combination of high spectral and spatial resolution, and are proving to be an effective solution to the feature classification challenge.

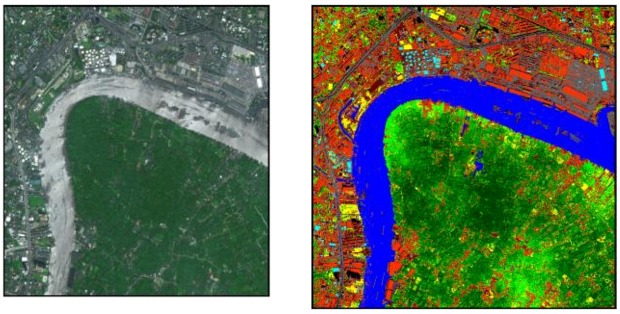
The increased spatial resolution of WorldView-2 is also expected to improve the efficiency of automated classification techniques. Studies using 2 m resolution 4-band multispectral aerial data have shown that object oriented techniques significantly improved classification accuracies without any manual intervention.

Feature Classification using Satellite imagery

The increased classification accuracies that can be achieved with 8 bands have already been demonstrated; therefore we expect that the combination of the increased spectral and spatial resolution will be particularly effective in automated feature extractions.

Feature Classification Applications

Highly detailed and comprehensive multispectral data is empowering feature classification and extraction analyses that bridge the gap between scientific studies and practical applications.



Land Cover classification using WorldView-2 – Bangkok, Thailand

Mapping invasive species with bio fuel potential Invasive plants are a serious environmental problem around the globe. They can choke out native vegetation, devastate wetlands and dramatically impact croplands. However, some species such as Chinese Tallow may have the potential to be the next source of bio fuel if their oil rich seeds can be effectively harvested. Remote sensing is a critical tool for understanding and mapping invasive species. Scientists can use detailed species classification and extraction to better understand how invasive species have penetrated native plant populations, in order to identify harvestable populations or to monitor eradication projects, and ensure the complete removal of a target species.

Managing city services

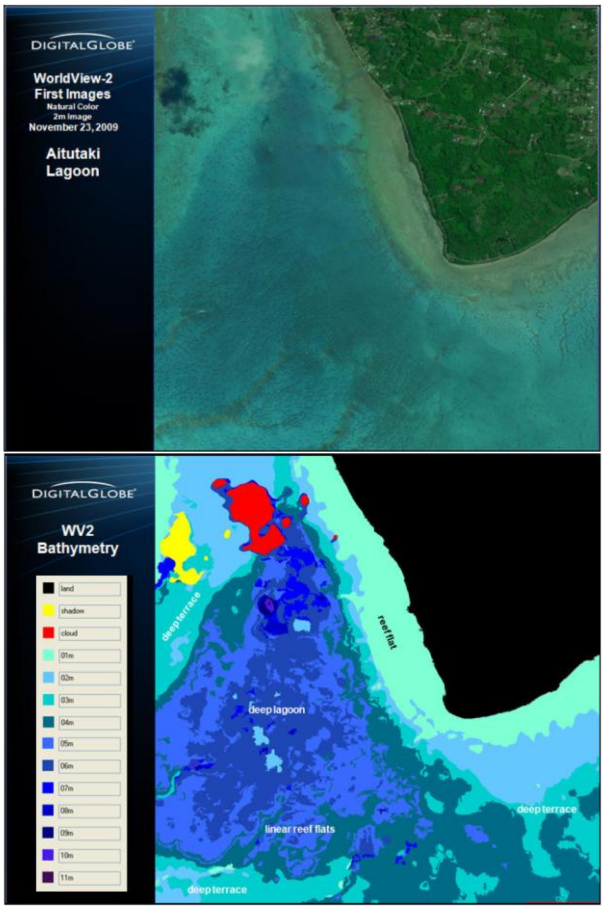
Understanding LULC in urban environments is critical for maintaining city services, managing resources and collecting tax revenue. From maintaining degrading road networks, to monitoring water consumption to tracking the conversion of open space into impermeable surfaces, civil governments are constantly in need of continuously updated, detailed information.

WorldView-2 enables agencies to synoptically map an entire urban area, and with increasingly automated feature extraction and classification capabilities, derive actionable information for managing scarce resources. Through a combination of spectral signatures and objected oriented methodologies, roads can be extracted and even classified by when they will need resurfacing.

Storm water management fees, based on changes to the amount of impermeable surfaces, can be accurately measured, and properly assessed without the need for expensive ground-based surveying projects. Spectral changes in urban areas can also indicate construction projects such as the addition of sheds, decks and other outdoor structures that may not be properly permitted.

Bathymetric Measurements

Coastlines, shoals and reefs are some of the most dynamic and constantly changing regions of the globe. Monitoring and measuring these changes is critical to marine navigation and an important tool in understanding our environment. Near shore bathymetry is currently calculated using high-resolution multispectral satellite imagery. However, with the introduction of WorldView-2's higher resolution, increased agility and Coastal Blue band (400-450 nm), bathymetric measurements will substantially improve both in depth and accuracy.



Bathymetric analysis using WorldView-2 – Aitutaki Lagoon

There are two established techniques for calculating bathymetry using multispectral satellite imagery: a radiometric approach and a photogrammetric approach.

The Radiometric Approach

The radiometric approach exploits the fact that different wavelengths of light are attenuated by water to differing degrees, with red light being attenuated much more rapidly than blue light.

Analysts have leveraged existing multispectral satellites' ability to detect light in the blue (450 – 510 nm), green (510 – 580 nm) and red bands (630 – 690 nm) to achieve good depth estimates, in water up to 15meters in depth. And, with the addition of sonar based ground truth measurements, they have achieved vertical and horizontal accuracies of less than 1 meter.

In order to improve bathymetric measurements, analysts have turned to airborne, high-resolution multispectral platforms. These sensors are able to detect light between 400 and 450 nm – the spectrum that provides the deepest penetration of clear water.

Studies using these data have shown that accurate bathymetric measurements can be achieved up to 20 meters and deeper. WorldView-2 is the first commercial high-resolution satellite to provide 1.84 m resolution multispectral imagery, plus a Coastal Blue detector focused on the 400 – 450 nm range. With the Coastal Blue band included in the mix, analysts expect to be able to calculate depths up to 20 m and potentially as deep as 30 m, by measuring relative absorption of the Coastal Blue, Blue and Green bands.

WorldView-2's large single-pass collection capabilities will also make the application of ground truth data more accurate and reliable. Multiple small collections contain differences in sun angle, sea state and other parameters and it is challenging to calibrate one series of measurements and then apply them across a broad area. Large synoptic collections, enabled by WorldView-2's agility and rapid retargeting capabilities, allow analysts to compare the differing absorption of the Coastal Blue, Blue and Green bands, calibrate their bathymetric estimations using a few known points, and then reliably extend the model across the entire collection area.

The Photogrammetric Approach

In this method, stereoscopic images are collected over the target area, and a data elevation model (DEM) of the shallow ocean floor is produced from the imagery.

Early studies with both satellite imagery, and digital photography appeared promising, and demonstrate that this technique can be used to provide accurate bathymetric models of shallow environments without ground truth. However, the technique has not been widely studied due to limitations in the capabilities of current sensors.

The challenge with collecting stereoscopic imagery of the shallow ocean floor is in how light interacts with the air/water interface (Figure 2). At high angles of incidence, light is completely reflected off the surface of the water, preventing any sub-aquatic features from being observed. Current multispectral satellite sensors are not able to collect enough high-resolution stereoscopic imagery within the narrow angle necessary to penetrate the ocean surface. In addition, none of them are able to measure the shorter wavelength blue light necessary for maximum depth penetration.

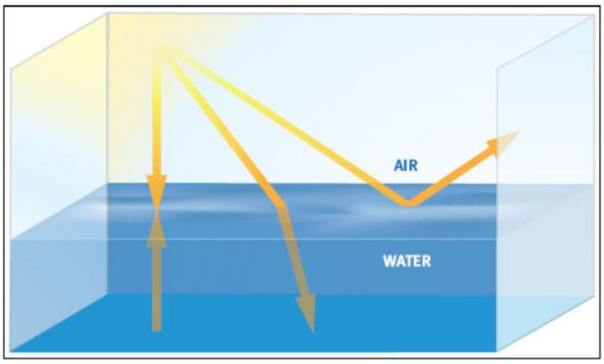


Figure 2. Light & the Air/Water Interference

WorldView-2 will make this new method for measuring bathymetry possible. The Coastal Blue band will deliver maximum water penetration, and WorldView-2's enhanced agility will enable the collection of large amounts of highresolution in-track stereo imagery at the ideal angle for water penetration. The advantage of this approach is that multiple images can be registered using tie points that are visible on land and in the water, and the resulting stereo composite can be used to calculate water depth without relying on ground truth measurements. No other satellite is able to deliver this unique combination of high spatial and spectral resolution, agility and stereo collection capacity.

Bathymetry Applications

Current, accurate and easily updatable bathymetric models will be an effective tool for gaining a clearer understanding of the world's waterways, and improving the safety of marine navigation.

Natural disasters increase marine navigational hazards In the aftermath of Hurricane Katrina, massive amounts of debris washed off shore and settled in the Mississippi Sound, becoming a serious threat to commercial and recreational boaters. As part of a NOAA funded project, five ships were sent to the area, and conducted multiple sonar surveys over the span of several months. These ships surveyed approximately 114 square nautical miles and identified over 1300 sonar contacts. Many of the identified objects were tens of meters across and pose a significant hazard to ships navigating throughout the Sound.

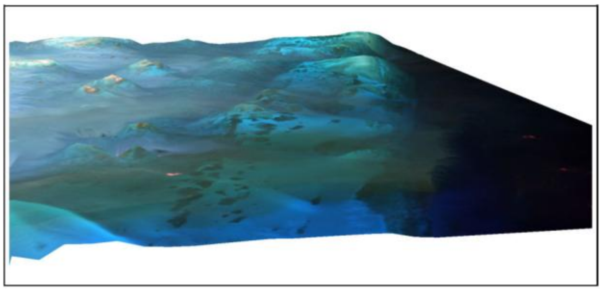
Satellite derived bathymetric measurements could provide a tremendous boost to the efficiency of this kind of project. The entire region could be imaged in a short amount of time, and bathymetric measurements could be made quickly in order to identify potential marine hazards. Ships could then be directed to investigate the objects that presented the greatest threat, and conduct sonar measurements that could be used to refine the satellite derived bathymetric measurements to create a current and more reliable nautical chart.

WorldView-2 True Colour image of Bu-Tinah Island, Dubai.

Accurate bathymetry helps to anticipate risk

In order to understand the impact on coastal communities from destructive marine forces, such as tsunamis, high-wave flooding, coastal inundation, and storm surges, specialists must have precise land-to-shore depth and elevation data. However maps and charts of coastal areas are typically generated from different data sources, and depict information about either the land, or the water. The lack of a seamless high-resolution map that extends from the land through the shoreline and beneath the water has been identified as a major hindrance in the efforts to accurately assess the nature of these threats.

By applying WorldView-2 and the photogrammetric methods, a contiguous elevation model could be created that encompassed the land and water interface. This seamless DEM would be an invaluable tool for modelling storm surge, and more accurately determining the risk to people and property.



3D View – Florida Keys, Bathymetry using WorldView-2

Vegetative Analysis

Vegetative analysis has been a mainstay of the satellite remote sensing community for decades. While the traditional Normalized Difference Vegetation Index (NDVI) method of measuring plant material has been very successful, there is increasing evidence that the addition of the Red-Edge spectral band can improve the accuracy and sensitivity of plant studies. WorldView-2 is the only commercial multispectral satellite to provide global, high-resolution access to the Red-Edge spectral band.

Measuring Plant Material

The NDVI is a well-established mechanism for calculating vegetation. It relies on the principle that the chlorophyll in living plant material strongly absorbs visible light, and strongly reflects near-infrared light.

Several multispectral satellites, including QuickBird, ICONOS, GeoEye-1, Spot-5 and LandSat-7, provide two bands, a red band (RED) in the 610 nm to 680 nm range, and a near infrared band (NIR) in the 750nm to 890 nm range that are routinely used to calculate the NDVI ratio: NIR-RED/NIR+RED. This ratio has been effective in calculating plant vigour, and is used around the globe to evaluate forest and crop heath and monitor environmental changes.

Red River, Vietnam collected by QuickBird.

With the increasing availability of hyper-spectral sensors that can measure dozens or hundreds of spectral bands, scientists have been evaluating the Red-Edge region of the spectrum (between 680 nm and 750 nm), which is the transition region between the minimum and maximum reflectance.

Researchers have shown that a RED to Red-Edge comparison is more sensitive to subtle changes in plant health than NDVI. A RED to Red-Edge comparison is better able to discriminate between healthy trees, and those impacted by disease. In addition, the Red-Edge band has been shown to reveal differences between young and mature plants enhance the ability to segment between conifers and broad leafed plants and even discriminate between species of weeds in crop fields. It is clear from the research that including the Red-Edge band enables far more sensitive and sophisticated analyses. Until now, the only satellite imagery available that contains Red-Edge data is medium to low resolution (5-30 m). It can provide some insights into the conditions of an entire field, but is unable to provide the segmentation necessary to evaluate small scale details, like the health of individual trees in an orchard, or map the impact of irrigation and fertilization within a field.

Airborne hyper-spectral sensors are available and contain both the spatial and spectral resolution necessary to make fine scale evaluations, but collecting this imagery requires extensive planning, and is cost prohibitive for very large projects that require a high rate of revisit.

Red Edge Measurements with WorldView-2

WorldView-2 is the first commercial high-resolution satellite to provide a Red-Edge sensor as part of its 8-band multispectral capabilities. The detector is focused on a narrow band of radiation from 705 to 745 nm, allowing for very sensitive measurements of Red-Edge reflectance. And, at 1.84 m spatial resolution, Worldview-2's multispectral imagery is more comparable to airborne sensors than other satellites. This combination of spatial and spectral resolution will enable the greater segmentation of physical features and more granular measurements of plant vitality.

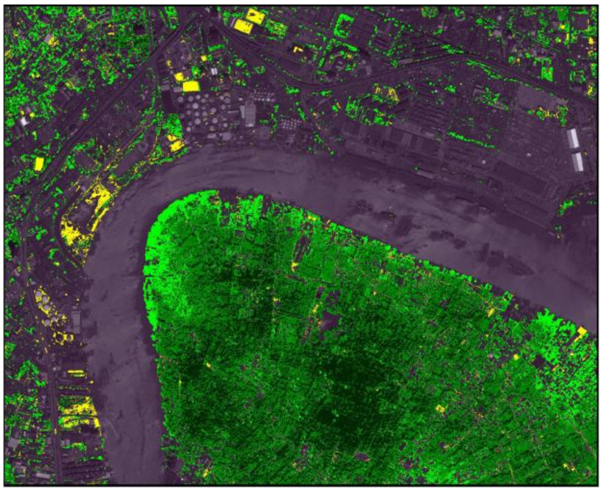
With wide-scale coverage and frequent revisit times, WorldView-2 will make Red-Edge data available on a global scale. Analysts can rely on current synoptic coverage of fields and forests with the most sensitive data available, allowing for the development of a new standard equation, similar to NDVI, but significantly more sensitive to subtle changes in plant health and growth states.

Vegetative Analysis Applications

Frequent and reliable access to Red-Edge data is enabling novel remote sensing applications that depend on the detection of subtle changes in plant health, offering more early-warning capabilities to a variety of industries that interact with, and depend on, the environment. Identifying leaks in gas pipelines Underground natural gas pipelines stretch across the globe, and travel through remote and inaccessible regions. When these pipelines develop leaks, the escaping natural gas causes stress to the surrounding vegetation. Using remote sensing techniques that rely on the sensitivity of the Red-Edge, scientists are able to identify plants that are experiencing physical stress, even in areas where the affects are not visible. By monitoring underground pipelines with high-resolution multispectral satellite imagery, utilities can identify potential gas leaks at their earliest stages, before they pose significant danger to people and the environment.

Monitoring forest health and vitality

Forest plantations are susceptible to wide-scale disease and pest infestations that can cause significant economical impact. Traditional monitoring techniques involve measurements using air and ground surveys; however they are costly and highly subjective. Red-Edge based remote sensing analyses were shown to be effective at identifying trees that were impacted by disease, and were able to provide quantitative information on the health of the trees. By using satellite-based remote sensing techniques that rely on the Red-Edge, large regions can be monitored synoptically. This represents a dramatic cost savings over the traditional monitoring techniques, and allows for more targeted and effective eradication strategies.



Vegetation Mapping – Bangkok, Thailand

Improving Change Detection with WorldView-2

For decades, satellite based remote sensing has been an immensely valuable tool for detecting change. No other platform can consistently revisit an area and repeatedly quantify and classify LULC on such a broad scale. However, the current mix of satellites often cannot detect the subtle details that are so valuable in understanding and reacting to change. WorldView-2's 8 spectral bands, 46 cm* panchromatic and 1.8 m multispectral resolution are able to reveal significantly more detail in the spectral changes of small ground features. Measuring the changes in road conditions, or the health of plants over an underground gas pipeline or the new location of a sandbar requires sensitivity that only WorldView-2 can provide.

2003 Image of Abu Dhabi taken by QuickBird

2009 Image of Abu Dhabi taken by QuickBird – wide spread developments

Increased sensitivity, however, is only part of the story. With WorldView-2's immense collection capacity and rapid revisit capabilities, large areas can be repeatedly imaged, providing the data necessary to conduct automated change detection.

5. OPTIMIZED COLLECTION

DigitalGlobe maintains a Direct Access Program, allowing select partners the ability to directly uplink and downlink to its constellation through Direct Access Facilities (DAF) located around the world. In Europe, European Space Imaging own a DAF located in Munich, Germany with access to WorldView-1 and WorldView-2. The DAF is jointly operated with the German Aerospace Centre (DLR). European Space Imaging has over seven years experience in the operational management and optimization of imagery collections through its own highresolution satellite ground station.

European Direct Access Facility Antenna in Munich, Germany

Advantages offered to customers as a result of regional tasking include:

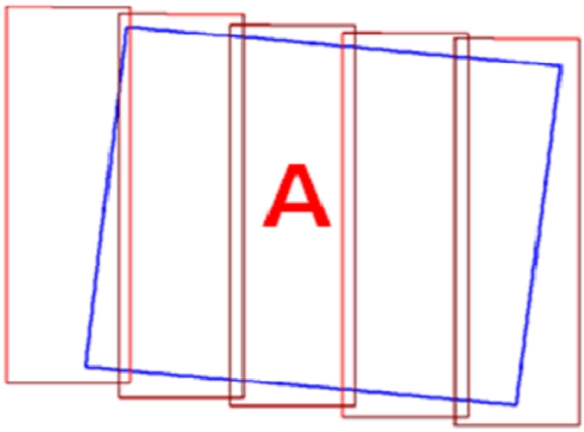
1. Faster response & rapid delivery to European customers
2. Feedback during collection planning
3. Improved image quality through real-time weather information
4. Detailed schedule editing
5. Increased imaging capacity

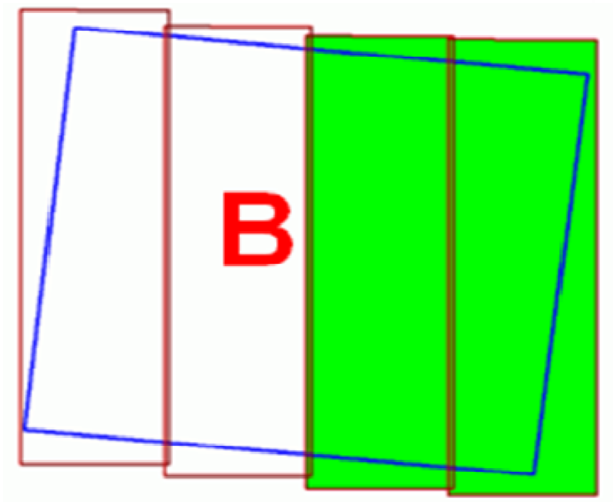
Having collection and production capability located within a customer's regional time zone provides a number of advantages. In many circumstances, orders placed before noon could be collected, processed and provided to the customer on the same day. Providing customers with the ability to make last minute order requests and changes allows European Space Imaging the ability to adjust accordingly and optimize their collection planning. The benefits of collection speed and optimization is not just limited to European customers, but also for customer outside of Europe requiring tasking of a European area.

Having the ability to take into account real-time weather reports can make a huge impact to both the quality of the image and what areas are collected. It is estimated that without the use of weather information, the percentage of cloud free imagery taken could be as low as 30%. Taking into account weather forecast prediction files can improve collection rates to 50%. However when you take in to account real-time weather information and have the ability to make changes minutes prior to the collection pass, this can provide a success ratio of more than 80%.

Detailed scheduled editing allows for the optimization of scan regions calculated by the Collection Planning System (CPS), and therefore maximise the time available to scan for more images. The aim is to make more scan time available by making the scan region shorter and optimised to collect the area of interest in the single collection pass.

As illustrated in Images A, B & C below, from the original plan of 5 scan regions generated by the CPS, through optimising and editing steps, we are able to reduce the number of scan regions and increase the overall area collection capability by rotating the scan region parallel to the ground track. Scanning closer to the ground track requires less satellite slew time, which can be traded for additional scan time. The end result being that we are now able to collect a desired area in less time, or more efficiently.





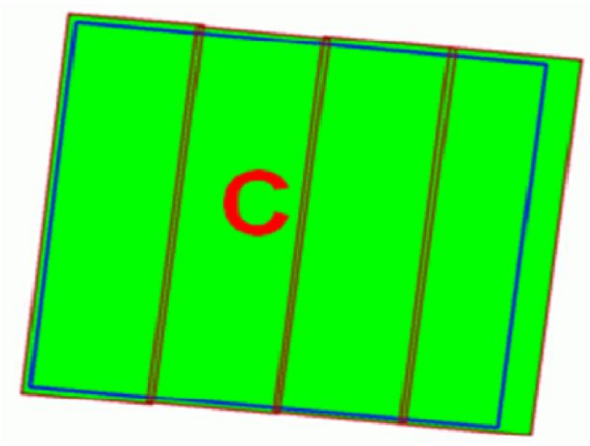


Figure 3.The effects of detailed schedule editing. (A) Illustrates the original plan as constructed by the CPS (B) shows less scan regions used to accomplish the same task by initial editing. By shortening the scan regions and (C) making them parallel to the ground track, allows for optimized collection of the required area in a single pass.

6. CONCLUSIONS

DigitalGlobe’s advanced satellite constellation already leads the Industry in terms of collection capacity, revisit, spectral diversity, high geolocational accuracy, most agile rapid targeting and greatest in-track stereo collection. When this is combined with the world’s largest ImageLibrary containing more than one billion km2 of high-resolution current and historical imagery, accessible on and offline. Supported by regional leaders in the geospatial industry in European Space Imaging and Space Imaging Middle East, the market has a reliable, credible source for all its global imagery requirements for now and the future.

DigitalGlobe, its partners, value-added resellers and strategic alliances are committed to the practical solutions that can be derived from premium quality imagery, and how these solutions can be applied to challenges in governments, enterprises and consumer applications around the world.

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IMPLEMENTATION OF A LAND REGISTRY SYSTEM SHOWING EROSION RISK ON LPIS

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KEY WORDS: LPIS, erosion prevention, erosion risk, maintaining agricultural land, good agricultural and environmental conditions

ABSTRACT: Soil erosion is a worldwide and also pan-European environmental problem that degrades soil productivity and water quality, causes sedimentation and increases the probability of floods. This paper presents a system within an exact calculated erosion risk of agricultural parcels in the German "Bundesland Saarland". The system is based on the regional Land-Parcel-Identification-System (LPIS) as part of the Integrated Administration and Control System (IACS).

1. INTRODUCTION

Regulation (EC) No. 73/2009 in Article 6 establishes that all agricultural land shall be maintained in good agricultural and environmental condition.
Member States shall define, at national or regional level, minimum requirements for good agricultural and environmental condition on the basis of the framework established in Annex III of this Regulation taking into account the specific characteristics of the areas concerned, including soil and climatic condition, existing farming systems, land use, crop rotation, farming practices, and farm structures. One of the issues covered by the good agricultural and environmental condition is soil erosion. Soil should be protected through the appropriate standards "Minimum soil cover" or "Minimum land management reflecting site-specific conditions". In Germany the obligation to maintain areas in a condition which minimises erosion risk is written down in the national policy "*Verordnung über die Grundsätze der Erhaltung landwirtschaftlicher Flächen in einem guten landwirtschaftlichen und ökologischen Zustand (Direktzahlungen-Verpflichtungenverordnung-DirektZahlVerpflV)*". This Regulation will be in effect in Germany starting from 1st July 2010.

2. CATEGORISATION OF EROSION HAZARD

Erosion control requires a quantitative and qualitative evaluation of potential soil erosion on a specific site, and the knowledge of terrain information, soils, cropping system and management practices. The new German legislation has foreseen two categories of potential erosion risk: the water erosion risk and the wind erosion risk. The national regulation describes exactly management practices requirements for the farmer. The categorisation of arable farmland with associated requirements has to be reflected in the local Land-Parcel-Identification-System.
In Germany all "Bundesländer" have to establish their own erosion control systems matching their own Land-Parcel-Identification-System. In Saarland a system based on agricultural parcels which accurately identifies the management conditions to be respected by the farmer is implemented. As the potential wind erosion risk is not important in Saarland, there are only requirements for the potential water erosion risk, departed in two risk classes and one no-risk class:
CC_{W0} for „no erosion risk"
CC_{W1} for „normal erosion risk"
CC_{W2} for „high erosion risk"
In Saarland all agricultural parcels are allocated to one of these groups. The allocation process is carried out using a complex model calculation. The purpose of this calculation should not only be the completion of the legal framework, but also to give an example of a practical application of the use of spatial data in an administrative process. Most Member States are working at parcel level with alphanumeric numbers, not with spatial data. Without the accurate acquisition of parcel boundaries in Saarland in form of spatial data, such a precise determination of the erosion hazard at the parcel level to implement the national law would not have been possible.
From July 2010 the following management conditions will be applied for farmland prone to water erosion risk:

- **Water erosion class 1 (CC_{W1})**
  In the period from 1 December to 15 February these areas may not be ploughed. Areas ploughed after harvesting have to be sowed before 1 December. The reason is to cover the soil during the winter months either with crop residues from the previous crop or with vegetation of the autumn sowed crop. For all parcels belonging to water erosion class1 ploughing across the slope is allowed.
- **Water erosion class 2 (CC_{W2})**
  Areas with high erosion risk should be covered with a vegetation or crop residues all over the year. Ploughing is not allowed from 1 December to 15 February. In the rest of the year (February 16 to November 30), the total area can be ploughed only if, immediately after the ploughing, the sowing takes place. Ploughing is not allowed prior to the sowing of row crops with at least 45 cm row spacing (for example: maize, potatoes).

3. ESTIMATION OF THE NATURAL EROSION HAZRAD

DIN 19708th is the basis for the calculation of natural hazards caused by water erosion in the context of the German regulation "*Direktzahlungen-Verpflichtungenverordnung* ". The DIN is based on the long-term model of the ABAG (=Allgemeine Bodenabtragsgleichung).
The ABAG is the transfer of the American equation USLE (universal soil loss equation) and the RUSLE (Revised USLE, see Renard et al., 1997) the newer, revised version to European standards by Schwertmann, Vogl, and Kainz, 1990. Lot of free and commercial software uses the USLE equation to model the erosion by rain. The calculation of the removal with the ABAG can be made GIS-based (= geographic information system).
Only the natural factors of the location are important for the estimation of the natural erosion hazard (E_{nat}). Variable anthropogenic factors (C-factor and P-factor), such as the crop grown, soil preparation, liming, etc. are not considered. The following factors are then left off:

- C = cover-management factor which is used to reflect the effect of cropping and management practices on erosion rates.
- P = support practice factor, i.e. the ratio of soil loss with a support practice such as contouring, stripcropping, or terracing compared with soil loss with straight-row farming up and down the slope.

Individual events like heavy rainfall events and other extreme weather conditions (e.g. thaw in frozen ground, etc.) that cannot be estimated are not considered either.

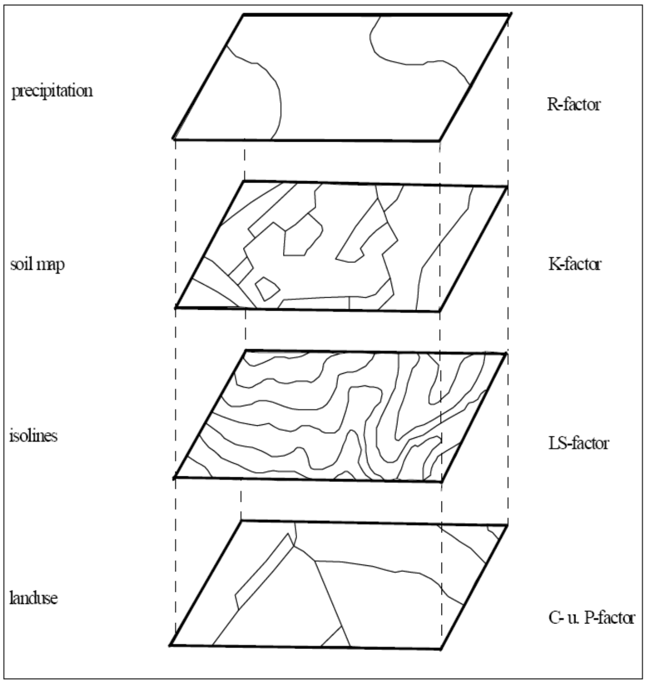

Fig 1: The concept of ABAG and (R)USLE

For the calculation of the natural erosion hazard DIN provides the following raw data (figure 1):

- rainfall-runoff erosivity (R-factor)
- soil erodibility factor (type of soil, K-factor)
- slope steepness factor (slope angle, S-factor)
- slope length factor (effective length of slope, L-factor)

R-factor (flow and surface runoff factor)

The rainfall-runoff erosivity factor uses the data from the own rainfall monitoring network. The R-factor is calculated and summarized into a regionalized isoerodent map (map with different rainfall zones), figure 2.

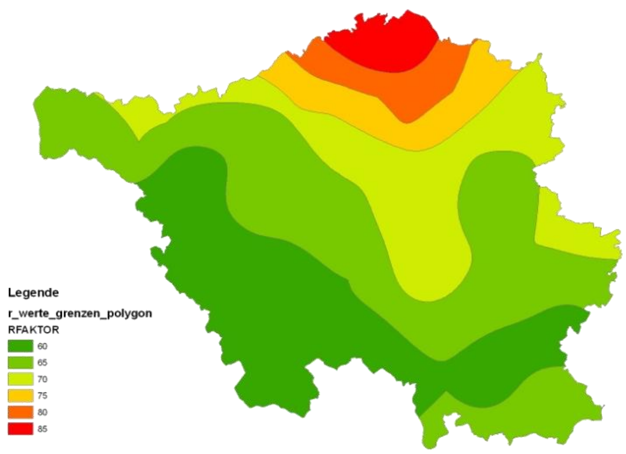

Fig. 2: Isoerodent map of rainfall zones in Saarland

K-factor (soil erosivity factor)

The risk of soil erosion depends on many soil properties. One of these properties is the K-factor. The derivation of the K-factor from the soil evaluation is based on the relevant DIN standard 19708 (DIN 19708 describes the soil evaluation in Germany), using a table from the combination of soil type and state level of the soil. Also the origin of the soil (primary rock) play an important role. The span of the K-factor ranges on a scale from 0.1 (e.g. sand) to 0.55 (e.g. clay of formation of loess). The higher the K-factor is the higher the risk of erosion. This K-factor is in addition to the S-factor and the L-factor very crucial for the assessment of erosion hazard in soil.

For arable land, which is estimated as pasture area, the class-sign allows only a much coarser derivation of the K-factor (tab. 1).

Tab. 1: K-factors in arable land

Mittlere K-Faktoren der Ackerbeschriebe der Bodenschätzung nach Schwertmann et al. (1990)

<table>
<tr><th rowspan="2">Bodenart nach Bodenschätzung</th><th rowspan="2">Entstehung*</th><th colspan="2">K-Faktor Zustandsstufe</th></tr>
<tr><th>≤ 4</th><th>≥ 5</th></tr>
<tr><td>S (Sand)</td><td>D, Al, V</td><td colspan="2">0,10</td></tr>
<tr><td>Sl (anlehmiger Sand)</td><td>D, Al, V</td><td colspan="2">0,15</td></tr>
<tr><td rowspan="3">lS (lehmiger Sand)</td><td>D, Al, V</td><td colspan="2">0,20</td></tr>
<tr><td>Lö</td><td colspan="2">0,25</td></tr>
<tr><td>Vg</td><td colspan="2">0,15</td></tr>
<tr><td rowspan="3">SL (stark lehmiger Sand)</td><td>D, Al, V</td><td>0,30</td><td>0,25</td></tr>
<tr><td>Lö</td><td colspan="2">0,35</td></tr>
<tr><td>Vg</td><td colspan="2">0,15</td></tr>
<tr><td rowspan="4">sL (sandiger Lehm)</td><td>D, Al</td><td colspan="2">0,40</td></tr>
<tr><td>Lö</td><td colspan="2">0,50</td></tr>
<tr><td>V</td><td colspan="2">0,30</td></tr>
<tr><td>Vg</td><td colspan="2">0,20</td></tr>
<tr><td rowspan="4">L (Lehm)</td><td>D, Al</td><td colspan="2">0,50</td></tr>
<tr><td>Lö</td><td colspan="2">0,55</td></tr>
<tr><td>V</td><td>0,40</td><td>0,35</td></tr>
<tr><td>Vg</td><td>0,25</td><td>0,20</td></tr>
<tr><td rowspan="3">LT (schwerer Lehm)</td><td>D, Al</td><td>0,40</td><td>0,35</td></tr>
<tr><td>V</td><td>0,30</td><td>0,25</td></tr>
<tr><td>Vg</td><td colspan="2">0,20</td></tr>
<tr><td rowspan="3">T (Ton)</td><td>D, Al</td><td colspan="2">0,30</td></tr>
<tr><td>V</td><td colspan="2">0,25</td></tr>
<tr><td>Vg</td><td colspan="2">0,15</td></tr>
</table>

* D: Diluvium (Pleistozän); Al: Alluvium (Holozän); V: Verwitterungsböden; Vg: Gesteinsböden; Lö: Löss

According to USLE the soil is highly erodible at:

1. decreasing clay content,
2. Increasingly content of silt and fine sand,
3. decreasing proportion of organic matter,
4. decreasing permeability and
5. larger aggregates.

S-factor and L-factor (topographical factors)

The calculation process for the slope steepness factor (S-factor) and the slope length factor (L-factor) takes place in one step because these two factors are both based on digital terrain model (DTM).

- L = slope length factor. The L-factor is calculated from the so-called erosive slope length. This is the slope length, from where the surface runoff occurs, up to that point, used in the sedimentation or where the runoff is channelled
- S = slope steepness factor, i.e. the ratio of soil loss from the field slope gradient to soil loss from a 9% slope under otherwise identical conditions.

The L-factor and the S-factor were calculated from a 5-m digital elevation model. The inclusion of the slope length results in a significant reduction in reported erodible surface compared with a calculation only using the factors K, S and R. Including the L-factor one can specifically describe the "hotspots" of soil erosion by water (long slopes, gullies).

The determination of the slope length to DIN is very global. In order to establish a comprehensive erosion hazard map in Saarland, a modified LS-factor (Length-Slope factor) including water catchment areas was used. The result was the identification of this combined factor in a grid cell of 5x5 meters (modifying the LS-factor is mainly taking the catchment

area being divided by the grid cell size of the DTM instead of the slope length).
In Saarland, all agricultural land (arable land and grass land) is located exactly in the LPIS in the form of agricultural parcels. For the best possible calculation of the erosion risk in this modified LS-factor water catchment areas were assumed that soil erosion occurs mainly on arable land. Under this fiction it was created a flow mask with the exact impact of the IACS boundaries of the LPIS.

Mean K-factors of the field descriptions of soil taxation by Schwertmann et al. (1990)

Soil type after land taxation	Origination *	K-factor state level ≤4	≥5
S (sand)	D, AL, V	0,10	
Sl (	D, AL, V	0,15	
	D, AL, V	0,20	
	Lö	0,25	
lS (loamy sand)	Vg	0,15	
	D, AL, V	0,30	0,25
	Lö	0,35	
SL (strong loamy sand)	Vg	0,15	
	D, AL	0,40	
	Lö	0,50	
	V	0,30	
sL (sandy loam)	Vg	0,20	
	D, AL	0,50	
	Lö	0,55	
	V	0,40	0,35
L (clay)	Vg	0,25	0,20
	D, AL	0,40	0,35
	V	0,30	0,25
LT (heavy clay)	Vg	0,20	
	D, AL	0,30	
	V	0,25	
T (potters clay)	Vg	0,15	

* Al = Alluvium (Alluvial); Lö = Loam (Pleistocene, Aeolian deposition; "wind land"); D = Pleistocene (ice age or tertiary soil); V = residual soil; Vg = stony residual soil

4. CLASIFICATION OF FARMLAND IN SAARLAND

The German national policy "*Verordnung über die Grundsätze der Erhaltung landwirtschaftlicher Flächen in einem guten landwirtschaftlichen und ökologischen Zustand Direktzahlungen- Verpflichtungenverordnung - DirektZahlVerpflV)*" describes in a table how to determinate of the potential (geographic location) erosion by water hazard in accordance with DIN 19 708 (Soil quality - Determination of the risk of soil erosion by water using the USLE).

Tab. 2: Determination of the potential risk of watererosion in the German policy

Water erosion hazard class	Description	K * S * R * L
CCwater 1	Erosion risk	30,00 - < 55,00
CCwater 2	High erosion risk	>= 55,00

In the first step, the classification of E_{nat} grid cells (made 5x5 m) where erosion hazard occurres.
In the second step all agricultural parcels of arable land were classified as $\mathbf{CC_{W1}}$ or $\mathbf{CC_{W2}}$.

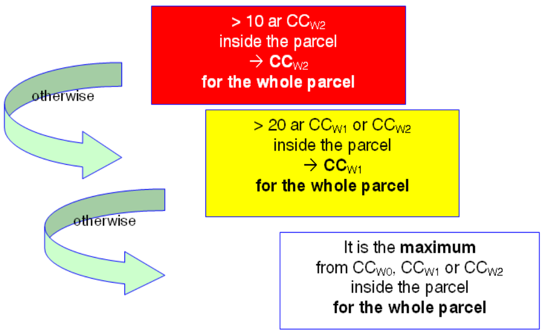

Fig. 3: Classification steps of farmland in Saarland

If the surface area of $\mathbf{CC_{W2}}$ is greater than 10 a, the whole parcel is classified in $\mathbf{CC_{W2}}$. If the sum of the areas in $\mathbf{CC_{W1}}$ and $\mathbf{CC_{W2}}$ is greater than 20 a, the whole parcel is classified in $\mathbf{CC_{W1}}$. For all parcels that are smaller than 20 a the largest surface area ($\mathbf{CC_{W0}}$, $\mathbf{CC_{W1}}$ or $\mathbf{CC_{W2}}$) determines the erosion hazard class.
The annual changes in the parcel boundaries, resulting from land use changes by the farmers, require an annual recalculation of the erosion risk of all parcels (because the slope length can change). The calculation is always valid for only one year.

5. RESULTS

After the calculation was made it was found that approximately 45% of the arable land in Saarland is classified with an erosion risk and only 55 % are without an erosion risk. This calculation for the whole country is largely identical to calculation made by the University of Saarbrücken (BARTH Bettina, KUBINIOK Jochen, 1989 and 1995).
With appropriate management (e.g. division of parcels) the farmer can reduce the erosion conditions for the rest of the parcel.
The classification of all arable land is realised in LPIS on the basis of the described E_{nat} grid cells (5x5m). Recalculations of modified geometries can be performed automatically. This

functionality is built into all software components of the application procedure of LPIS in Saarland

Tab.3: Results of classification in Saarland

CC_W class	Number parcels	Parcels in %	Area in ha	Area in %
0	19217	76,40	20662	55,98
1	2808	11,17	6053	16,40
2	3126	12,43	10198	27,62

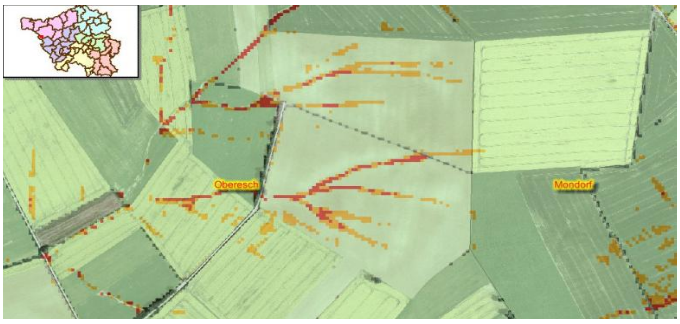

Fig. 4: Erosion risk in the 5x5 m grid

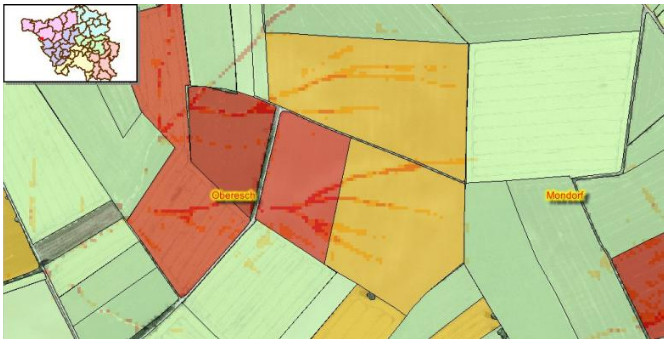

Fig. 5: Allocation of risk classes to agricultural parcels

If there are arising changes in geometries (e.g. through exchange of parcels or new rent of parcels), farmers themselves can request recalculations to the digital home software if using this. Applicants, who draw their land manually and don't work with digital home software, can inform themselves about the new erosion classification of new geometries in their office.

6. CONCLUSION

The final product of this work is to create a system for erosion hazard in agricultural farmland in Saarland and to create a software tool for the farmers to calculate erosion risk by changing parcel boundaries (a user can do a wide range of scenario predictions for soil erosion). The next step will be an online web site inside the Infrastructure for Spatial Information in the European Community (INSPIRE) Directive.
Due to the accuracy in determining the potential erosion hazard through the precise identification of parcels, the system has encountered a wide acceptance among farmers.
Because of the exact determination of erosion risk on every parcel which is part of the local LPIS, the system contributes to a better protection against erosion than determining erosion in physical block systems.

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OVERVIEW OF RAPIDEYE DATA PROCESSING AND USE WITHIN CWRS 2009 IN THE CZECH REPUBLIC

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KEY WORDS: RapidEye, satellite data**,** new sensors**,** orthorectification, PCI Geomatics, red-edge, CAPI

ABSTRACT

This paper presents the first experiences with processing and interpretation of the data from the new high resolution sensor – Rapid Eye – in frame of CwRS 2009. RapidEye managed to acquire the data over three of eight control sites in the Czech Republic. The paper gives an overview of both geometrical processing of the data and imagery use for the computer assisted photo-interpretation (CAPI). The orthorectification process was done using the new RapidEye model, based on RPC adjustment, incorporated in PCI Geomatica version 10.2.1. The quality of the model was assessed measuring RMSEs and maximal residuals of resulting orthoimages on independently collected check points. The other part of this paper is focused on benefits of 6.5meters resolution RapidEye data with incorporated red-edge spectral band for purposes of the CAPI.

1. INTRODUCTION

In the frame of CwRS 2009, data from RapidEye – a constellation of five sun-synchronous Earth observation satellites which provides large area coverage of high resolution multi-spectral images with frequent revisit intervals - have been introduced into the Controls with Remote Sensing campaign. For the Czech Republic, three RapidEye scenes have been acquired over three out of eight control zones as the HR+1[1] window imagery. With 6.5meters ground sampling distance, resampled into 5meter pixel, and incorporated new "red edge" spectral band, the RapidEye data represented both a valuable contribution for the computer assisted photo-interpretation (CAPI) as well as a subject of investigation.
The orthorectification of the data was done in PCI Geomatica software using the RPC model applied to RapidEye Basic Product (Level 1B imagery) - with highly convincing results proven by following geometrical quality assessment. Accurate rational polynomial coefficients provided with the data enabled to generate high accuracy orthos and mosaics even without using ground control information, which significantly speeded up the process of preparing the data for the photo interpretation.
Later, the contribution of the new sensor data for eligibility assessment and crop discrimination have been observed and evaluated during the CAPI. The unrivalled spatial resolution compared to other sensors data within HR windows brings the biggest benefit for the interpretation of the agricultural land use, especially for the uplands control sites with prevailing pastures and large amount of small parcels.
In this paper, both geometrical processing of the RapidEye data as well as using the orthorectified images for the interpretation are described and discussed.

2. RAPIDEYE CHARACTERISTICS

Launched on August 29, 2008 from the Baikonur cosmodrome in Kazakhstan on a DNEPR rocket, RapidEye is a constellation of 5 satellites, each of them carrying multispectral sensor capable to collect image data in five spectral bands (namely blue, green, red, red-edge and near infrared) at GSD 6.5m. (Jung-Rothenhaeusler, F. et al. 2007) The RapidEye constellation is the first commercial satellite system providing spectral information in red-edge band, which, according to preliminary studies, is suitable for measuring variances in vegetation, species separation and monitoring vegetation health. (Cheng, P. et al. 2009) Capturing the high spectral variability of crops (Fig.1) from May to July, while other spectral bands like visible red or near infrared already reached their spectral local maxima or minima, red-edge band shows a high significance on the vitality of vegetation. (Völker, A. et al. 2009)

[1] The acquisition windows are calendar periods during which the HR satellites are programmed and are in competition to acquire data. HR+1 opens after the VHR window and its opening date is defined by adding the dead period defined by the MS to the acquisition date of the satellite or aerial VHR image (European Commission, 2009)

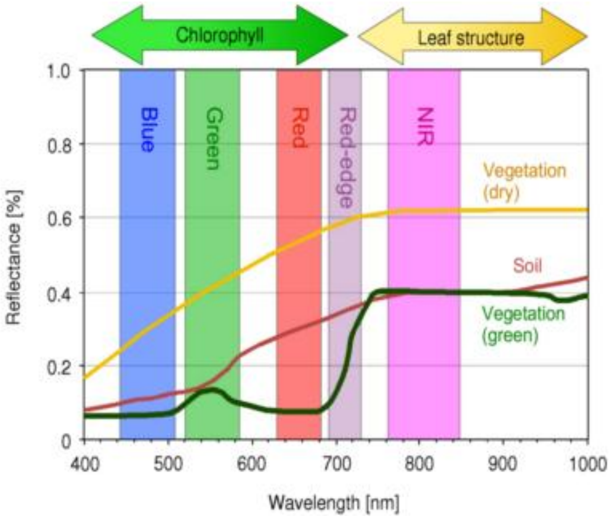

Figure. 1 Spectral performance of RapidEye sensor (Jung-Rothenhaeusler et al. 2007)

Beside this enhanced multispectral capacity, the most significant advantage of the RapidEye system is the daily revisit interval, resulting from the existence of constellation of five sun-synchronous satellites. Therefore, RapidEye is of special interest for remote sensing in agricultural monitoring. (Völker, A. et al. 2009)

3. RAPIDEYE DATA FOR CZ SITES

Over the Czech Republic, Rapid Eye data have been acquired for three out of eight control zones, namely CUKR, OCET and PEPR (Fig.2). All three scenes have been acquired as HR+1 window data within one day – 14th of June 2009, area of each of delivered scenes was about 76 x 60km.

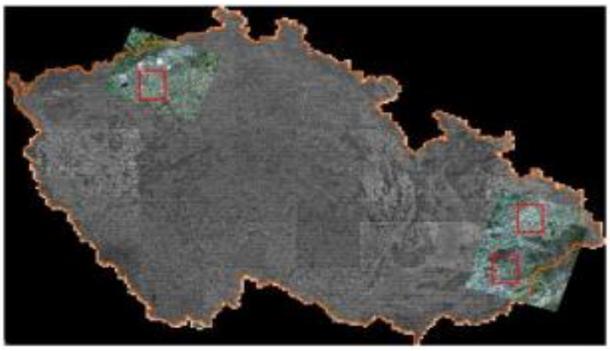

Figure. 2 RapidEye scenes acquired over the Czech Rapublic
on 14th of June 2009 for three CwRS 2009 control sites

For the CwRS purposes, RapidEye data Level 3A were offered to the contractors. This radiometrically corrected product, rectified using a DTED Level 1 SRTM DEM or better, can - with appropriate ground control – meet positional accuracy of 6meters. (Cheng, P. et al. 2009) In this particular case of the data, JRC had reported, that this product needs to be shifted to achieve declared accuracy.
As we intended to test the new rational polynomial coefficients (RPC) model for RapidEye data incorporated in new version of PCI Geomatica (version 10.2.1., released on 5th of June 2009), we decided to ask the provider for Sensor-Level Product of 1B Level, with only on-board spacecraft attitude and ephemeris and radiometric corrections applied to the data and perform the orthorectification in this new PCI Geomatica suite.

All three RapidEye scenes were delivered via FTP, with 5 bands in NITF format. For the CUKR site, the first delivery contained a scene (CUKR_1) with incomplete coverage, the re-uploaded scene (CUKR_2) had full coverage, but later orthorectification result had shown lower accuracy of the rational polynomial coefficients provided with this re-uploaded scene.

4. ORTHORECTIFICATION AND GEOMETRICAL QUALITY ASSESSMENT

As mentioned before, PCI Geomatica suite version 10.2.1. was used for processing of the RapidEye data. Orthorectification was done using the new RapidEye model based on RPC adjustment, incorporated in this version of the PCI software, with rational polynomial coefficients imported from the datafiles.
As a reference image, 0.5meters pixel size RGB aerial orthophoto was used, and for elevation correction, rasterized DEM extracted from 2meters interval contours based on ZABAGED (Fundamental Base of Geographic Data for the Czech Republic).
The results of 0 order RPC adjustment (reported in Table 1.), were very convincing, showing high accuracy of both RapidEye model incorporated in Geomatica as well as RPCs provided with RapidEye data. Without any GCPs, check points residuals and RMESs were under 2.5 pixels.
The only exception was the re-uploaded scene for CUKR site (CUKR_2). For this particular scene, without using GCPs, both RMSE and residuals were about 50meters. Therefore, it was necessary to collect GCPs to improve the model accuracy and derive required geometrical quality of the ortohoimage for the controls. Using already one GCP has significantly improved the accuracy of the model and both RMSE and residuals values decreased below 2.5 pixels.
The test done on originally uploaded scene for the CUKR site (CUKR_1) has shown, that RPCs delivered with the original scene were more accurate (at the comparable accuracy level with OCET and PEPR scenes coefficients), and the lower accuracy of RPCs of re-uploaded scene was probably caused by some error during pre-processing.

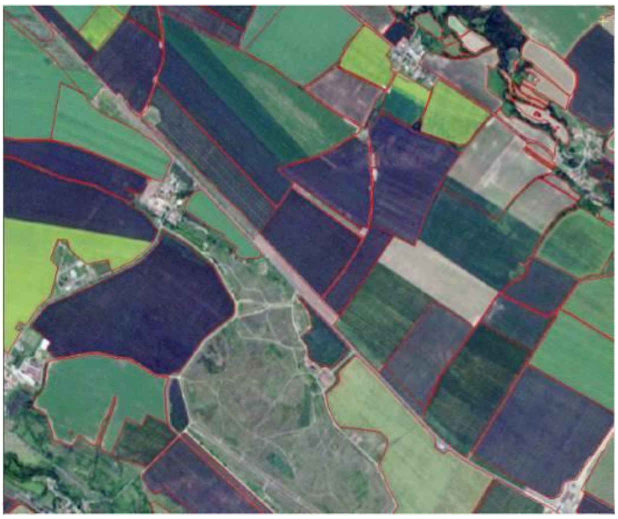

Figure. 3 Visual checks on positional accuracy, orthorectified RapidEye data overlaid by LPIS

To evaluate the orthorectification result, accuracy checks based on RMSEs and residuals on independently collected check points (ICPs) were done. For that purpose, two different sets of ICPs were used. At first, an accurate set of ICPs distributed over control sites (+ 5km buffer) based on 0.5m georeferenced aerial orthophoto, to check the accuracy of the data used for CwRS. For the rest of the area covered by three RapidEye scenes (outside the CwRS control sites) the 0.5m reference aerial orthophoto was not available. Therefore, to check the positional accuracy over full scenes, another set of ICPs – based on 5m georeferenced aerial orthophoto - was collected.

			Zone name:							
			PEPR		OCET		CUKR_1 (zone not fully covered)		CUKR_2 (RFC less accurate (high res. without GCPs))	
		number of points	0 GCPs + 30 CPs	1 GCPs + 29 CPs	0 GCPs + 30 CPs	1 GCPs + 29 CPs	0 GCPs + 30 CPs	1 GCPs + 29 CPs	0 GCPs + 30 CPs	1 GCPs + 29 CPs
max. residuals and RMSE on ICPs (in meters)	RMS of all CPs	**RMS of CPs**	**6,4**	**6,1**	**5,7**	**3,9**	**8,5**	**6,4**	**48,2**	**6,1**
		RMS (X)	5,1	5,0	3,8	3,1	5,0	4,1	23,1	3,8
		RMS (Y)	3,9	3,5	4,3	2,3	6,9	4,9	42,3	4,8
	0,5 m ortho	*max. Res.*	*10,2*	*5,3*	*9,3*	*4,7*	*6,3*	*4,1*	*51,7*	*4,7*
		RMSE	**7,1**	**3,6**	**5,9**	**3,0**	**4,1**	**3,0**	**48,9**	**4,3**
		RMSE_X	6,4	2,6	4,1	2,2	2,1	1,6	20,8	2,1
		RMSE_Y	3,2	2,5	4,3	1,9	3,6	2,6	44,3	3,7
		count	12	11	23	22	9	8	9	8
	5 m ortho	*max. Res.*	*12,2*	*11,0*	*9,0*	*7,1*	*15,1*	*12,1*	*52,4*	*11,0*
		RMSE	**5,7**	**7,1**	**4,5**	**5,7**	**9,6**	**7,2**	**46,7**	**6,8**
		RMSE_X	3,8	5,9	2,4	4,8	5,7	4,6	23,5	4,3
		RMSE_Y	4,3	3,9	3,8	3,2	7,7	5,4	40,4	5,3
		count	18	18	7	7	21	21	21	21

Table 1. Results of the accuracy checks using two sets of independent check points; RPC adjustment with 0 or 1 GCP

The result of accuracy checks confirmed the expectation of very good accuracy of the model (indicated already by visual checks with LPIS overlay; see Fig. 3) even without using GCPs, with discrepancies on three out of four scenes (except CUKR_2) below 2.5 pixels. The positional accuracy of orthoimages fulfilled convincingly the JRC requirements on orthoimage quality for the CwRS.
For the verification, adding already one GCP could be very efficient for improving the model accuracy, especially in case of potentially less accurate RPCs of particular scene (see CUKR_2 scene example).
As one GCP has improved the accuracy significantly, there was logically an assumption of further potential improvement of the model stability by adding more GCPs over the scene. However, the following test disconfirmed this assumption, as the stability of the model had decreasing tendency by adding GCPs, until finally achieving the model stability with 15 and more GCPs added. With this amount of GCPs, the positional accuracy of the resulting orthophoto could be slightly improved (according to RMSEs/discrepancies values on ICPs; see Table 2.), but RPC adjustment without GCP (or with one GCP for verification) gives fully sufficient result with significant savings of time and effort.

			ZONE name:			
			OCET	PEPR	CUKR_1	CUKR_2
		number of points	15 GCPs + 15 CPs	15 GCPs + 15 CPs	15 GCPs + 15 CPs	15 GCPs + 15 CPs
max. residuals and RMSE on ICPs	0,5 m ortho	**RMSE**	**2,0**	**3,5**	**1,6**	**1,4**
		RMSE_X	1,4	2,8	1,1	0,9
		RMSE_Y	1,4	2,1	1,2	1,1
		max. Res.	*3,5*	*4,8*	*1,8*	*1,6*
	5 m ortho	**RMSE**	**3,5**	**3,9**	**4,4**	**4,8**
		RMSE_X	2,8	3,1	3,5	3,5
		RMSE_Y	2,2	2,3	2,6	3,3
		max. Res.	*3,9*	*6,0*	*6,2*	*6,5*

Table 2. Results of the accuracy checks using two sets of independent check points, first order RPC adjustment of full RapidEye scenes, using 15 GCPs.

5. USE OF RAPID EYE DATA FOR CAPI

Beside the accurate and high speed orthorectification possibilities, the suitability of the sensor imagery for the photointerpretation, with particular emphasis on agricultural land assessment, agriculture land use discrimination and ineligibility detection, is the other crucial aspect in evaluating the new sensors data potential for the CwRS.
As mentioned before, in 2009, RapidEye constellation managed to acquire HR+1 window scenes for three out of eight control sites over the Czech Republic. Each of covered sites has different landscape character. CUKR is an intensive agricultural area with high amount of arable land and hop fields, OCET site has an upland character with prevailing pastures and small parcels and PEPR site contains both arable and grassland agriculture land. Given by the landscape character of each site, the biggest benefit from RapidEye data disposing with higher spatial resolution than SPOT5 or SPOT4 data (which were the only other sensors with successful HR windows acquisitions over the Czech Republic in 2009), was expected for the interpretation on upland region OCET.
Preparing the orthorectified data for the image interpretation, the next crucial step was to set appropriate colour composite of spectral bands. During this process, the important requirement was to retain the colours possibly most similar to conventionally used colour composite on which interpretators are used to:

- detect basic landscape features (such as artificial surfaces, forest, water or bare soil)
- discriminate agricultural land use (especially grassland from arable land) and as much crop types as possible
- detect ineligible land as easy as possible

After testing some combinations of spectral bands, NIR, RED-EDGE, RED composite was finally selected for interpretations. Using the image composed in this way, basic landscape features have similar spectral appearance as on the commonly used spectral band composite for SPOT (NIR, SWIR, RED) and it is easy to distinguish between arable, pasture and permanent crop land use, as well as to detect ineligibilities inside parcels. The selected colour composition could be modified for following campaigns, as there were other combinations of spectral bands acceptable for the interpretation. Verification of the most appropriate composite could be an important task for the next campaign.

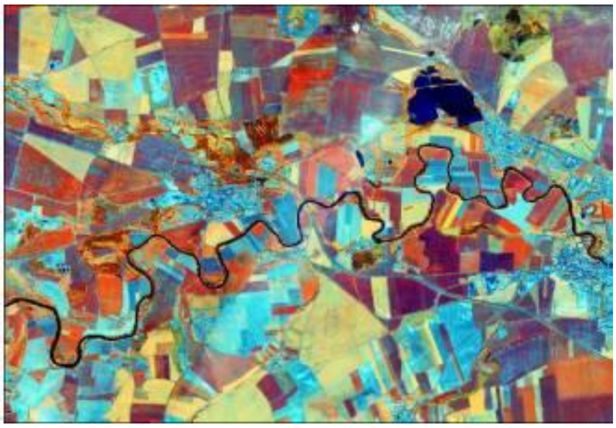

Figure. 4 NIR, RED EDGE, RED colour composite of RapidEye spectral bands used for the CAPI

The other aim in our effort was to learn spectral characteristics typical for different crop types. For that purpose, a set of training samples representing basic crop types was selected based on dedicated field survey, which was targeted on collecting the ground reference data about crop coverage of the parcels. The result of that investigation has shown, that it is possible to discriminate some crops or crop groups even using only one RapidEye image, based on spectral characteristics of particular crop groups of given acquisition date (Fig. 5). However, a multitemporal set of multispectral images will be more appropriate source for potential classification of different crop types.

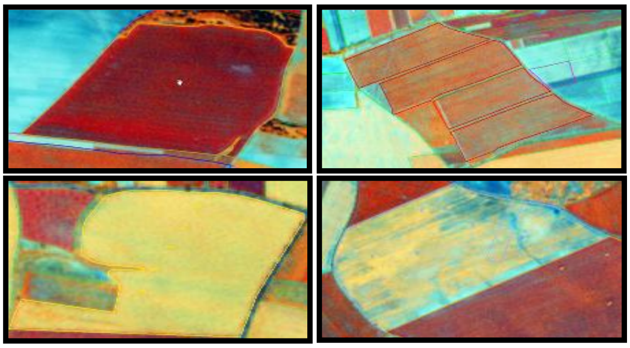

Figure. 5 Appearance of winter wheat, spring barley, oilseed rape and sunflower on NIR, RED EDGE, RED composite of RapidEye acquired on 14th of June 2009

For the CwRS purposes, detection of ineligible parts of the parcels, which are not excluded from the LPIS area, is a crucial issue. As presented on Figures 6 and 7, RapidEye, which provides unrivalled spatial resolution of the HR window data, significantly enhances possibilities for both ineligibilities detection, as well as their boundary delineation based on HR image.

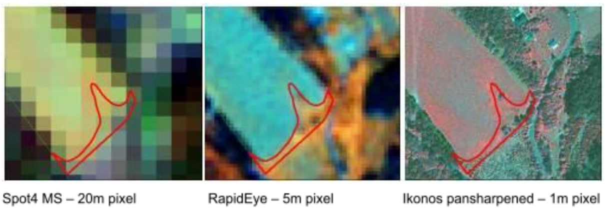

Figure. 6 Example of RapidEye data benefit for ineligibility detection

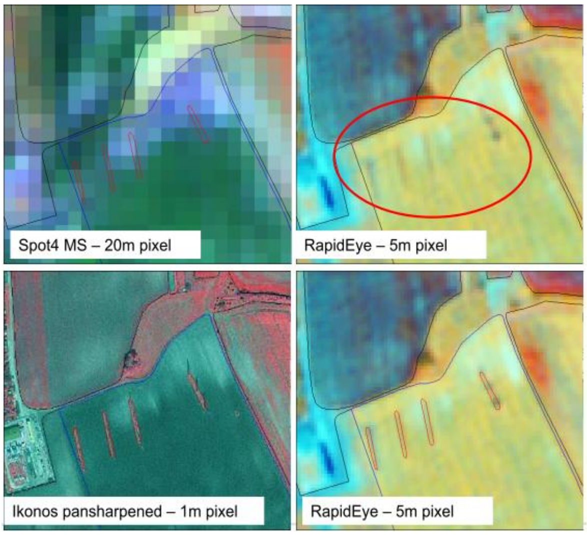

Figure. 7 Example of RapidEye data benefit for detection of small landscape features

According to our experiences with the interpretation, even with 5m pixel size RapidEye data for HR window, the VHR image still remains the main and most reliable source for ineligibility interpretation (see Fig. 6 and 7). However, in some cases, having a multitemporal "almost VHR" information could be very proficient for proving suspicions on possible ineligible land use (Fig. 6). Moreover, in cases of late (or lack of) VHR acquisition, RapidEye (mainly due to its higher resolution) could be very helpful and in particular cases is even sufficient for ineligibility detection.

6. CONCLUSIONS

According to our experiences with processing and using the RapidEye data in its first CwRS year, it is obvious that the introduction of this new sensor brought a valuable benefit into the campaign.

Flexible acquisition possibility, resulting from daily revisit interval of the RapidEye constellation, increases the acquisition capacity for the CwRS high resolution windows.

With accurate rational polynomial coefficients provided with the scenes, the orthorectification of the RapidEye data is effective and the positional accuracy of resulting orthoimages is very good even without collecting ground control points.

For the CAPI, the most significant benefit is the high spatial resolution of RapidEye data. With pixel size at least four times lower than by HR sensors data like SPOT or IRSP6, which have been used as HR windows data for the controls during last years, RapidEye data widely extends the possibilities for the land use interpretation, especially in cases of control sites with extensive type of agricultural land use, characterized by small parcels and high amount of pastures.

Due to these advantages, RapidEye will probably become the most interesting HR window sensor for the contractors during the next campaign (with its attractiveness even more empowered by opening dedicated HR windows for RapidEye).

This overview does not claim to be a report of a benchmark of the RapidEye data, but a potential benchmark would be interesting for the CwRS contractors.

It is obvious, that incorporation of RapidEye data into the Controls with Remote Sensing in 2009 brought indisputable benefits for the campaign. Both potential for fast and accurate geometrical processing as well as advantages of higher spatial resolution for the CAPI have been demonstrated in this review.

However, there still remain tasks concerning the RapidEye imagery, which are to be tested and proven during following campaigns. This concerns for example the declared flexible acquisition ability of RapidEye constellation or specification of the most appropriate spectral bands composition for CAPI. Detailed exploration of the potential of the new red-edge band for crop classification could be beneficial not only for controls, but also for many other remote sensing applications.

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ORFEO TOOLBOX AN OPEN SOURCE TOOL FOR HIGH RESOLUTION IMAGE PROCESSING

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KEY WORDS: OTB, Image processing, open source, C++, template, multi threading, streaming

ABSTRACT
The paper presents an introduction to the **OTB** (**Orfeo ToolBox**). This C++ project is an open source image processing library. Several other open source libraries are embedded and used for vector and raster data manipulation (reading, writing, modification) and to perform new efficient image processing algorithms. Here we introduce the context of the OTB and its technical advantages. We'll try to show you its large application capabilities through examples of the OTB-Applications (a set of GUIs based on the OTB library) and the global end-user application: Monteverdi. At last, we'll describe how to join the OTB community.

1. INTRODUCTION

The Orfeo ToolBox (**OTB**) is an open source C++ library for high resolution image processing.
It is developed as a of part of the ORFEO (Optical and Radar Federated Earth Observation) program, a dual earth observation satellite system lead by Italy and France. The ASI (Italian space agency) is responsible for the Radar sensor called Cosmo-Skymed. The optical sensor Pleiades (HR) is cared by the French spatial agency (CNES). This accompaniment program has multiple goals:

- Make easier the development of new algorithms,
- Algorithm validation and capitalisation,
- To fill the gap between researchers and ORFEO users.

For that, it is divided in two parts. The first one is the thematic part that is mainly responsible for User's needs (extracted information), product definition and validation. The second one is the Methodological part that coordinates research activities in image processing:
The aim of this paper is to introduce the OTB (what is it, what does it deal with, how does it work) and to show what can be done using the library through a presentation of some OTB applications and Monteverdi, a generic image processing application dedicated to remote sensing end-users.

2. WHAT IS THE OTB?

OTB started in 2004. It is designed and funded by the CNES and has mainly been developed by CS since 2005.
OTB is an open source C++ image processing library under the French CECILL licence. This project is multi platform (Windows, Linux/Unix, MacOSX) and daily tested on multiple configurations. The results of the nightly tests are available in the OTB dashboard.
The OTB project provides a set of GUI applications and a generic application (**Monteverdi**) for remote sensing images processing and information extraction based on the OTB library.

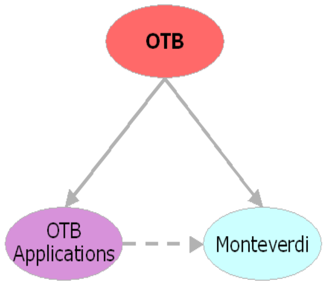

Figure 1: Link between OTB library, OTB-Applications and Monteverdi.

This library is fully based on the ITK (Insight ToolKit), C++ library for medical image processing but it embeds a lot of other libraries such as GDAL for image reading and writing, OSSIM for the sensor modelling and map projections, 6S for radiometric processing, LIBSVM to be able to do Support Vector Machine supervised classification, FLTK for GUIs ...
The OTB provides bindings that allow using the library through Python, Java and IDL languages.
As all open source project, OTB has an international users community that becomes bigger and bigger. This large community ensures feedbacks for potential needs or interesting evolution, the library manipulation (conception weakness, possible bug reporting or correction, ...). Thus, with years, OTB has been evolved to fit to image processing breakthroughs, evolutions and needs.

3. WHAT DOES IT DEAL WITH

OTB allows to manipulate N dimensional image data (real or complex, mono or multi channel) without size limitation. Thanks to GDAL and internal drivers, OTB supports most of the remote sensing image format.
It also handles raster data manipulation such as vector data (shape file or kml, graphs, meshes, Label Object Map).
These datas are used as input or output of all the available algorithms. Those algorithms can be sorted in several families such as:

- Filters: optical/SAR, morphological operators, denoising ...
- Segmentation: Watersheds, Hough, ...

- Image registration: transforms, interpolators ...
- Learning and classification: Markov, K-means, SVM
- Measure of similarities: correlations, mutual information, K-means, Kullback …
- Geometric corrections module (with sensor model and common map projections)
- Change detection module supporting multi-temporal, multi-sensors series
- …

4. HOW DOES OTB WORK

The use of templates, the open and evolving architecture provides to the OTB a real very useful code genericity.
The OTB is a high performances tool. It implements multi threading and streaming mechanisms to take advantage of computer capacities and to be able to deal with huge image and memory consuming process. Thus, the execution of a chain can independently use every available CPUs (Central Processing Unit). That is called calculation parallelization. In the same time, it divides the input image to process division by division or only a specified area of an image.

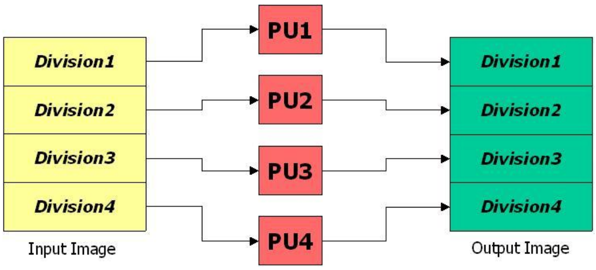

Figure 2: Threading and Streaming.

Of course such mechanisms have impact on the filter implementation. Most of the available filters were thought to be compliant with these technologies.
Moreover, OTB philosophy is based on pipeline mechanism. Functionality can be seen as a box with an input and an output that are automatically managed. The typical user only has to link boxes to create his process chain.

Figure 3: Pipeline illustration.

5. OTB AND GIS

OTB has a lot of interested functionalities for GIS. One of the most important is that it can read, write vector datas and change format KML between shapefile format. Thanks to the OSSIM library, it also can process to on the fly projections (vector data on remote sensing image using image geometry):

1. Raw: using sensor model and digital elevation model,
2. Ortho: using cartographical projections.

Registration functionalities are also available. It allows to register:

- Image to image,
- Image to vector data,
- Vector data to vector data registrations are available too.

Besides, the OTB visualization tools supports vector datas and allows vector rendering, layer management …

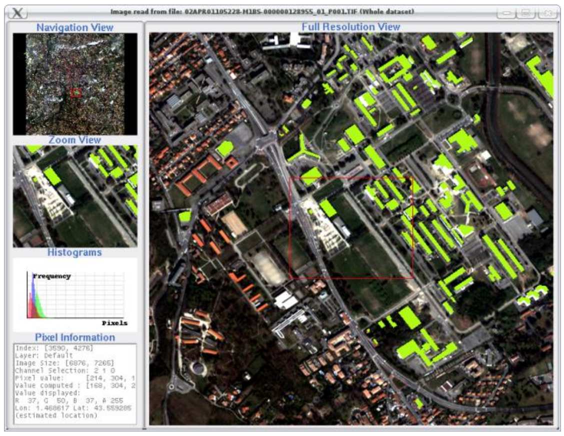

Figure 4: Example of Vector data rendering.

6. OTB-APPLICATIONS

The OTB-Applications provides a lot of demonstrating tools for a lot of image processing topics. Among them:

- Image type convertor,
- Image extractor,
- Radiometric calibration (optic and Radar)
- SAR polymetric analysis tool,
- Object counting
- Urban area extraction and vectorization,
- Registration (Image/Image, Image/Vector),
- Feature extraction,
- …

An application of detection and vectorization of urban area is available. This application discards clouds detection, vegetation detection (using NDVI), and edge density detection. The algorithm can be applied to an extract and run over the full scene if the first results are good enough.

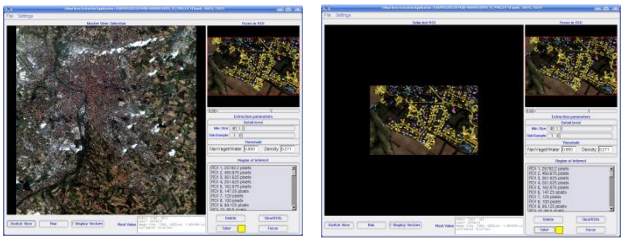

Figure 5: UrbanAreaExtraction application.

The output can be neither a mask of the detected area or a vectorization of these areas as shapefile or kml.
An application which implements a pan sharpening algorithm is also available. The aim of the application is to fuse XS and panchromatic images. by selecting a region of interest. The following figure synthesizes the process.

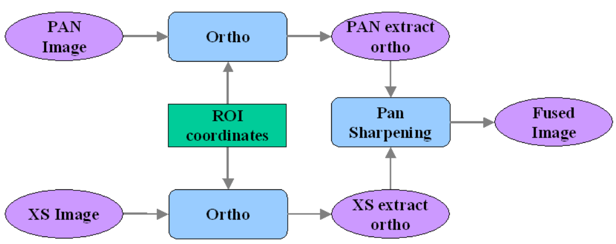

Figure 6: Pan sharpening application process

The orthorectification is processed using OSSIM. OTB is smart enough to only orthorectified the extract region and not the full scene.

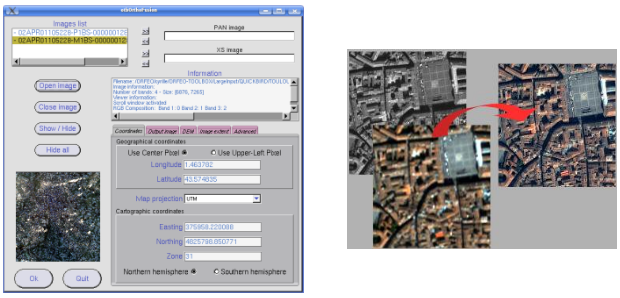

Figure 7: PanSharpening application.

Another GUI is dedicated to supervised classification. The used algorithm is based on SVM (Support Vector Machine). In this application, user needs to select learning sample that represents his classes. These samples will be used for the learning step by creating statistics over each labeled pixels group and used after to classify the entire image.

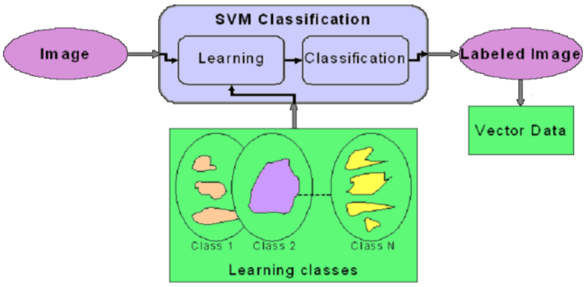

Figure 8: Supervised classification application process.

The output is an image of the founded classes but can either be a vector data file.

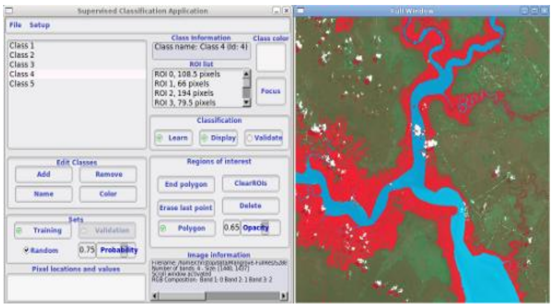

Figure 9: Supervised classification application.

7. MONTEVERDI

Monteverdi is a generic image processing application dedicated to remote sensing end-users. It is a request from CNES' Strategy and Programs Office in order to provide an integrated application for capacity building activities

This GUI is made of a main module (principal window) which different menus allow to call other thematic modules.

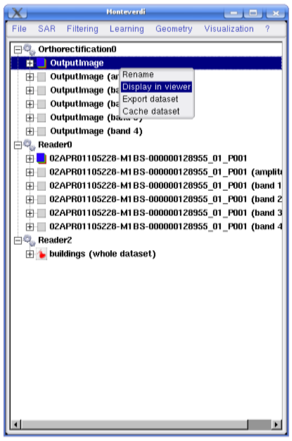

Figure 10: Monteverdi main window.

Among all existing modules, some of them are evolutions of OTB-Applications, but Monteverdi provides also other new tools such as ::

- Display vector data using a re projection using image geometry,
- Allow to visualize and change image histogram,
- Change the RGB color composition
- Display optic and RADAR image,
- ROI extraction by selecting image or geographical coordinates,
- Evolution of OTB-Application such as supervised classification or orthorectification,
- ...

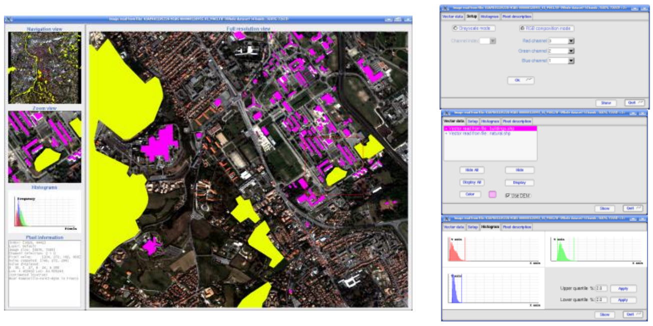

Figure 11: The Monteverdi viewer.

A Monteverdi module is dedicated to sensor model estimation using GCP (Ground Control Point) selection. The user selects point on the image, enters its geographical coordinates and the application computes the transformation and generates an adapted sensor model. Thus any image can be re projected or orthorectified.

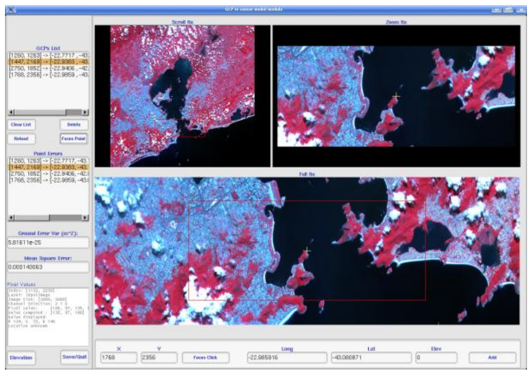

Figure 12: The Monteverdi GCPToSensorModel module.

The MeanShift module is an application of the mean shift algorithm (developed by Comaniciu and Meer). It allows image blurring, clustering, and cluster boundaries extraction.

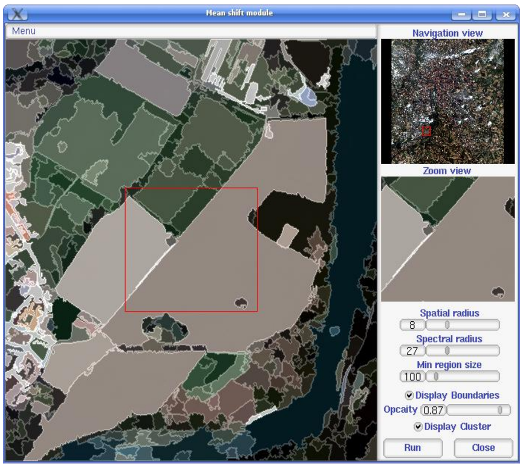

Figure 13: The Monteverdi MeanShift module.

The previous snap shot shows the input image and the cluster boundaries computed with the algorithm.

8. HAVE ACCESS TO OTB AND CO.

You will find here a list of useful link to find information about the Orfeo Toolbox .
The latest releases of OTB, OTB-Applications and Monteverdi are available at http://sourceforge.net/projects/orfeo-toolbox/files/orfeo-toolbox/OTB-3.2. Current development versions are available on the OTB Mercurial server.
The compilation procedure is described in the Software Guide documentation available at the OTB web site.
To help you the best as it can, OTB provides an online documentation, an user mailing list available for everyone where you can ask for more information or submit a specific problem to the community. A blog and a wiki are also available to help you to discover the library, its philosophy and news.

9. CONCLUSIONS

The **Orfeo Toolbox** and its applications offer a great architecture and allow the user to practice and experiment with real datas and tools. OTB is especially adapted to

- Have an easy access to a wide range of well tested algorithms,
- Develop efficiently new image processing GUI applications,
- Benchmark process (for algorithm performances evaluation, test or validation)

This ambitious goal can't be met without wide users participation and the federation of existing projects. The Orfeo ToolBox is an efficient and state-of-the-art Open source software for image processing. Its users constitute a real community that is steadily spreading and which mixes newbies and specialist with the same aim : help each other and improve the tool.

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Mercurial, a free, distributed source control management tool, http://mercurial.selenic.com.

Mean shift: A robust approach toward feature space analysis. D. Comaniciu and P. Meer, IEEE Trans. Pattern Anal. Machine Intell, 24:603–619, 2002.

3D DATA EXTRACTION TECHNIQUES AND VALIDATION METHODS, FOR THE INTEGRATION IN THE LPIS

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KEY WORDS: LPIS, IACS, 3D, CwRS, features extraction, changes detection

ABSTRACT
Since 2006 Abaco has invested in the field of IACS-related technologies, working together with real users in order to apply several techniques available in the IT industry, with a focus on the spatial data included in IACS systems. The Land Parcel Identification System ("LPIS") is the container of the spatial information which can be used to know the land parcels; the LPIS, with the upcoming technologies, can now contain also complex information that can be used for controls, like 3D information. With the adoption of three-dimensional (3D) technologies, among which real-time modelling and representation, it is now possible to extract features or to include 3D information of buildings in the LPIS. This allow to produce preliminary analysis of proposed infrastructures and to monitor the status of the projects, if talking about Rural Development subsidies, or to extract specific features (relevant elements on the territory). The 3D world offers well-known datasets, like the Digital Terrain Models, but also the new LiDAR (laser scanning) acquisitions, which, together with all the existing spatial information, help visualizing the impact of certain buildings, to calculate volumes, and to follow the process of works development, facilitating remote control.

1. INTRODUCTION

The LPIS is the main instrument called upon by the CAP Regulation to identify land and quantify areas eligible for payment.
The LPIS is, underneath, based on GIS technologies whose high technical growth rate offers the possibility to use this container to store more and more information on land objects than not just those related to parcels.
With such possibility, together with advanced spatial data analysis techniques, it is possible to think of using these technical characteristics in order to enhance the opportunities for new remote sensing works.
Even if Digital Terrain Models (DTM) are already well-known, they are not used thoroughly, and new 3D data representations, like LiDAR (point clouds) and SAR (satellite images), are usually forgotten.
For example, point clouds techniques have made giant leaps and they provide the possibility to discover attributes of the real world which are not possible with common remote sensing analysis.
Other 3D capturing techniques, like Pictometry® also provide further information on land features, together with new measurement tools.
Storing this new geo-information within a spatial-enabled repository and applying cross-analysis with the usual bi-dimensional data, can be the starting point to simplify the recognition of land features (especially finding buildings or vegetation), to discover unlikely land cover definitions of certain areas, or to control the development of infrastructures subsidised with EU funds.

The aim of this piece of work is to present the new 3D data available, to present how they can be integrated in the LPIS, to understand how they can be used, and to show which achievements can be obtained.
The issues raised during this study, although actual results have already been achieved in several LPIS applications in Europe, should not be treated as a document describing the specific image processing techniques, rather it should be a spur for discussion for the inclusion of these data into the LPIS, taking advantage of GIS and ICT evolution.
This work produced an "extended" LPIS concept which follows the ISO standards; the techniques and software applications are currently applied to existing LPIS.

2. 3D INFORMATION

We will now provide an overview on some of the geo-information that can be used to extract 3D attributes and some of their applications.

DIGITAL ELEVATION MODEL (DEM)

A digital elevation model (DEM) is a digital representation of ground surface topography or terrain. It is also widely known as a digital terrain model (DTM), when excluding features such as vegetation, buildings, bridges, etc., or as digital surface model (DSM), when including such features. A DEM can be represented as a raster (a grid of squares), or as a triangular irregular network (TIN), or as an ASCII text file.

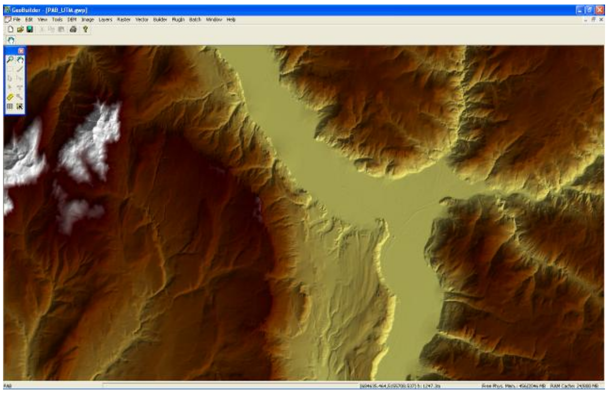

Figure 1. DEM as a raster

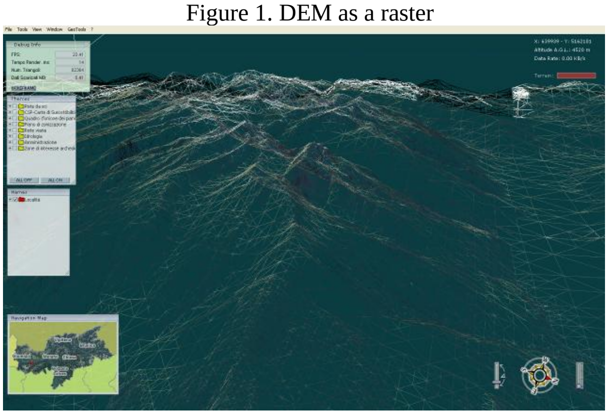

Figure 2. DEM as a triangular irregular network

DEMs are widely used for different applications, from pure terrain representation to 3D analysis.

Art. 17 of the EU Regulation 73/2009 expects that the three-dimensional area of a parcel on a slope should be projected into two-dimensional space in accordance with the national geodetic system. Comments say that there is no logical agronomic reason to use the 3D area (see WikiCAP: Area Projected).

Despite of that, the LPIS core conceptual model suggests to store additional 3D parcels attributes, i.e slope, altitude and exposure, within the Reference Parcel sub-classes. With a DEM inside the LPIS those values can be obtained real-time.

The importance of DEMs goes beyond the "maximum eligible area" concept and the pure subsidy eligibility, being important also, to name a few:

1. to determine Less Favoured Areas (those where cultivation is difficult, for example because of slope),
2. to discover unlikely crops at certain altitudes, i.e helping controls and remote sensing
3. to check for GAEC and SMRs related to slope. i.e. helping discover likely cross-compliance breaches remotely

Also processes not necessarily related to CAP subsidies can be managed, for example the control of quality productions (just think how important is the exposure to sun for wine productions).

So the DEM is definitively a source of information that helps in multi-faceted activities related to reference parcels.

SYNTETHIC-APERTURE RADAR (SAR)

Synthetic-aperture radar (SAR) is a form of radar in which multiple radar images are processed to yield higher-resolution images than would be possible by conventional means.

SAR has seen wide applications in remote sensing and mapping, and one of its specific techniques called Interferometric synthetic aperture radar (InSAR or IfSAR) can be used to generate maps of surface deformation or digital elevation.

We will not dwell on this type of data, since the result of processing the InSAR images is usually a DEM, which is therefore used as explained before. We just highlight that managing SAR information is just a matter of treating huge quantity of data, therefore requiring ICT architectures that can treat them.

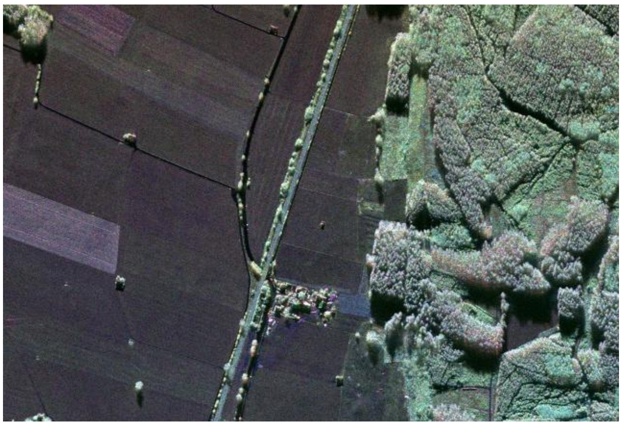

Figure 3. SAR image

LIGHT DETECTION AND RANGING (LiDAR)

LiDAR (Light Detection And Ranging) is an optical remote sensing technology that measures properties of scattered light to find range and/or other information of a distant target.

Airborne LiDAR sensors are used by companies in the Remote Sensing area to create point clouds of the earth ground for further processing (e.g. used in forestry or urban areas). Almost all the companies providing orthophotos are producing sets of point clouds during their flights.

LiDAR can be used to produce DEMs as well, but the production of point clouds can help discovering buildings in rural areas or, in general, ineligible features in the Reference Parcels.

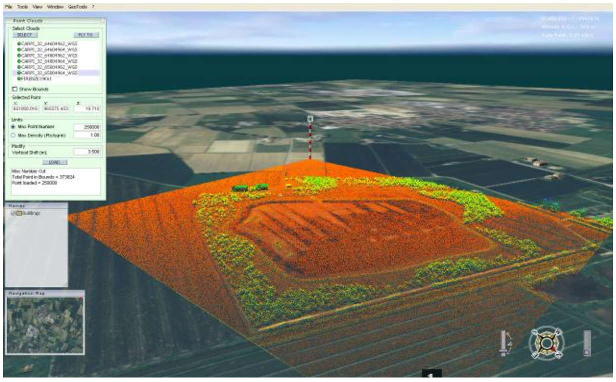

Figure 4. LiDAR point cloud

LiDAR point clouds become "readable" only when overlaid to other 3D models, like a DEM "draped" onto orthophotos. We will come later to this possibility in the paragraph talking about 3D viewing techniques.

Managing LiDAR information is a matter of treating huge quantity of data, but also to have a proper technical storage to query cloud points for further analysis and representation, i.e. specific ICT tools are required.

OBLIQUE AERIAL PHOTOS (PICTOMETRY®)

Pictometry is the registered trademark for those that are commonly known as "oblique aerial photographs". These

images are taken at a 40 degree angle from low-flying airplanes and, most important, they are geo-referenced.
Oblique images allow a variety of measurements to be taken directly from the image, including height, distance and area as well as elevation and bearing. The images can be overlaid with shapefiles and GIS information can be exported from the images as well.
The oblique photographs show buildings, infrastructures, and land from all sides. Pictometry also shoots looking straight down from the airplane. In general, this approach results in much more visual detail than using satellite photography, because there are multiple perspectives, with overlap resulting in as many as 12 to 20 images of the same location.

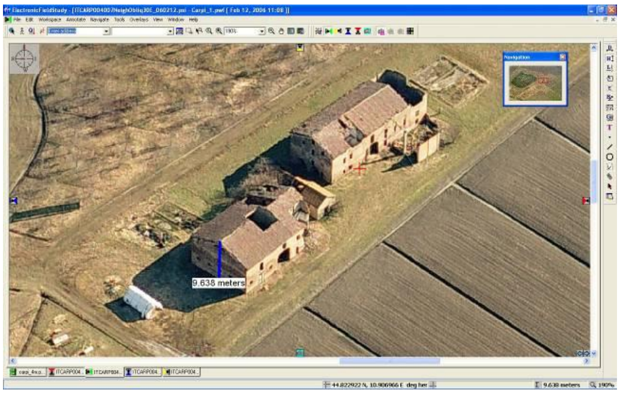

Figure 5. Measuring on oblique photographs

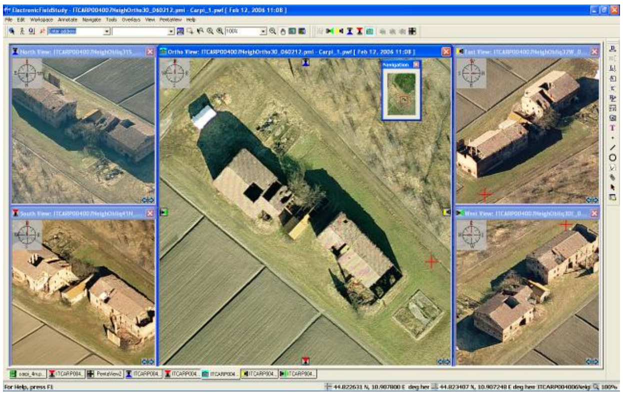
Figure 6. Multi-view on oblique photographs

Oblique photographs, as told before allow to measure objects, but also to have a more visual detail that can be helpful to control subsidised Rural Development Schemes, like those granted to build new farms.

PANORAMIC IMAGES (PICTOMETRY®)

Panoramic photography is a technique of photography, using specialized equipment or software, that captures images with elongated fields of view. It is sometimes known as wide format photography.
One of its application is known as 360° photography or, in technical terms, full rotation photography. These specialised images are shot with rotating cameras.
Although widely used for urban areas, applications can be thought for rural land also as an alternative to geo-tagged photographs.
These images can complement knowledge of the territory given by DEMs and cadastral information (mostly vectorial), allowing to have a close view of buildings and other features.
Like Pictometry, panoramic images are geo-referenced and measures can be taken with various techniques.

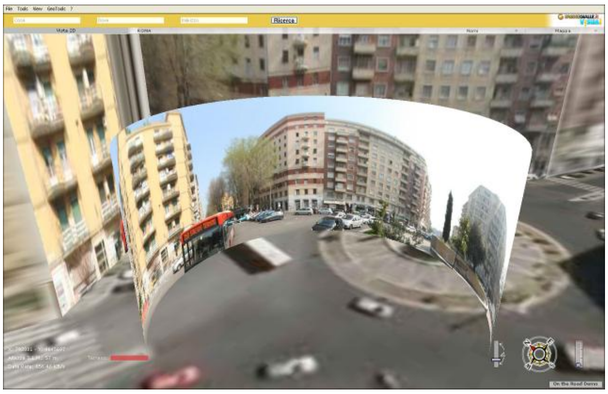
Figure 7. Panoramic image

3. HOW TO DEAL WITH 3D DATA

All the 3D information can be stored into a geo-referenced database. Some database technologies currently available on the market even include specialised data types.
Together with 3D data types, existing databases provide also functionalities to analyze those data.
When an LPIS is based on a spatial-enabled centralised database, possibly containing alphanumerical data within the same store, it is possible to intersect, overlay, analyse and discover many features, quality problems, ineligible land, and so on.
Therefore it is necessary to choose the right platforms to store this information, something that facilitates the management of huge datasets and with special functionalities for 3D analysis.
When used for CAP purposes, the architecture may be named as extended LPIS.
For the purpose of this study let us concentrate on four major 3D elements that can complement standard GIS layers within the LPIS:

- DEM storage for detailed and precise terrain analysis
- Multi-resolution optimised meshes for large scale terrain visualization and analysis
- 3D models storage for complementing oblique images
- LiDAR storage for feature extraction and analysis

DEMs can be used to precisely determine/calculate/show some environmental impacts, viewsheds, basins, dams. DEMs can provide more detailed information than the Triangulated Irregular Networks, but they require specialised processing and computational power.
During this work a series of new algorithms were developed/refined as a proof-of-concept to analyze a DEM.
One of these algorithms allows the construction of the related Triangular Irregular Network.

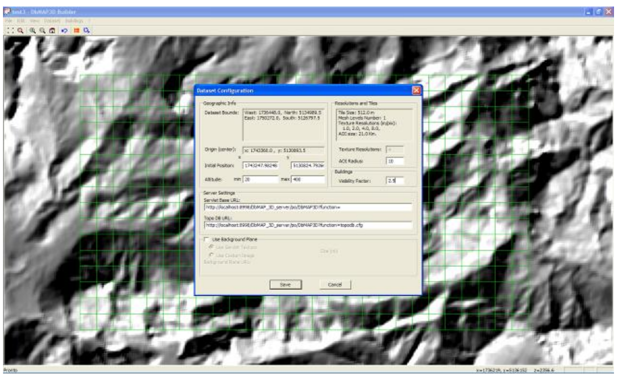
Figure 8. Processing a raster DEM to get a TIN

A TIN is less precise, since it is the result of an interpolation, in spite of that, adding the new multi-resolution mesh concept, we created a system that can show different levels of detail (a type of zooming) also to TINs. Therefore the TINs lose precision only when seen from a long distance.
Even the TIN is less precise, it still provides the lightness required for 3D visualization. As an example, serving streamed 3D content on the Internet has still limitations for DEMs, while TINs can be easily rendered by several 3D engines.
DEM and TIN can be combined to other raster images and vector layers to produce very complex calculations. In the image below you see the analysis of a drainage basin which was subject of a separate study (see bibliography).

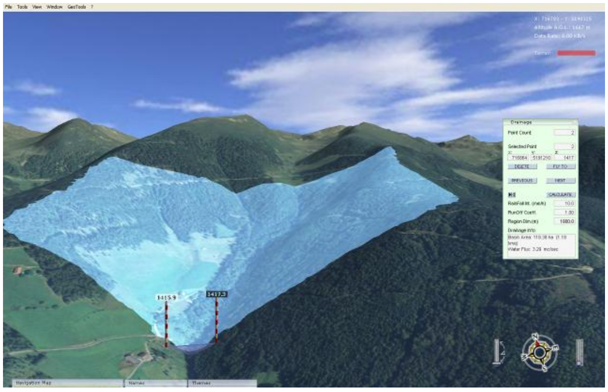

Figure 9. Drainage basin calculation

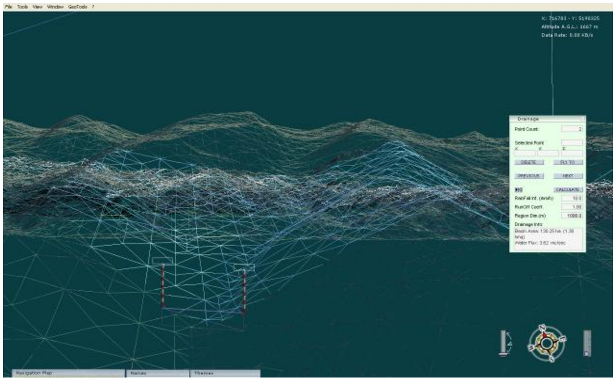

Figure 10. Drainage basin, underlying TIN

Several others analyses can be performed and for this purpose a tool has been programmed to accept plug-ins, basically algorithms, which have easy access to the underlying spatial information (2D and 3D).
The tools will be presented in the next chapter.
If talking about the LPIS and the ICS (Integrated Control System) as defined by the EU Reg. 73/2009, from DEMs and TINs the 3D attributes of a Reference Parcel can be determined on-the-fly (including precise x,y slope, altitude and exposure, and their average values on the parcel).
Once the information is available, some likelihood tests can be done like, for example, determining the possibility of presence of land cover type "arable" within certain slope and altitude parameters. As an example:

	Most certainly arable	**Hardly to be arable**	**Unlikely to be arable**
Slope	0 to 15%	15 to 35%	> 35%
Altitude	< 700 m	700-1300 m	> 1300 m

Table 1. "Arable" likelihood

The next category of 3D information is related to feature models. In most cases we are talking about buildings, but they could eventually be any objects on the land.
To simplify we will talk about buildings.
Discovery of rural buildings is important for two main reasons:

1) They are ineligible for direct payments
2) They may be financed with Pillar II funds

Whatever the reason, buildings can be easily discovered automatically from 3D information, compared to photo-interpretation, since the "z" value (height) is immediately visible.
Volumes of buildings could be assessed when having the footprint of the building itself (normally available at the buildings cadastre) and the height of the building (sometimes available in the building cadastre). So to say that vector layer might help.
When used in combination with Pictometry, the "z" value can be immediately determined, even automatically. Not to speak about the real status of the building in terms of its development. This latest attribute is important for Rural Development subsidies control.
To bring the 3D analysis to an higher level, LiDAR datasets help to discover more features.
Of course point clouds analysis is helpful to determine height values, which apply also to vegetation. These latest can be obtained, of course, also from Interferometric SAR images.
Let's make a curious example: in the 2D world it is possible to cheat olive trees parcels simply laying some nice rounded green groundsheets. Such cheating is immediately discovered using LiDAR datasets without waiting for it to be found by on-the-field inspectors.

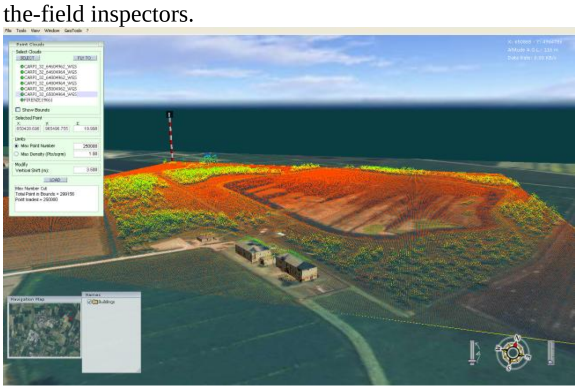

Figure 11. Finding buildings or vegetation

4. VIEWING AND USING 3D INFORMATION

To provide the operators working in Remote Sensing activities with practical tools, we built an architecture and interfaces helping both manual and automated activities.
The first step was to build an architecture supporting the relationships among this different data, so that they can be intersected and overlaid.
The data are stored within a spatial-enabled database supporting 3D operations and powerful enough to manage this huge quantity of information.
The 3D combined dataset is then complemented with existing LPIS data.

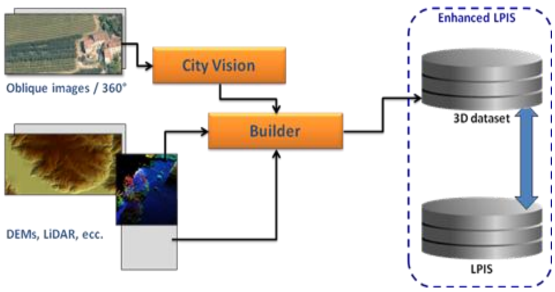

Figure 12. 3D authoring tools and extended LPIS

In the above figure, two major tools are designed to create a 3D dataset and to connect it to the usual LPIS database.

As a complement, a set of libraries (3D SDK) are provided to developers to query the 3D database and build new analysis functionalities within the applications using the extended LPIS. These include also automated analysis and transformation services.

Finally a viewing technology, with high rendering performances, easily helps human operators to visualise the different datasets, for example combining them to support decisions on ambiguous cases.

We report below some examples of applications and algorithms developed for 3D analysis purpose.

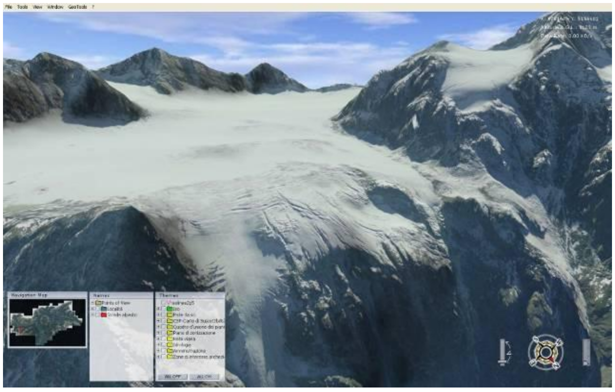

Figure 13. Precise rendering

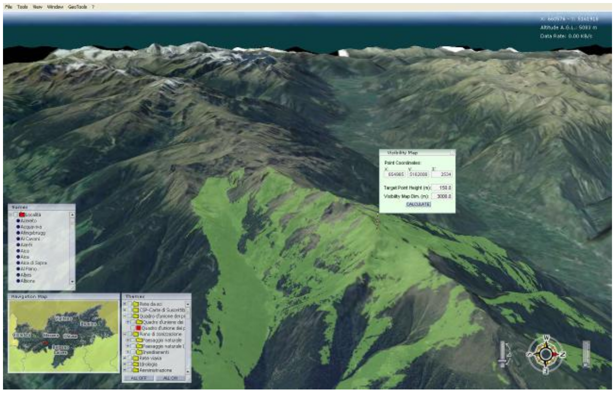

Figure 14. Visibility/viewshed maps

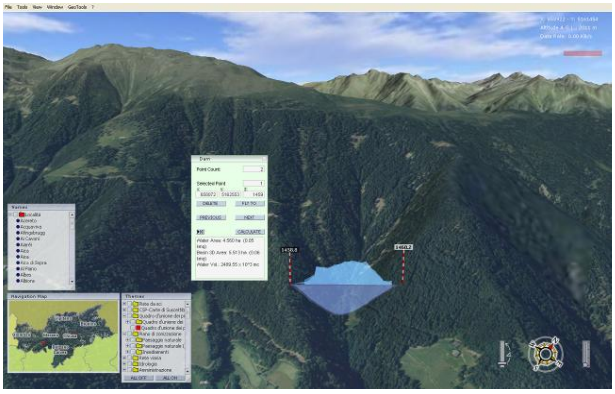

Figure 15. Building a dam

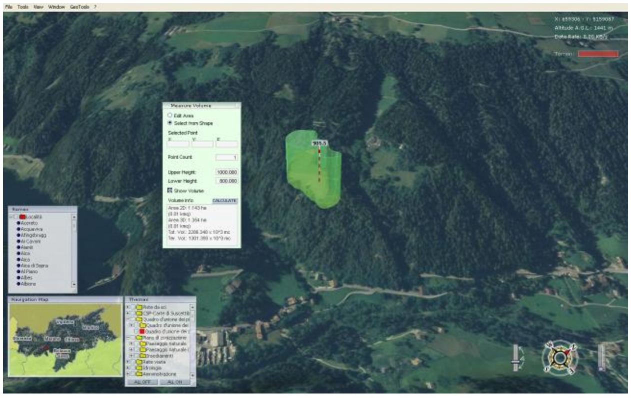

Figure 16. Terrain volumes

Figure 17. 3D land cover

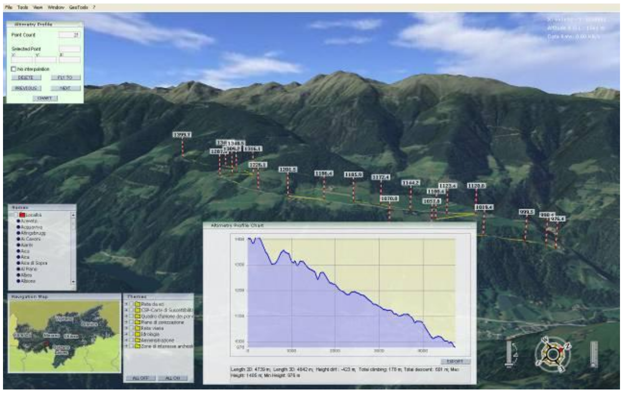

Figure 18. Altimetry profiles

5. INTEGRATION WITH THE LPIS AND BENEFITS

As expressed before, the integration with existing LPIS is straightforward in presence of a spatial-enabled database. We made several proofs with commercial and open-source software, each of which has pros and cons.

We tried to evaluate also the performance, reliability and the built-in analysis functionalities of each of the above platforms.

These statistics are out of the scope of this paper, but we have to mention that there is a lot of differences among the current available database technologies.

If the LPIS is not built upon a 3D supporting platform, there is still the possibility to complement the LPIS with the 3D extended functionalities. This may cause some performances problems, but still provides good results.

We also currently use the results achieved to start studying and implementing new complementary tools, for example related to Quality Assessment of the LPIS.

In fact, the 3D information can lighten the work needed to discover LPIS inconsistencies, both at the level of the Reference Parcels and on the land cover definition.
Some other examples include:

- Finding disadvantaged parcels (i.e related to Less Favoured Areas subsidies)
- Seeing rural developments (buildings, infrastructures, etc.)
- Finding new ineligible features (walls, infrastructures, etc.)
- Determining quality parameters of production (ex. vineyards)
- Complementing texture analysis (aka photo-interpretation)

6. CONCLUSIONS

The "extended LPIS" has been designed integrating 3D information within the standard LPIS architecture.
Together with the architecture some software components and tools have been built; a set of algorithms have been created to analyze the 3D datasets combined with 2D datasets in order to help understanding the reality.
The application are numerous, from pure 3D analysis to quality assessment, from feature extraction to rural development controls.
All the new tools and techniques can be applied together with the usual remote sensing techniques and provide tangible results.
The new datasets therefore can now be used to enhance the quality of LPIS information and to foster better controls.

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8. ACKNOWLEDGEMENTS

We wouldd like to thank the R&D department of Abaco which gave the possibility to make it real. The researchers of the company were able to transform ideas into real and usable tools.

FINDINGS OF THE 2009 LPIS WORKSHOP IN TALLINN (EE)

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KEY WORDS: LPIS, Common Agricultural Policy (CAP), Quality Assurance (QA) , Quality assessment, ATS, ETS

ABSTRACT

The 2009 issue of the annual workshop on the Land Parcel Identification System (LPIS), took place in Tallinn (Estonia), on 6th-8th October 2009. The LPIS workshops, organized by JRC and the Estonian Agricultural Registers and Information Board (ARIB), targets the technological responsible persons from the EU member state administrations. The 2009 workshop 'LPIS applications and quality" focused first on sharing experiences gained from the refresh activities launched by several member states and second, on presenting and discussing a common quality assurance strategy to support member states in managing their LIPS in order to comply with the requirements from the Common Agricultural Policy.

Other topics covered during this workshop were the general geomatics and data integration aspects involved, proven practices on specific applications such as recording eligible landscape features or managing retro-active financial recuperation. A presentation on Land Cover standardisation illustrated a future path towards common LPIS mapping specifications.

This paper highlights the findings of this workshop.

1. INTRODUCTION

The Land Parcel Identification System (LPIS) is a 'thing to stay' and its importance will likely grow over the coming years. This view was expressed by the Estonian host and also DG Agri labelled LPIS as a key instrument of Integrated Administration and Control System after the CAP's 2009 Health Check. To ensure the LPIS stays a prominent and effective instrument, the Commission will launch a revision of Commission Regulation (EC) no 796R2004 art 6.2.

Against this background, the workshop would look into experiences of Member States and look towards dealing with the eminent LPIS challenges in an effective yet practical manner.

2. SHARING EXPERIENCES

Session 1: LPIS refreshes

Three Member states shared their experiences with redesigning and refreshing their system. A "refresh" is defined as a systematic inspection and, where appropriate, subsequent remapping of all reference parcels of the system.

UK-England discussed the importance of linking LPIS data to external topographic data and stressed the need to communicate effectively with the farmers. Although England is still in the planning phase, its pilot study already indicated that no significant change in overall eligible area is to be expected from this refresh.

Denmark introduced for its refresh a "net area" concept as an attribute value, separate from the GIS polygon area. An extensive risk analysis is applied to focus the refresh efforts on the high risk zones. Denmark noted that the resulting LPIS specification of this refresh far exceeds the minimum regulatory scale requirement of 1/10.000.

Greece also implemented risk analysis, not at the reference parcel level but at project management level. Under strong pressure to divert a substantial financial correction, Greece implemented a tight quality control system with success. Upon completion of the refresh, Greece will develop a methodology for the upkeep of its system to prevent ever arriving in a similar situation as before the refresh.

Session 2: LPIS Quality Assurance Frameworks

Standardized and agreed quality tests are the central part of any quality assurance (QA) setup. The testing procedures should address the key requirements laid upon the LPIS system. As a starting point, the European Commission has identified seven quality elements which it considers critical. From this start, several prototype components of a QA framework were developed by JRC and have been presented in the workshop.

Independent from this development, several Member States already implemented a formal quality policy, often under pressure of the European Commission Audits.

Portugal designed its quality policy around the PDCA (Plan, Do, Check, Act) cycle. The approach was applied for each objective of the LPIS update plan. To facilitate the refresh process, Portugal introduced a sub-parcel concept covering the agricultural land inside the more stable reference parcel. It had completed its refresh activities but awaited the ultimate compliance test of passing the next audit.

The Belgium-Flanders' quality policy spans all its IACS components and procedures. Flanders introduced risk parcel categories and extensively used external data sources for identifying ineligible land use or land cover changes. These external sources ranged from yellow pages queries to Cadastral map extracts. All involved staffs are trained to detect and resolve database issues during their daily duties. Although this system yields numerous parcel information changes, the net result in financial terms is found to be very limited.

3. A COMMON QUALITY FRAMEWORK

Session 3: Quality Framework: Measuring LPIS data conformity and quality

Abstract Test Suite (ATS)

In the course of 2009, JRC had developed an Abstract Test Suite for the verification of structural conformance of a Member States' LPIS implementation. This conformance is referenced to the common LPIS Core Model (LCM) derived from regulatory requirements and common practices. JRC presented the methodology and the Estonian paying agency, who was one of four participants to a feasibility trial, complemented the theory with the practical experiences.

The prototype ATS was experienced to be the right way to exchange information on the data base structure. Each national implementation has several times more data layers than the number of explicit spatial concepts mentioned in the CAP regulations. A comprehensive method to identify which national layer corresponds to a specific CAP concept is therefore appreciated. To make the application of the proposed method practical, Estonia found it useful to produce a consolidated table ("Frozen View") of its native database.

The most difficult ATS module was reported to be the one that deals with the implementation of eligible land. As the concept of eligibility varies over the aid schemes and depends also upon national choices, the result is often an individual and complicated implementation of this eligibility concept.

A last advantage of the ATS is that it facilitated the member states themselves for a much better understanding of their implementation.

Executive Test Suite (ETS)

In parallel to the ATS, the JRC developed the LPIS Executive Test Suite, targeting conformance of data values of a Member States' LPIS implementation. A detailed description of the methodology and workflow design (including parcel sampling, parcel inspection and reporting) was complemented with a first provisional feedback from the four ongoing ETS feasibility pilots. The ETS method presentation of JRC was followed by a report from Belgium-Flanders; one of the ETS pilots. Flanders acknowledged the value of the ETS, as it found the results to be in line with the findings of their own, much more extensive, quality policy. The comparison between the approaches allowed Flanders to suggest improvements of some ETS criteria definitions.

The first experiences demonstrated, even at this early stage, the ability of the prototype LPIS Quality Framework to provide an objective and comprehensive picture of the LPIS status at moderate costs. This overall result confirms that this approach was technically feasible. For none of the participating systems, the whole procedure had taken more than 2-3 months. Still, better guidance and clarification were requested as some quality measures were considered to be too vague and complicated. Especially, "parcels with potential critical defects" were, in the view of the participants, not necessarily erroneous parcels; additional analysis and explanation of these 'potential' defects in the national context is necessary.

The land cover mapping applied to collect recent field data is not experienced as a straightforward process; specific mapping and coding rules needed to be defined, especially where landscape features are mapped.

The VHR Orthoimagery acquired for CwRS program used during the trials appeared to offer a generally sufficient source for ETS, although some land features were difficult to be properly mapped. The use of ancillary data could support the decision process and considering the effect of acquisition date for each image is identified as important.

In conclusion, we can state that the participants to the ETS feasibility trial mostly agreed that the approach was relevant and that it provided structured and objective information on the status of the LPIS. The set of quality elements seemed meaningful and allowed for a comprehensive analysis irrespective of LPIS type and design, whilst individual quality elements remained specific enough to target particular components of LPIS performance.

Session 4: Quality Framework: Data source issues

A common quality framework, based on external tests of data values, relies on the data collection for the ETS. This relies in particular on adequate requirements of the reference orthoimagery as the external data source. Orthoimagery specifications for LPIS update projects, published in WikiCAP were discussed; compared to earlier specifications, they gave more attention to the evaluation of the radiometric quality as this is crucial for the representation of the information content.

To translate the regulatory concepts on "eligible hectares" into a practical common methodology, a solution was outlined, comprising common land cover mapping at large scale and subsequent translation of mapped land units into eligibility values, via an "eligibility profile", applicable for each individual EU Member State or regional LPIS implementation.

Flanders-Wallonia adopted a strategy for the orthophoto renewal for their LPIS updating based on a 3 years cycle, with the oldest acquisition of the country being done in 2006-2007. The University of Liege was contracted to develop the external quality control process. Wallonia appreciated the benefits of the introduction of digital CIR camera compared to their previous black and white analogue devices. This higher quality of their orthoimagery led to an improved photo-interpretation of the reference parcels by allowing better evaluation of shadow areas, easier detection of ponds and identification of various small land features.

4. OPERATIONAL LPIS CHALLENGES

Session 5: Undeclared land and retroactive control procedure

Hungary presented quality improvements in its LPIS as well as its method to manage non-declared areas and retroactive procedures. Quality improvements resulted from both dedicated and systematic LPIS updates, relying on better quality orthophotos and semiautomatic procedures for image interpretation.

Undeclared land and past over-declarations are identified by spatial cross-check procedures between land declarations over the last three years (2007/2008/2009) for the individual eligible patches inside of the Hungarian physical blocks. These procedures are especially monitoring blocks where undeclared area is decreasing or changing. Additional control for over-declarations is provided during the cross-check between the sum of the declared area in IACS and the GIS area of the block.

Session 6: LPIS update and application developments

This session dealt with experiences of different cases of LPIS use for managing 1st and 2nd pillar schemes.

Estonia presented its e-application development while the Netherlands outlined their plan to remediate the audit findings of an insufficient integration of controls between 1st and 2nd pillar schemas. Both Slovakian and Danish presentations provided an overview on their projects for registration of eligible landscape elements in their LPIS.

Session 7: New outlooks

This more technical session started with a broad overview of the 3rd generation of the Czech LPIS, presented as a real-time solution for the management of the agriculture land, integrating all possible datasets at national level. Farmers benefit from the online access to the LPIS data and on-the-fly registration of any changes at reference parcel level. The Czech LPIS supports the registration of the eligible landscape features.

An FAO representative presented the draft third version of the Land Cover Classification System, known as Land Cover Meta Language (LCML). He addressed the harmonization of different Land Cover Classification Systems, so that data from multiple sources and from different application environments could be compared and integrated; a crucial factor for the LPIS QA in view of its common inspection method. Any GIS

(including the LPIS), is an approximation of the reality with an inherited degree of vagueness and generalization caused by the human interpretation. The standardizations and formalization of the semantics provided by LCML is a key factor for proper communication between LPIS custodians and LPIS users on the stored information. LCML has been proposed to become an ISO standard under ISO TC211.
JRC presented its plans and technical outlooks for facilitating the LPIS Quality Framework. This future holds the development of a solution for data handling and services to automate LPIS QA processes, all implemented through a GeoPortal. JRC also launched its idea of a CAP test bed.

5. GATHERING OPINIONS

Session 8 of the workshop was a "tour de table", dedicated to the gathering of opinions from the audience. Every "Member State delegation" was invited to reflect on what has been presented or discussed and to report their main conclusions. JRC summarized this feedback in five "most frequent opinions".
1. There is a general welcome to the development of the new quality elements, replacing the existing 75/90% rule (art 6.2 Commission Regulation (EC) No 2004R796). Standardisation of LPIS QC for an unbiased assessment allowing comparisons over the years as well as between countries is regarded as the number one priority.
2. The very development of this QA framework should be more transparent to MS; working documents should be published sooner, indicator thresholds should be tried and discussed and be established with respect to the type and particularity of the reference parcels in each MS. MS who operate relatively small reference parcels fear disadvantages from universal threshold values.
3. Examples by those MS with a developed QA policy demonstrated that a controlled way to upkeep LPIS costs less than paying up financial corrections or than organising an overall upgrade/refresh project for the system;
4. Concerning landscape features (LF), Member States feel that messages from Dublin and Tallinn workshops are confusing: there is no consistent guidance on whether to register or not or to digitize or not. A consolidated European Commission position is urgently requested, evaluating the cost-benefits of the registering landscape features. It was mentioned that there is no need for a standardized European landscape and that local particularities should therefore be accommodated for.
5. There is an urgent need to reduce the semantic problems regarding eligibility and land cover and to further elaborate the temporal aspects of this eligibility.

6. CONCLUSIONS

This 2009 LPIS Workshop confirmed that all Member States face similar challenges and appreciate some convergence of methods. In particular, the various Member States' experiences illustrated that the use of external data to monitor the LPIS condition is crucial, covering orthoimagery as well as external geospatial databases.
Managing LPIS data requires a formal quality policy and priorities can be determined using appropriate risk analysis. The concepts of "Net area' or "subparcel" indicate that systems operate several "layers" of geospatial data.
The threat of failing a financial audit offers a strong drive towards this formal and even common quality policy within a framework that provides objective and comparable test results. The prototype quality framework of the JRC is generally welcomed, but the methodology needs optimization and its technical documentation needs improvement. Clear and simple guidelines are essential. A trial year without formal compliance thresholds was requested as well as provisions for the intrinsic heterogeneity between implementations and landscapes across Europe.
Some discrepancy seems to have grown between the nominal specifications in the Regulations and guidelines and the far better detail of the actual LIPS implementations.
The high quality and clear relevance of the presentations and discussions facilitated an active and effective sharing of information between member states.

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ASSESSMENT OF THE APPLICATION OF RAPIDEYE IMAGERY FOR THE INVENTORY AND MONITORING OF 'ELIGIBLE' LAND UNDER SAPS IN BULGARIA

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KEY WORDS: Common Agricultural Policy (CAP), Remote Sensing, Single Area Payments Scheme (SAPS), RapidEye, LPIS, GAC

ABSTRACT
The Common Agricultural Policy (CAP) was established by the European Union (EU) to maintain balance between farming industries and the environment and also to provide economic sustainability in rural areas. Under CAP, the Single Area Payment Scheme (SAPS) involves payment of uniform amounts per eligible hectare of agricultural land. In accordance with EU Regulations for agricultural and rural development, these schemes are obligatorily adopted by countries upon entry into the European Union (EU) as a Member State. A research project was established between the GeoCAP Action of the Monitoring Agricultural Resources (MARS) Unit of the IPSC at the Joint Research Centre of the European Commission, the Bulgarian Government, RapidEye and ASDE/RESAC, to evaluate the suitability of remotely sensed imagery from RapidEye for detection of land cover features representing eligible land under SAPS in Bulgaria, in order to assist their annual LPIS update and reporting. This paper provides preliminary analysis based on object and pixel based segmentation approaches and shows that multitemporal RapidEye imagery can be successfully used for landcover identification.

1. INTRODUCTION

For many EU countries applying SAPS, the agricultural area eligible for payments, is the utilised agricultural area, maintained in good agriculture condition (GAC) at a given reference date. This means that the land that can be declared by the farmers, and can be a subject to administrative and control processes that manage the CAP payments, is limited to the historical extent from a fixed reference year. Land, which is not considered part of this "SAPS envelope" is not subject to the CAP direct payments and in most of the cases, is not recorded in the Land Parcel Identification System (LPIS).
Bulgaria and Romania are exceptions of the above-mentioned rule, as the requirement for the "reference year" was omitted in their Accession Treaties. As a result, any utilised agricultural land, maintained in good agricultural condition at the time of the farmer declaration, regardless its past status, can be considered eligible for CAP payment. This creates a particular challenge for both countries, having significant dynamics in land management in the years following their EU accession, as they are required to assess agriculture land eligible for payments on annual basis.
As an EU Member State since 2007, Bulgaria is receiving technical assistance from the Joint Research Centre (JRC) of the European Commission (EC) for implementing CAP regulation. In that respect, a research project was established between the GeoCAP Action of the Monitoring Agricultural Resources (MARS) Unit at the Institute for the Protection and Security of the Citizen in JRC, the Bulgarian Government, ASDE/RESAC, Bulgaria and RapidEye, Germany. The projects core objective was to investigate and develop a technical methodology for annual monitoring and assessment of land eligible under SAPS in Bulgaria, which can be efficient enough to be deployed operationally.
The proposed methodology envisages the use of remotely sensed imagery, as an efficient source of up-to-date information, to detect and quantify (for the entire country), the agriculture land representing eligible area (i.e. utilised agricultural area), through monitoring of land cover dynamics. The recently launched constellation of RapidEye satellites was considered particularly suitable for developing an inventory of this nature, as the satellites were designed with the primary application of monitoring agricultural and natural resources at relatively large cartographic scale.
Test zones within Bulgaria were selected for analysis with consideration given to the variability of landcover features across the country, which potentially represent eligible land [5]. Several RapidEye images were programmed for capture over each of the test zones. The subsequent image processing and multitemporal classification were performed using the spatial data of the LPIS, as an integral part of the input data. Finally, an estimation of the agriculture area in GAC, for each reference parcel of the LPIS, has been provided.
The content of the paper is organized as follows: Section 2 introduces the concept of Good Agricultural Condition (GAC) elaborating on a proposal for its legal definition; Sections 3 and 4 provide an overview of the test areas of the study and Rapideye sensor specifications. Section 5 describes proposed methodology for detection and quantification of the GAC/non-GAC land cover types and features, using an object-oriented approach; Section 6 and 7 present initial results of the study, as well as further geoprocessing done in order to derive important statistics at LPIS level; Section 8 explores concurrent testing using Self-Organizing Maps, as an alternative of the object-oriented approach; Section 9 outlines initial project conclusions.

2. GOOD AGRICULTURAL CONDITION

The Common Agricultural Policy (CAP)[2] entitles landholders to receive subsidy payments for their land if they satisfy criteria of their land being in 'good agricultural condition' (GAC). There is however, no legal definition of what is deemed to be

[2] ec.europa.eu/agriculture/publi/capexplained/cap_en.pdf

GAC and is suggested that each member state defines the term. Therefore, in order to ensure a correct assessment of the agricultural land suitable for SAPS payments, the concept of "Good Agricultural Condition" requires clarification at national scale, prior to further action in the scope of this current study.

The CAP has a number of policies that are applicable to agriculture or forest practices however, for this study the policy for Single Area Payments scheme (SAPS) was targeted as a reference of the proposed methodology. Under Council Regulation 73/2009 Article 124 (1), it is stated that 'utilised agricultural area' subject to the SAPS must be maintained in 'good agricultural condition', even if the land is not in production. To suggest a robust and plausible concept of GAC, current legal definitions within regulations were consulted. From these definitions, land cover types that were potentially eligible for SAPS and the principle of GAC from regulatory requirements gave leverage to develop a concept of GAC in Bulgaria.

The reasoning behind the necessity of a GAC concept in Bulgaria is Council Regulation 73/2009, Article 124 paragraph 1, which states:

'For Bulgaria and Romania, the agricultural area under the single area payment scheme shall be the part of its utilised agricultural area which is maintained in good agricultural condition, whether or not in production, where appropriate adjusted in accordance with the objective and non-discriminatory criteria to be set by Bulgaria or Romania after approval by the Commission'

From Regulation 73/2009 Art 124, the definition of utilised agricultural area (below) is introduced and is important to the foundation of GAC concept as it lists the main land cover types, which can represent eligible land, but also can be easily detected (monitored) on the ground or through remote sensing data:

'... utilised agricultural area shall mean the total area taken up by arable land, permanent grassland, permanent crops and kitchen gardens as established by the Commission for its statistical purposes'.

The definitions of the following terms are already defined in current EU regulations: arable land [380/2009 Art 1 s2(a)], permanent grassland [380/2009 Art 1 s2(b)] , permanent crops [370/2009 Art 1 (b)] and kitchen gardens [1444/2002 Annex 1]. By integrating the definitions from regulations, the resultant proposed concept of GAC is as follows:

'Good Agricultural Condition shall apply to accessible land which is maintained as active, or has the potential to become active, agricultural area or agricultural activity within a reference parcel'.

Definitions for agricultural area and agricultural activity are defined in Regulation 73/2009 Art 2 while the reference parcel is defined in Regulation 796/2004 Art 2 (26). This concept is a good starting point for establishing and developing a consistent technical framework, allowing proper classification of the agriculture land in GAC. The two key elements in the proposed GAC definition are:

- The potential of the land to become agriculture – this means that the land shall have the potential to produce biomass either due to its natural properties or due to the implementations of certain standard agriculture activities a general European farmer can afford.
- The accessibility of the land - this means that there are no obstacles, neither natural nor man-made, preventing access and use of the land for agricultural activities.

These two key elements are the core assumptions, on which the proposed technical methodology is based.

3. STUDY AREA

Bulgaria joined the European Union on January 1st, 2007[3]. As a Member State, the country has adopted the legislation of the European Community for the management and monitoring of their agricultural land and benefit payments. Bulgaria is approx 111.000 km^2 in size, extending from the western boundaries of the Black Sea to Serbia and FYROM on the East. The country borders Romania on the North and Turkey and Greece [4] on the South. The northern boundary follows partially the Danube River.

Figure 1. Map of Bulgaria with the Test zones (KARD, PLOV and VARN).

To capture the diversity of landscape within the country, the study area has been stratified into three testing zones: Zone 1 - Kardzhali (KARD); Zone 2 - Plovdiv (PLOV) and Zone 3 - Varna (VARN). Two additional 'back-up' zones, were also selected in the event suitable RapidEye imagery over the main zone could not be obtained (Figure 1).

Zone 1: Kardzhali: The zone is situated in the area of Eastern Rhodope, Bulgaria. The landscape is hilly to mountainous, with an average altitude of 444 meters. The climate is mild to Mediterranean with an average annual temperature of about 11**°C** and an average annual rainfall between 650-700mm. Droughts are common during the summer. The soil, having limited mineral chemical elements, makes the area suitable for the cultivation of vines, tobacco (main cultivation in the region), fruits and grains. Slopes are deforested and eroded; with areas prone to landslides. Most of the hills are covered by low-productivity grassland used for grazing.

Zone 2: Plovdiv: Situated on alluvial plains along the Marista River, the area of Plovdiv is one of the highly productive regions of Southern Bulgaria.[5] The climate in this region is very hot and dry in summer and cold during the winter. Average temperatures range from 5°C to 31°C in summer and -3°C to 16°C in winter. Rainfall ranges from 31- 66mm.[6] The primary cultivation in the area is horticulture, annual crops and permanent crops (mostly orchards). Vineyards are also common on the Northern slopes of Rhodope Mountain.

Zone 3: Varna: Boarding the Black Sea and covering a portion of the Danube Plain, the area of VARN is located in the north-eastern area of Bulgaria.[7] The area is extensively used for agriculture due to the presence of highly productive soils, which are however, subject of water and wind erosion. The primary cultivation in this region is cereal cropping.

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[3] http://news.bbc.co.uk/2/hi/europe/country_profiles/1059735.stm
[4] http://www.bcci.bg/bulgaria.htm
[5] http://www.plovdiv.org/home/intro.html
[6] http://en.wikipedia.org/wiki/Plovdiv
[7] http://en.wikipedia.org/wiki/Varna_Province

4. RAPIDEYE IMAGERY

A constellation of five multispectral satellite sensors were launched by RapidEye in August 2008 with a primary focus on agricultural applications. These satellites have a lifespan of seven years; a ground sampling distance of 6.5m resampled to 5 m; and a daily overpass[8] (Figure 2). A new feature, introduced in RapidEye sensor, is the RedEdge band (690-730nm), which could allow better distinction of the different phenological stages of the vegetation.

Mission characteristic	Information
Number of Satellites	5
Spacecraft Lifetime	7 years
Orbit Altitude	630 km in Sun-synchronous orbit
Equator Crossing Time	11:00 am (approximately)
Sensor Type	Multi-spectral push broom imager
Spectral Bands	Capable of capturing any of the following spectral bands: Name — Spectral Bands (nm) Blue — 440 – 510 Green — 520 – 590 Red — 630 – 685 Red Edge — 690 – 730 NIR — 760 – 850
Ground sampling distance (nadir)	6.5 m
Pixel size (orthorectified)	5 m
Swath Width	77 km
On board data storage	1500 km of image data per orbit
Revisit time	Daily (off-nadir) / 5.5 days (at nadir)
Image capture capacity	4 million sq km/day
Dynamic Range	12 bit

Figure 2. RapidEye Specifications

5. METHODOLOGY

As stated in Section 2, the key elements derived from the GAC definition, are the prerequisites for the choice of a particular methodological approach and technological solution.
From the adopted GAC definition, a land could be considered in GAC, if at least the following two criteria are met:

- vegetation is growing or can be grown on that land
- the land is accessible for agriculture activities (cropping, grazing, etc..)

Both conditions can be evaluated, through:

- monitoring the development of the vegetation during the year (phenological cycle), together with
- analysis of the texture properties of the land cover and its spatial context.

Indeed, the lack of legal obligation to cultivate the land in order to receive SAPS payments, gives the possibility of wide and flexible interpretation of the GAC definition. In fact, any land which produces vegetation and is accessible for farming activities, could be considered in GAC. Thus, instead of detecting the land which is in GAC, it was deemed logical to focus the project on detecting and qualifying land which definitely has no GAC potential.
From land cover (physiognomic – structural) point of view, land which is not in GAC:

- will be constantly bare during the cultivation year for example, sealed surfaces; natural bare areas.
- contain features preventing agricultural activity regardless of if the land is vegetated, for example, closed forest, woodland, wetland, etc.

Thus, the methodological approach was based on a multi-temporal analysis of RapidEye time-series, using object-oriented classification techniques in order to detect and mask the pure non-GAC features and estimate their impact at reference parcel level.
An overview of the proposed methodology used for decision-making and analysis can be seen on Figure 3. The selection, acquisition and pre-processing of imagery was important in providing a solid foundation for future analysis. The acquisition windows were carefully defined on the base of crop calendars, provided by ReSAC. Imagery from April, May, June, July and September were acquired over the test zones to reflect the phenological cycles of the vegetation. Due to unfavourable weather conditions during image capture, the use of the RapidEye data from September was relatively limited.

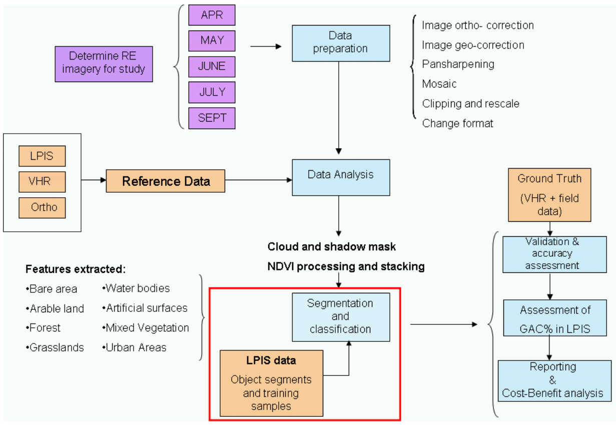

Figure 3. Proposed methodology

Imagery was obtained from RapidEye at standard processing level 3A[9] (orthorectified). Pre-processing of imagery was carried out in ERDAS Imagine and ESRI ArcGIS software. This entailed further geo-referencing of the satellite imagery to the national orthoimagery provided by the Bulgarian government, thus ensuring data consistency between the RapidEye imagery and the LPIS datasets. Nearest neighbour approach was used for the resampling. In addition to the RapidEye imagery, VHR data from IKONOS, acquired in the frame of the annual CwRS campaign, was also provided for the study. The availability of this imagery was an important source of ground truth. An orthorectification of this VHR data was carried out using the reference orthophoto, additional ground control points and the SRTM DEM available freely to the public.
In order to develop methodology and suitable classification algorithms, a smaller area of interest (AOI) was defined in each test zone. This was also useful in reducing the influence of clouds, by selecting cloud-free portions of the images.
The main objective of the study was to capture and mask out the permanent bare areas, as well as areas not accessible for agriculture. It was assumed that the permanent bare areas should have low NDVI values in all time series. For that purpose Red Edge Normalised Difference Vegetation Index (NDVI) (eq 1) [1] was calculated for all images.

$$\text{Red Edge NDVI} = \frac{(\text{NIR} - \text{Red Edge})}{(\text{NIR} + \text{Red Edge})} \qquad \text{(eq 1)}$$

Figure 4 shows a stacked imagery composed by the NDVI images calculated for 4 consecutive months. Analysis of the stacked NDVI imagery clearly highlights permanent bare areas like quarries or water bodies (low NDVI values) as dark

[8] http://www.rapideye.de/home/system/satellites/index.html

[9] http://www.rapideye.de/home/products/standard-image-products/standard-image-products.html

features, contrary to the forested or vegetated agricultural areas (high NDVI values), which appear in brighter shades.

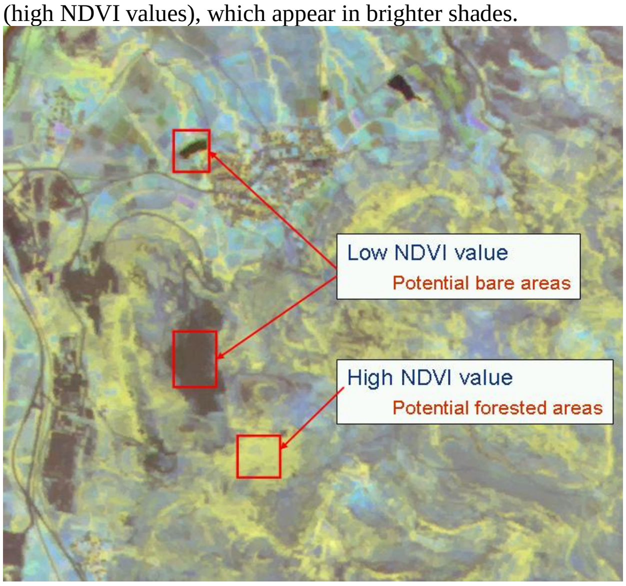

Figure 4. KARD site: Preliminary visual analysis of the colour composite image of the NDVIs from 4 consecutive months: April, May, June and July.

The choice of using the Red Edge channel, instead of the Red channel for the NDVI calculation, was mainly driven by literature [3] citing a higher level of performance from RedEdge NDVI compared to the traditional NDVI equation over highly vegetated (forested) areas.
After obtaining the Red Edge NDVI images, a 5-band image containing the stacked NDVI images for the months of April, May, June, July and September were created in ERDAS Imagine. It was finally rescaled to the dynamic range of the RapidEye imagery, which is 12 bit.
A segmentation of this 5-band image was done in Definiens eCognition, using the spatial data of the LPIS as athematic layer input. The segmentation was performed at high detail to preserve features up to 0.1 ha within the imagery; as a consequence the land cover features larger than the minimum mapping unit, were over-segmented.
The resulting segments were further classified in eCognition, to extract various land cover features. Different variables, such as Brightness, Mean value of Red, Relative Border to, Border Index and Thematic Attribute, have been used. The exhaustive toolbox of eCognition, together with the extensive use of RapidEye and LPIS data, gave the possibility to define and extract more land cover types – thus, enrich the initial simple “binary” classification of vegetated and non-vegetated areas.
The land cover types were further grouped in two categories – GAC and Non GAC. The GAC group encompasses all land cover classes, which have the potential to represent eligible land, such as arable land and grasslands. The non-GAC group contains the opposite – the land cover classes, which cannot be considered potential for agriculture, such as inaccessible areas, constantly bare areas and forest (see Figures 7 and 8).
After the land cover classification and subsequent validation (using training sets from the VHR imagery), statistical analysis was carried out to determine the presence of GAC and non GAC features in each reference parcel. Currently such statistics have been done only for test zone of KARD.

6. PRELIMINARY RESULTS

The first results obtained only encompass the KARD test area. These results indicate that non-GAC features can be detected with a high success rate. The overall thematic accuracy of the land cover classification was above 80%. Unfortunately, due to the limited amount of ground truth data, the validation of the classification was done on the basis of information obtained from the VHR imagery. Even though having sufficient spatial, spectral and radiometric resolution, the IKONOS imagery represents only a single snapshot of the ground; a limitation, which cannot always ensure that the information available on the image will be sufficient for an accurate interpretation of the ground truth. Figure 7 shows the derived land cover map of the AOI of KARD. Figure 8 shows the GAC/non-GAC mask of the same area, generated by grouping of the landcover classes in the GAC/non-GAC categories.

7. FURTHER ANALYSIS AT LPIS LEVEL

The spatial and alphanumeric data from the LPIS plays an integral role in the segmentation and classification of the RapidEye imagery. As a consequence, the resulting land cover segments aligned well with the spatial extent and design of the reference parcels of the LPIS. In addition, valuable information regarding the type of landuse represented by the reference parcel (stored in the LPIS attribute data) was used in subsequent merging and aggregation of image segments into meaningful landcover features. This facilitated further geoprocessing of the LPIS and thematic land cover data, in order to calculate the ratio of the GAC/non-GAC land cover features inside each reference parcel.
The type of reference parcel used in the Bulgarian LPIS is the physical block. The LPIS itself covers the whole country; therefore agricultural land, and also natural and urban areas are included in the LPIS dataset. In order to distinguish the physical blocks eligible for SAPS payments, each of the reference parcels was assigned one of the following groups:

- Group 1: Physical blocks where areas are registered by the farmers and eligible for payment.
- Group 2: Physical blocks where areas, are registered by the farmers and could be eligible for payment only after a field inspection.
  Group 3: Physical blocks where areas cannot be registered by the farmers as they are not eligible for payment.

Reference parcels belonging to Group 1 are crucial in GAC/Non GAC classification as the area declared (or registered) inside the reference parcel is accepted, by default, as correct during administrative checks. In order to prevent any incorrect payments or over-declaration for these reference parcels, the agriculture area that may represent eligible land should be quantified correctly and subject to an annual update.

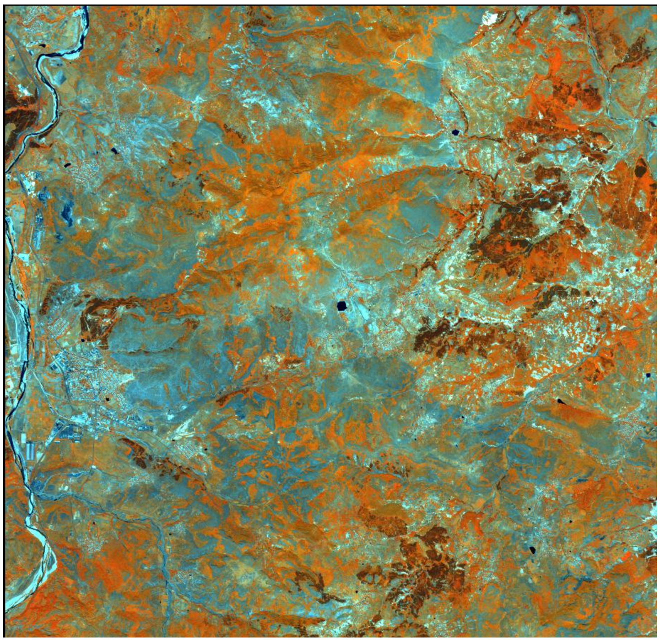

Figure 5. Colour composite image of the AOI of KARD site (NIR, Red Edge and Red)

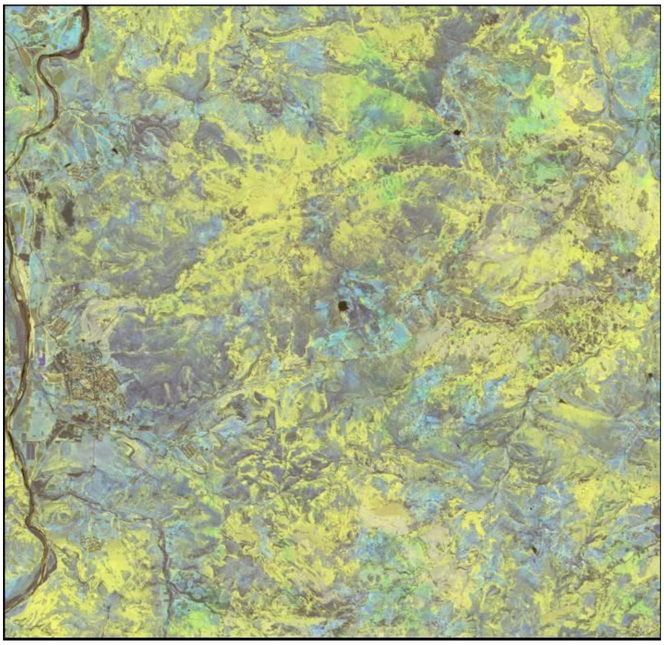

Figure 6. KARD site: Colour composite image of the NDVIs from 4 consecutive months: April, May, June and July.

Figure 7. Preliminary results for the land cover map of the AOI of KARD. The area potential for agriculture comprises: arable land, permanent cultivated and natural grassland, low productivity mountain grassland, mixed vegetation and permanent crops.

Agriculture (potential)

Bare Surface

Forest (conif)

Forest (decid)

Water

Inland Grassland (Veg)

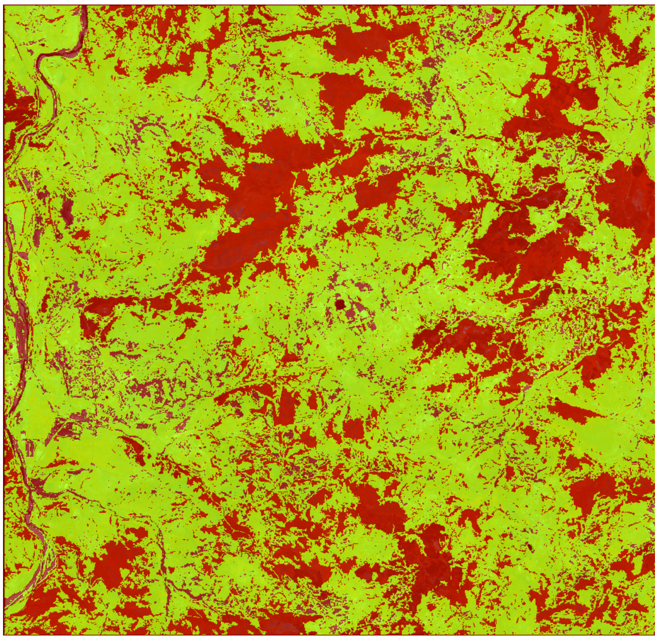

Figure 8. Preliminary results for the GAC/non-GAC mask of the AOI of KARD

GAC

Agriculture (potential)

non-GAC

Bare Surface
Forest
Water
Inland Grassland (Veg)

The resulting GAC/non-GAC mask can be used to assess the currency of the LPIS in respect to the agriculture land stored in the system. For each reference parcel, the total area of the GAC land cover found inside, is calculated and stored as a percentage from the total eligible area of the reference parcel as recorded in the system. Those reference parcels, belonging to Group 1, which have greater than 3% difference between the agricultural area detected and agricultural area recorded in the LPIS, are highlighted as potentially incorrect (Figure 9) .

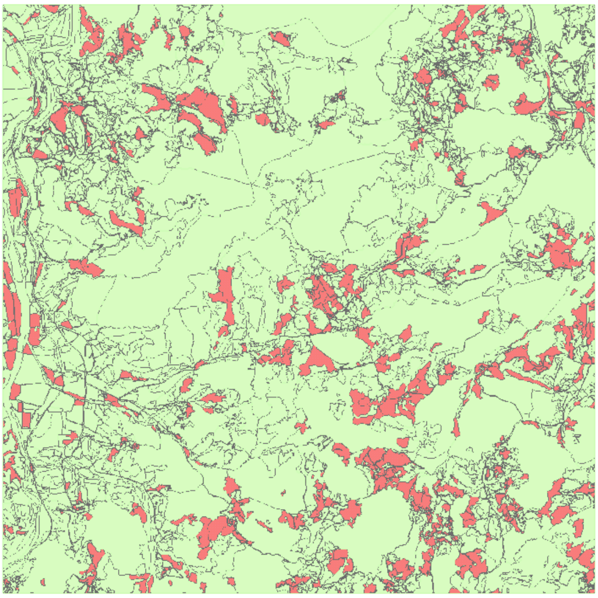

Figure 9. KARD site: Physical blocks (highlighted in red) coded in Group 1, with more than 3% difference between the agriculture area found and area recorded

Figure 10 shows the distribution of the reference parcels, flagged as potentially incorrect, according to the type of land use recorded in the LPIS. It becomes evident that most of the "potentially incorrect" reference parcels which may need revision are recorded in the LPIS as representing permanent pastures and meadows, or areas of mixed land use. This important outcome needs further investigation however, some immediate observations are:

- Most of these pastures are in fact marginal areas, located close to mountain slopes, covered in sparse vegetation. They often contain highly eroded areas, which have very little, or no agricultural application.
- Permanently bare areas, efficiently captured from RapidEye were not clearly distinguished from vegetated areas on the orthophoto (used for the LPIS creation and update). This could explain the current inclusion, rather than exclusion, from the agricultural area of the reference parcels.
- Reference parcels classified in the LPIS as mixed land use, require close revision and modification as the concept of mixed land use implies the probable occurrence of non-agricultural landcovers in the reference parcel.

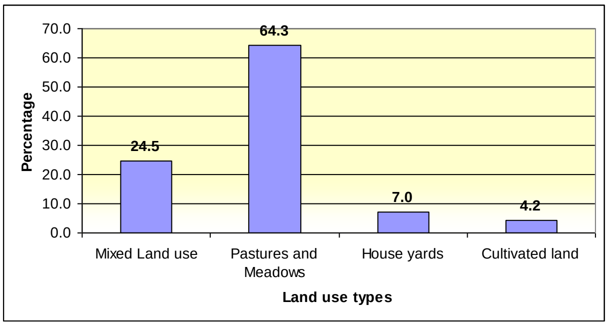

Figure 10. Distribution of the reference parcels, flagged as potentially incorrect, according to the type of land use recorded in the LPIS

8. CONCURRENT TESTING

In addition to the object oriented analysis of RapidEye imagery, an alternative method using Self-Organizing Maps (SOMs) [6] for the detection of GAC features is being explored.

SOMs are unsupervised artificial neural networks that use a self-organizing learning algorithm inspired from the neural maps on the cerebral cortex, to produce topology preserving mappings of data spaces [6]. SOMs provide an adaptive vector quantization of the data samples to approximate the unknown density distribution of the data. In addition, SOMs simultaneously distribute the quantization prototypes on a rigid lattice by preserving neighborhood relations in the data space so that high-dimensional data spaces can be visualized in lower dimensions (preferably 2D or 3D). SOMs provide detailed information which can be used for cluster extraction and knowledge discovery from large data sets using interactive or automated methods [7, 8].

For GAC detection and extraction from the imagery, a SOM was obtained by using 20-band image and Matlab SOMtoolbox[10] and was clustered by using a hierarchical agglomerative clustering based on density based similarities, proposed in [8]. As a result, a cluster map, focusing on the land cover types of permanent bare areas, water, forest and vegetated areas, was extracted. The cluster maps obtained by SOM and by object oriented analysis are shown in Figure 11. Despite some minor details such as incorrect labelling of small fields by object-oriented approach due to its use of spatial averages, and inability of pixel based SOM to detect inland grass which requires spatial information, these cluster maps have a high degree of similarity. The main advantage of the SOM based clustering is that it is a faster, semi-automated method which requires much less user interaction than the object-oriented segmentation.

[10] http://www.cis.hut.fi/somtoolbox/

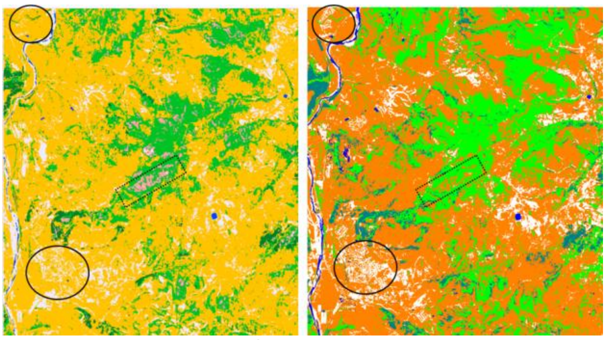

Figure 11. Comparison of cluster maps extracted using object oriented analysis (left) and self-organizing maps (right) for GAC detection. Some urban areas within the ellipses, extracted correctly by SOM (shown as white on the right), are incorrectly captured as GAC (orange on the left). Inland grass, pink regions within the rectangle on the left, cannot be extracted by the SOM (orange on the right) due to the SOM's pixel based approach.

9. FUTURE PROJECT DEVELOPMENTS

The first results obtained over the test area of KARD, even though very encouraging, are not yet sufficient to pass a clear verdict on the expected performance on the methodology and developed tools in operational mode (i.e. entire country coverage). The ongoing work on PLOV and VARN is expected to give more evidence on the robustness and reliability of the methodology proposed. Resources could still be allocated for better classification of the small features inside urban areas. However, these zones are excluded for declaration in the LPIS by default (Group 3), and are not of primary interest for the current study. In addition, a more comprehensive validation of the thematic accuracy of the produced land cover datasets need to be performed based on more representative ground truth data, for example, using results from annual on-the-spot checks carried out by the National Administration on selected agriculture parcels from the test zones.

Another important task foreseen is the cost-benefit analysis, which needs to evaluate the feasibility of the set up and deployment of a semi-automated system for annual GAC assessment and support of the LPIS update in Bulgaria. The cost of the equipment, imagery and resources needed, also requires assessment.

Currently, the methodology has been based on a substantial amount of RapidEye time series (up to 5 acquisitions over a 6-month period). However, capturing entire country coverage of Bulgaria, five times in the active agriculture season will be a challenging task for the image provider. Therefore, the minimum number of image acquisitions and optimal acquisition dates, while maintaining a robust methodology needs to be defined in agreement with the National Administration and the image provider.

10. CONCLUSIONS

The intermediate results clearly indicate that multi-temporal remote sensing data can contribute effectively to the differentiation between currently active and potential agriculture land, and land which cannot be considered suitable for agriculture in the context of SAPS.

RapidEye imagery (in terms of information content) seems to be particularly suitable for feature detection and land cover mapping of agricultural landscapes. As the spatial resolution does not correspond to 1:10 000 scale, the imagery cannot be used directly for LPIS update; however it can provide essential information on the overall currency of the LPIS in relatively short timeframe, provided that the acquisition approach is adapted to the user expectations.

The paper showed the current developments of the methodology for annual inventory and monitoring of 'eligible' land under SAPS in Bulgaria, using RapidEye imagery. A legal definition of "Good Agriculture Condition" has been proposed as a starting point for the technical elaboration of the project. An object-oriented classification of the multi-temporal RapidEye data was performed in order to quantify the agriculture area being in GAC on annual basis. In addition, the quality of the LPIS in respect to the correctness of the eligible area recorded has been assessed, by estimating the ratio of non-GAC feature inside the reference parcels, available for farmer declarations.

The proposed methodology may also help Bulgaria (and Romania) to revise and improve their concept in respect to the eligibility conditions currently applied under SAPS.

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AUTOMATIC DETECTION OF HEDGES AND ORCHARDS USING VERY HIGH SPATIAL RESOLUTION IMAGERY

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KEY WORDS: Object recognition, texture analysis, shape analysis, image classification

ABSTRACT

Automatic mapping and monitoring of agricultural landscapes using remotely sensed imagery has been an important research problem. This paper describes our work on developing automatic methods for the detection of target landscape features in very high spatial resolution images. The target objects of interest consist of hedges that are linear strips of woody vegetation and orchards that are composed of regular plantation of individual trees. We employ spectral, textural, and shape information in a multi-scale framework for automatic detection of these objects. Extensive experiments show that the proposed algorithms provide good localization of the target objects in a wide range of landscapes with very different characteristics.

1. INTRODUCTION

Several EU Member States have defined various regulations for the planning, control, maintenance, and monitoring of agricultural sites as part of the EU Common Agricultural Policy. Remote sensing has long been acknowledged as an important tool for the classification of land cover and land use, and provides potentially effective and efficient solutions for the implementation of such regulations. Consequently, development of automatic and robust classification methods has become an important research problem when the analysis goes beyond local sites to cover a wide range of landscapes in national and even international levels.

We have been developing pattern recognition techniques for automatic detection of target landscape features in very high spatial resolution (VHR) images. Classification of land cover has traditionally been performed using pixel-based spectral information given as input to statistical classifiers. However, detection of specific objects is not necessarily accurate when the goal is to classify the whole land cover. Furthermore, it may not be possible to discriminate between certain terrain classes using only spectral information in VHR images with limited spectral resolution. Therefore, it is of great interest to find new methods that incorporate new types of information peculiar to such images.

This paper focuses on the detection of *hedges* that are linear strips of woody vegetation and *orchards* that are composed of regular plantation of individual trees. Hedge detection exploits the spectral, textural, and shape properties of objects using hierarchical feature extraction and decision making steps. Spectral and textural information are used to select groups of pixels that belong to woody vegetation. Shape information is used to separate the target objects from other tree groups and quantify the linearity of these objects. Extensive experiments using QuickBird imagery from three EU Member States show that the proposed algorithms provide good localization of the target objects in a wide range of landscapes with very different characteristics.

Orchard detection uses a structural texture model that is based on the idea that textures are made up of primitives appearing in a near-regular repetitive arrangement. The texture model for the orchards involves individual trees that can appear at different sizes with spatial patterns at gradually changing orientations. The former is related to the granularity of the texture primitives, and the latter corresponds to the structural properties of the texture. The method uses an unsupervised signal analysis framework that can localize regular textured areas along with estimates of granularity and orientations of the texture primitives in complex scenes. Experiments using Ikonos and QuickBird imagery of hazelnut orchards in Northern Turkey show good localization results even when no sharp boundaries exist in the image data.

The rest of this paper is organized as follows. Section 2 describes the approach for hedge detection. Section 3 provides an overview of orchard detection. Section 4 concludes the paper. Full description of the proposed methodology, detailed discussion of related work, and detailed performance evaluation can be found in (Aksoy et al., 2010, Yalniz and Aksoy, 2010, Yalniz et al., 2010).

2. HEDGE DETECTION

The framework that we developed for hedge detection exploits spectral, textural, and object shape information using hierarchical feature extraction and decision making steps. First, pixel-based spectral and multi-scale textural features are extracted from the input panchromatic and multispectral data. Then, discriminant functions trained on combinations of these features are used to obtain the candidate objects (woody vegetation). Finally, a shape analysis step identifies the linear structures within the candidate areas and separates the target objects of interest from other tree groups. The parts of the candidate objects that satisfy the width and length criteria are labeled as detected targets (hedges). These steps are summarized below. Experiments are also presented using QuickBird imagery from three European sites with different characteristics. More details can be found in (Aksoy et al., 2010).

2.1. STUDY SITES

Panchromatic and pan-sharpened QuickBird-2 sensor data with 60 cm spatial resolution were employed in this study. The data used were from three EU member states with a hedge conservation standard: Baden-Württemberg, Germany; Decin, Czech Republic; and Paphos, Cyprus. These sites were chosen to collect a diverse sample of hedges with different characteristics. The Baden-Württemberg site is a rolling agricultural landscape typical of large parts of the temperate EU, with large clumps of variably sized agricultural parcels intersticed with medium and large forest patches. Hedges are nearly exclusively parcel separations. Pasture dominated Decin site hedges are much larger on average and riparian vegetation is more frequent. Paphos site represents a rather extreme situation of thin hedges in a very fragmented

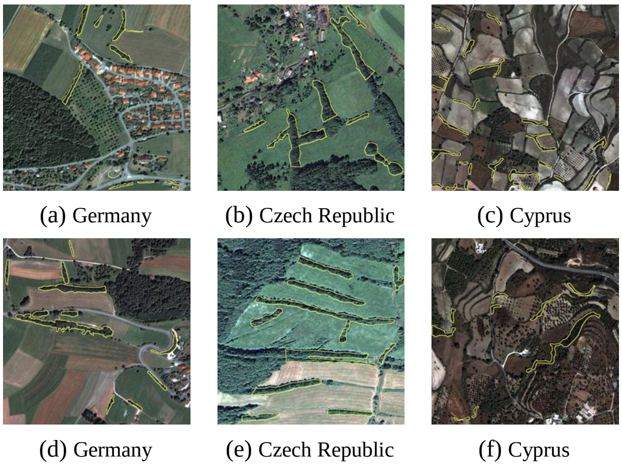


Figure 1: Example QuickBird images (pan-sharpened visible bands) containing hedges marked with a yellow boundary by an expert. Raster images in this paper are 1000×1000 pixels in size corresponding to 600 × 600 m.

environment containing many other small linear features. Performance evaluation was done using a total of 33 subscenes with 11 subscenes of size 1000 × 1000 pixels cut from each site. Examples are shown in Figure 1.

2.2. PRE-PROCESSING

The first step of the analysis consisted of low-level image processing tasks where pixel-based spectral and multi-scale textural features were extracted from the input panchromatic and multispectral data. The normalized difference vegetation index (NDVI) was computed from the pan-sharpened multispectral data to separate green vegetation from the rest of the land cover. Texture features were used for identifying areas that have similar spectral responses but different spatial structures. In particular, Gabor features and granulometry features were used to model the arrangements of individual trees and the appearance of linear structures with respect to their surroundings. Gabor features were extracted by applying a bank of scale and orientation selective filters to the panchromatic band. Six scales were designed to include both the fine texture of individual trees within a hedge and the coarse texture of hedges among agricultural fields. Granulometry features were extracted using morphological opening and closing of the panchromatic image with a family of structuring elements with increasing sizes. These features were used to summarize the size distribution of image structures brighter or darker than their neighborhood.

2.3. IDENTIFICATION OF CANDIDATE OBJECTS

The next step was to find the image areas that gave high responses to the extracted features so that they could be considered as candidate objects. We used a two-step decision process. First, a threshold on NDVI was used to separate green vegetation from the rest of the land cover. The threshold was selected so that there was no omission of any hedge structure. However, we observed that such thresholding could not distinguish hedges from other types of vegetation and kept many fields, large groups of trees and other vegetated areas in the output. On the other hand, the thresholding eliminated some linear human-made structures that gave high responses to the texture features.

Given the obtained vegetation mask, the next step was to identify candidate objects according to their texture characteristics.

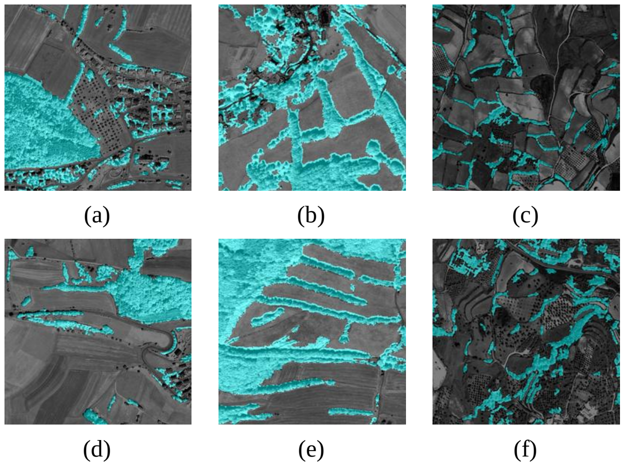


Figure 2: Example results for woody vs. non-woody vegetation classification. The image areas identified as woody vegetation are marked as green on the panchromatic image. Note that woody vegetation can have very different appearances in different sites.

Pixel-based texture modeling was not sufficient for detecting the linearity of a structure but was capable of modeling its woodiness. Hence, we concentrated on the separation of woody vegetation from the rest of the areas in the vegetation mask. Manual labeling of image areas as woody vs. non-woody vegetation was used to generate the ground truth for training and evaluation. Different combinations of features and different classifiers were studied. The Gaussian maximum likelihood classifier was found to perform as good as any other classifier with an overall classification accuracy of 94.83%, and was used in the rest of the analysis.

After the discriminant function identified the pixels that could belong to targets of interest (woody vegetation), connected sets of these pixels were grouped to obtain the candidate objects. Example results are shown in Figure 2.

2.4. DETECTION OF TARGET OBJECTS

After the candidate objects were found, object shape information was used so that the objects could be labeled as target or are rejected. An important observation was that the results of the pixel grouping in the previous step were not directly suitable for computing object level features. The reasons were twofold: hedges were often connected to other larger groups of trees, and they often followed natural boundaries where they did not necessarily exhibit a perfectly straight structure. Hence, an important step was the separation of hedges from other tree groups and piecewise linearization of the object regions where linearity was defined as piecewise elongation along the major axis while having an approximately constant width, not necessarily in the strict sense of a perfectly straight line.

The object-based feature extraction process used morphological top-hat filtering to locate the woody vegetation areas that fell within the width limits of an acceptable hedge and skeletonization and an iterative least-squares fitting procedure to quantify the linearity of the objects. Given two thresholds that specified the maximum and minimum acceptable width of a hedge, the morphological filtering step eliminated the structures that were too wide or too narrow. This also decreased the computation time by excluding the structures that were not within the shape limits of an acceptable hedge from further processing. However, it did not guarantee that the remaining structures were linear.
The next step used skeletonization as a structural representation of the object shapes, and an iterative least-squares fitting based

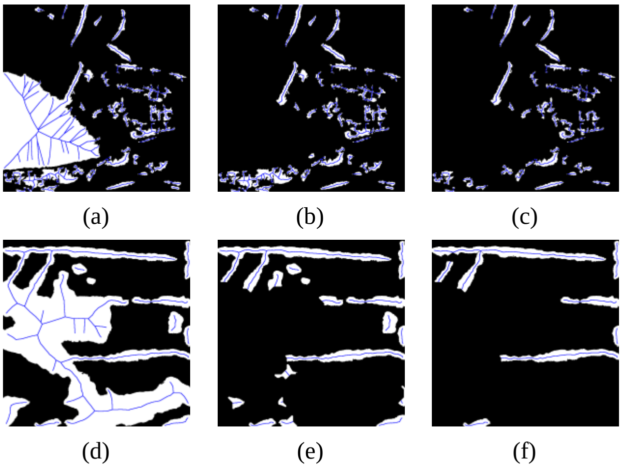


Figure 3: Example results for object-based feature extraction. The first column shows initial skeletons overlayed on the woody classification maps. The second column shows the parts that remained after morphological top-hat filtering. The third column shows the objects corresponding to the final set of segments selected as linear using the least-squares fitting procedure.

segment selection procedure was employed to extract the parts of this representation that might correspond to a hedge. First, the skeleton of the binary classification map of candidate objects was computed as an approximation of the symmetry axis of the objects. The output of this step was the set of points on the skeleton, and, for each point an estimate of the radius (width) of the shape around that point. We assumed that the linearity of a segment could be modelled by the uniformity of the radii along the skeleton points that corresponded to the uniformity of the width perpendicular to the symmetry axis. This assumption was implemented using an iterative least-squares procedure for selecting the group of pixels having uniform radii. The measure of how well a set of points were uniform in radii was computed using the least-squares error criterion, and the subsegments passing this criterion were kept as candidates for the final decision. This idea is similar to a least-squares procedure of fitting a line to pixel locations along a uniform slope, but the main difference is that the fitting is done to the radii values instead of the position values because the hedges that follow natural paths do not necessarily exhibit straight structures in terms of positions along a fixed slope but can be discriminated according to the uniformity of their width along a symmetry axis. Examples are shown in Figure 3.
The final set of shape features consisted of the aspect (length/width) ratio for each resulting object. The length was calculated as the number of points on the skeleton of the corresponding subsegment, and the width was calculated as the average diameter for the points on the skeleton of the subsegment. The final decision for accepting a segment as a target object was done using a threshold on aspect ratio.

2.5. PERFORMANCE EVALUATION

Manual photo-interpretation was used to produce the reference data. Object-based performance evaluation was done in terms of the overlaps between the skeletons of the reference objects and the detected objects. The objects whose skeletons had an overlap of at least 60% were considered as matches. Object-based precision (the number of true positives divided by the total number of objects labeled as hedges by the algorithm) and recall (the number of true positives divided by the total number of objects labeled as hedges by the expert) were used as the quantitative performance criteria. Overall precision was 35.23% and recall was

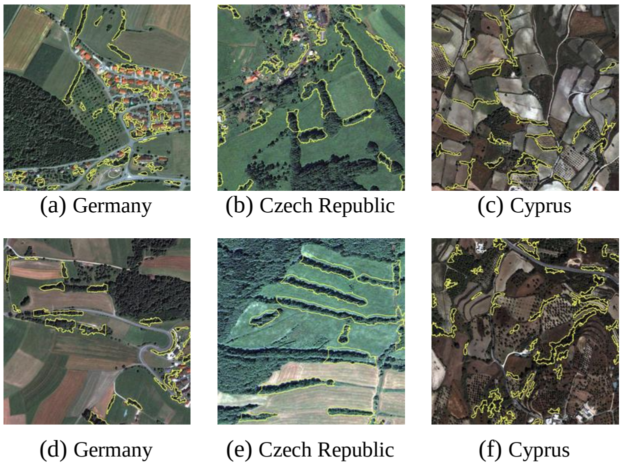


Figure 4: Example results for hedge detection. The objects detected as hedges are marked with a yellow boundary.

58.69%. Example results are shown in Figure 4. Visual interpretation showed that the performance was actually better than the quantitative results due to limitations in the reference data. False negatives were mainly caused by the errors during the identification of candidate objects. False positives were mainly caused by groups of individual but nearby trees in orchards, groups of trees in residential areas, and linear vegetation that did not look woody enough and was not included in the reference data.

3. ORCHARD DETECTION

Our framework for orchard detection is based on texture analysis of panchromatic data. The approach starts with a pre-processing step involving multi-granularity isotropic filters for enhancing tree-like objects in the image. The local maxima in the filter responses are assumed to correspond to potential tree locations, and the regularity of these locations along a scan line with a particular orientation in the image is measured using periodicity analysis of projection profiles within oriented sliding windows. The periodicity analysis is performed at multiple orientations and granularities to compute regularity score at each pixel. Finally, a regularity index is computed for each pixel as the maximum regularity score and the principal orientation and granularity for which this score is maximized. The image areas that contain an orchard composed of regular arrangements of trees can be localized by thresholding this regularity index. These steps are summarized below. Experiments are also presented using Ikonos and Quick-Bird imagery of a site in Turkey containing hazelnut orchards. More details can be found in (Yalniz and Aksoy, 2010, Yalniz et al., 2010).

3.1. STUDY SITES

Panchromatic Ikonos and QuickBird-2 sensor data were employed in this study. The area experimented corresponded to the Merkez county in the province of Giresun in the Black Sea region of Turkey. A specific property of the region is the strong relief, which makes hazelnut production the main cultivation there. In addition, the hazelnut orchards in the region are often small and have a high planting density relative to orchards in other countries. Performance evaluation was done using a total of 15 subscenes with five subscenes of size 1000 × 1000 pixels cut from each of one Ikonos and two QuickBird images. Seven images, each with size 1680 × 1031 pixels that were saved from Google Earth over Izmir, Turkey were also used in the experiments. Examples are shown in Figure 5.


(a) Giresun — QuickBird


(b) Giresun — QuickBird


(c) Izmir — Google Earth


(d) Izmir — Google Earth

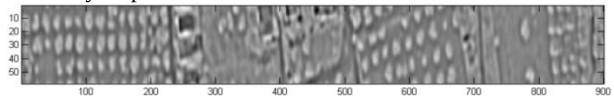
Figure 5: Example images containing orchards. Color data are shown but only the panchromatic information was used in the study.

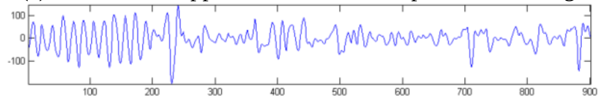
3.2. PRE-PROCESSING

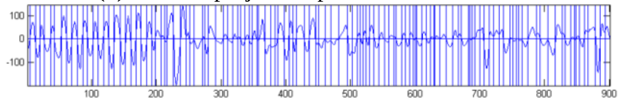
The tree model was assumed to correspond to a filter for which the image areas with a high response were more likely to contain trees than areas with a low response without any strict requirement for exact detections. We used the Laplacian of Gaussian filter as a spot filter for a generic tree model sensitive to contrast differences in any orientation. The isotropic spot filter had a single scale parameter corresponding to the Gaussian function, and this parameter could be selected according to the sizes (granularities) of the trees of interest. Note that any other filter could also be used because the following step will use the filter responses that enhance the tree-like objects in the image.

3.3. REGULARITY DETECTION

After the tree-like objects were enhanced in an image, the pixels having high responses (local maxima) on a scan line along the image indicated possible locations of such objects. In a neighborhood with a regular repetitive structure, the locations of local maxima along the scan line with an orientation that matched the dominant direction of this structure also had a regular repetitive pattern. The next step involved converting the image data into1D signals using projection profiles at particular orientations, and quantifying the regularity of the trees along these orientations in terms of periodicity analysis of these profiles.
Given a scan line representing a particular orientation, the vertical projection profile was computed as the summation of the values in individual columns (in perpendicular direction to the scan line) of an oriented image window constructed symmetrically on both sides of this scan line. This profile would contain successive peaks with similar shapes if the orientation of the scan line matched the orientation of the texture pattern. The regularity of the texture along a particular orientation was assumed to be represented in the periodicity of the corresponding projection profile. Since it might not always be possible to find a perfect period, especially for natural textures, we designed an algorithm that measured the amount of periodicity and located the periodic part within the larger profile signal. This was achieved using three constraints. The first constraint used the peaks and valleys of the profile signal where the peaks were assumed to correspond to the trees and the valleys represented the distance between consecutive trees.


(a) A window cropped from the filter response of an image


(b) Vertical projection profile of the window


(c) Segmentation of the projection profile into its peaks and valleys

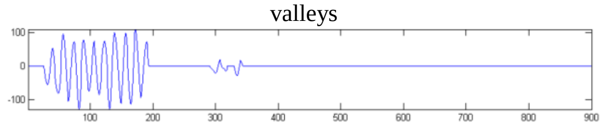
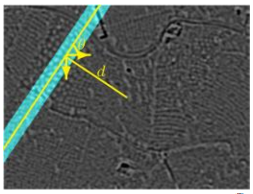

(d) Periodic intervals located in the profile signal

Figure 6: Periodicity analysis of the projection profile of an image window.


(a) d = −120, θ = −55°, δ = 30

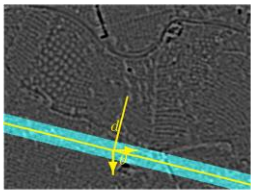
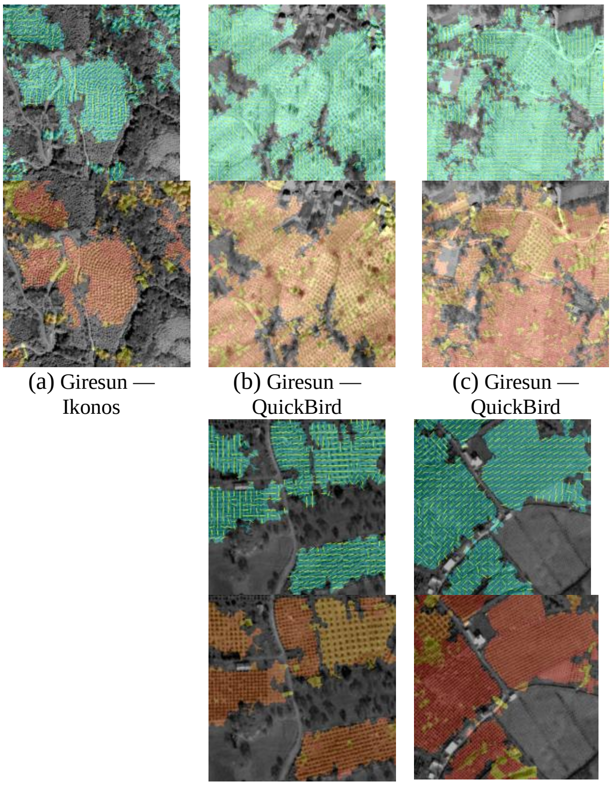

(b) d = 90, θ = 15°, δ = 30

Figure 7: Example windows for computing the projection profiles. Each window is marked as green together with the scan line that passes through its symmetry axis that is marked as yellow.

A regularity score between 0 and 1 was computed for each pixel using signal analysis so that pixels with a score close to 1 were candidates to be part of a regular periodic signal. The second constraint selected the parts of the signal where there were alternating peaks and valleys corresponding to a regular planting pattern of trees and the spacing between the trees. Finally, the third constraint checked the width of each peak and eliminated the ones that were too narrow or too wide with respect to the sizes of the trees of interest. Figure 6 shows an example for periodicity analysis.

3.4. MULTI-ORIENTATION AND MULTI-GRANULALITY ANALYSIS

An image may contain periodic textures at multiple orientations composed of multiple granularities of texture primitives. Therefore, different granularities were approximated using different spot filters, and the projection profiles for different orientations were analyzed by sliding image-wide oriented windows over each spot filter output. Example windows are shown in Figure 7. The windows were parametrized by a distance parameter d, an orientation parameter θ , and a height parameter δ with respect to the center pixel of the image as the origin. The resulting regularity scores for all orientations and all granularities for all pixels were stored in a four dimensional matrix denoted as $\rho(r,c,\theta,g)$ where (r,c) were the pixel locations, $\theta\epsilon[-90°,90°]$ were the orientations, and g represented the granularities.



(a) Giresun — Ikonos (b) Giresun — QuickBird (c) Giresun — QuickBird (d) Izmir — Google Earth e) Izmir — Google Earth

Figure 8: Example results for orchard detection. The areas detected by thresholding the regularity index are marked as green on the panchromatic image, along with orientation estimates marked as yellow line segments (top row) and scale estimates marked using shades of red and yellow (bottom row).

3.5. TEXTURE SEGMENTATION

The goal of the last step was to compute a regularity index for each pixel to quantify the structure of the texture in the neighborhood of that pixel along with estimates of the orientation of the regularity as well as its granularity. For robustness, it was expected that the regularity values were consistent among neighboring pixels for a certain range of orientations and granularities. The noisy cases were suppressed by convolving $\rho(r,c;\theta,g)$ with a four dimensional Gaussian filter with size 11 × 11 × 11 × 3. A final regularity index was defined as the maximum regularity score at each pixel and the principal orientation and granularity for which this score was maximized. Texture segmentation was performed by thresholding this regularity index.

3.6. PERFORMANCE EVALUATION

The performance of orchard detection was also evaluated using reference data produced using manual photo-interpretation. Pixel-based precision and recall were used as the quantitative performance criteria. Overall precision for Giresun data was obtained as 47.07% and recall was obtained as 78.11%. When the performances on Ikonos data and QuickBird data were compared, higher accuracy was observed for the QuickBird data due to the increased spatial resolution. We also observed that the time of the image capture affected the results as higher accuracy was obtained when the individual trees were more apparent in the panchromatic image. Overall precision for the Izmir data taken from Google Earth was obtained as 85.46% and recall was obtained as 88.35%. The lower accuracy for the Giresun data was mainly due to the irregularities in the planting patterns, mixed appearances of other trees within the orchards, and the deformations in the visual appearance of the patterns due to the strong relief in the region. Example results for local details of orchard detection along with orientation and granularity estimates are shown in Figure 8. Most of the false positives were observed along roads where there was a repetitive contrast difference on both sides and around some building groups where a similar regular contrast difference was observed due to neighboring edges. False negatives mostly occurred at small vegetation patches that were marked in the reference data due to a few rows of regularly planted trees but were not large enough for the algorithm.

4. CONCLUSIONS

We presented new methods for automatic detection of hedges that are defined as linear strips of woody vegetation and orchards that are composed of regular plantation of individual trees as target objects in VHR images. The approach for hedge detection exploited the spectral, textural, and shape properties of objects using hierarchical feature extraction and decision making steps. Orchard detection used a structural texture model that was based on the idea that textures were made up of primitives (trees) appearing in a near-regular repetitive arrangement (plantation patterns). An important design goal was to minimize the amount of supervision needed so that the methods could be applied on a wide range of landscapes with very different characteristics. Experiments using Ikonos and QuickBird imagery showed good detection and localization results on a diverse set of test sites.

5. ACKNOWLEDGMENT

This work was supported in part by the European Commission Joint Research Centre contracts 252972 and 253352.

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CONTROLLING THE NEW GAEC FRAMEWORK RESULTING FROM THE HEALTH CHECK

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KEY WORDS: Health Check, GAEC, cross compliance, controls

ABSTRACT
The paper presents the main changes brought by the Health Check of the Common Agricultural Policy in relation to the good agricultural and environmental condition (GAEC) standards. The EU framework for the GAEC has been modified at this occasion in two ways. The status of the standards has been clarified in the new framework by distinguishing the standards which have to be implemented by Member States on a compulsory basis and those which are implemented on an optional basis. A number of GAEC standards have also been specified or added to the framework. The paper presents some important questions raised by these changes in term of control.

1. CHANGES BROUGHT BT THE HEALTH CHECK

The so-called "Health Check" was an important review of the Common Agricultural Policy (CAP) undertook in 2008. The main purpose of this exercise was to fine-tune the various components of the CAP as resulting from the major 2003 reform, in order to remedy the significant problems appeared at the light of the experience of its implementation by Member States. Cross compliance can be counted among the significant novelties brought by the 2003 reform and was also naturally subject to this review. The Health Check has therefore led to a review and subsequently a modification of the cross compliance system. This is the case for its scope and in particular for its good agricultural and environmental condition (GAEC)[11] component. This paper presents the situation of the GAEC resulting from the Health Check, in particular from the point of view of the control.
The GAEC instrument is a set of standards addressing a number of issues (relating to soil, maintenance of the land cover and now water), defined at EU level by a common framework and which shall be translated by Member States into requirements at farm level taking into accounts the local conditions and challenges. The EU framework is set up through a table attached to the EU relevant Regulation[12]. Pursuant to the EU legislation Member States shall use this framework to define the national requirements for farmers.

Situation before the Health Check:

Three main aspects characterised the situation before the Health Check as regards the GAEC.
Firstly the legal status of the EU standards was disputed with the Commission and Member States. A number of Member States considered that the EU framework was to be taken into account but not necessarily exhaustively followed. In other terms, following that approach not all EU standards would have to be applied at national level and there would be possibilities to apply national requirements not stemming from EU standards. By contrast the Commission was taking the view that the EU framework was binding in its entirety and was exhaustive. In other terms, Member States had according to that approach to implement each and every EU standard, where relevant, and they could not implement a requirement not foreseen in this framework. Clear cases where this implementation was not relevant were for instance the standards on olive groves or wines in northern Member States.
Secondly the implementation of the EU framework was uneven between Member States, certain of them being quite ambitious while others took a less ambitious stance. This was the case for both the number of standards implemented and the degree of requirements for each of them. Not only the level of ambition of each Member State but also the dispute on the legal status were factors leading to this situation.
Thirdly certain Member States implemented standards not foreseen in the EU legal framework, for issues such as water or biodiversity.

Situation after the Health Check

The question of the legal status of the EU GAEC framework was raised during the Health Check discussion at the Council. The Commission continued at this occasion to defend its legal interpretation by which the EU framework is compulsory where relevant and exhaustive. The main argument put forward was that there is a need to have a minimum level-playing field between EU farmers in respect of GAEC requirements and this can only be ensured by implementing a defined and exhaustive set of measures. Most Member States on their side advocated for a flexible tool, with possibilities to implement EU standards on an optional basis. Both side however agreed that the legal dispute should be closed by a clarification of the legislation. The discussion resulted in a modified EU framework distinguishing between EU standards which shall be applied by Member States in any case (compulsory standards) and EU standards which may be applied if the Member State decides so (optional standards). The optional nature of certain EU standards was due to provide Member States with the flexibility to define targeted measures on certain cropping systems (vines, olive groves, terraces, etc) while the compulsory EU standards have a more general nature.

[11] Article 6 of Council Regulation (EC) N°1782/2003 (before the Health Check) and Article 5 of Council Regulation (EC) N°73/2009 (after the Health Check)
[12] Annex IV of Council Regulation (EC) N°1782/2003 (before the Health Check) and Annex III of Council Regulation (EC) N°73/2009 (after the Health Check)

However two caveats were introduced to limit the optional nature of the concerned standards. First where the Member State defined national requirements before the Health Check, there should not be a backward evolution in respect of this standard. Second, the EU standard remains compulsory when national legislation includes provisions addressing this standard. The regulation further specifies that Member States may not define requirements at farm level which are not foreseen in that framework.

The other main modification of the EU GAEC framework after the Health Check concerns the content of this framework. A new issue concerning the protection and management of water has been introduced including two compulsory standards. The first concerns the establishment of buffer strips along water courses. The second concerns the respect of authorisation procedures for the use of water for irrigation. Moreover the issue concerning the minimum level of maintenance and the protection of habitats has been enriched with a specification of the standard dealing with landscape features and with the addition of a new –optional– standard for the establishment and/or the protection of habitats.

2. THE NEW STANDARDS: CONTROL ISSUES

In term of controls, the changes of legal status of the EU GAEC standards should not raise any new problem or challenge. The main impact of this change will be on the obligations for Member States in defining national requirements for farmers. Now that the status of the standards is clear, Member States will have where this is not the case to define the on-farm requirements for the missing standards. This may of course raise some control question but the guidelines from the Commission and the experience of other Member States may help in this respect. The question is different when we consider the new standards since they sometimes touch upon new issues (water) or specification of existing issues (land management). It is useful to assess at an early stage which control questions are raised by these new or modified standards. Indeed Member States should consider very carefully the implications in term of control when they define the national requirements translating the EU standards.

Standard "*Retention of landscape features including, where appropriate, hedges, ponds, ditches, trees in line, in group or isolated and field margins*."

This is a specification of a standard existing before the Health Check and which remained compulsory: the landscape features to consider are listed but the list is not exhaustive. This consideration does not necessarily mean concluding that the feature needs to be retained: the decision must be based on an assessment in relation to the objective of the standard, which is specified through the wording of the issue: to ensure a minimum level of maintenance and avoid the deterioration of habitats. One must also take into account that the rationale for the specification of this standard is the compensation of adverse effects of abolition of the set aside obligation.

In terms of control, this specified standard raises a number of questions. The question of the definition of the feature is essential. The farmer shall indeed know without any ambiguity which feature is to be retained. If this is a hedge, the definition of a hedge must be clear. In this respect it must be noted that Member States have full flexibility to define the various features, however while basing these definitions on standards agreed at international or European level if any. Another aspect which needs to be defined is the notion of retention. This implies potentially various management practices possible and the farmer needs to know precisely which practices should be followed. An aspect to cover in particular is the evolution of the feature in the time: what to do when the shrubs develop as trees in a hedge for instance. Another control aspect is the geographical identification of the features and various possibilities exist, which would be too long to develop here. The question of the control methods is also important: is there a need to measure the feature and if yes how, can remote sensing be used, etc. Finally the question of defining the sanctions matrix should not be underestimated: the way the national requirement is designed should allow an easy translation of infringements into possible reductions of payments.

Standard "*Establishment and/or retention of habitats*."

This is a new a standard resulting from the Health Check. It has an optional character which allows Member States not having such provisions in their national legislation not to implement it if their assessment concludes that there is no need. While the wording is to a large extent open the objective is clearly related to the same issue as for landscape features. Here also the rationale for the introduction of this new optional standard is the compensation of adverse effects of abolition of the set aside obligation.

In terms of control, the questions are very similar to these for the previous standard. There is a need to define unambiguously habitats, establishment and retention. Here also the subject, the habitat, evolves with time and the definition of the requirements needs to address this aspect. The geographical identification of the habitats is also needed for both defining the farmer obligation and allow controls. The possible control methods are of the same nature as for areas and landscape features. And finally the design of on-farm requirement must allow a clear-cut decision on possible reductions in case of infringements.

Standard "*Establishment of buffer strips along water courses*"

This is a new standard resulting from the Health Check and it has a compulsory character. Following the conclusion that protection and management of water in the context of agricultural activity has increasingly become a problem in certain areas the issue of water has been introduced into the scope of the GAEC framework at the occasion of the Health Check. The objectives are more particularly the protection of water against pollution and run-off and the management of the use of water. This new standard clearly relates to the first objective of this new issue. Due to the fact that the same objective of protection of water against pollution is underlying to +the buffer strips established pursuant to the Nitrates Directive[13] an articulation between this Directive and the new GAEC standard has been specified in the EU framework.

In terms of control, Member States must first define the various components of the requirement for farmers. What is a water course is not defined in the EU framework and there is a need to specify this at national level, in relation with the objective of the standard. This definition should also take into account the possibilities of identification of the feature, e.g. its possible characteristics on a map. The notion of buffer strip is also left open in the EU framework and the national authorities must further define it, including its location relative to the water course and possibly the management practices imposed to farmers. The geographical tools are important for the control of this standard and a careful analysis needs to be carried out in this respect. In particular the question of location (e.g. the “point zero”) and the measuring are important. The possible use of remote control can also be assessed. Finally the need for allowing sanction matrices must here also be taken into account as from the stage of definition of the national requirements.

Standard "*Where use of water for irrigation is subject to authorisation, compliance with authorisation procedures*"

This is also a new a standard resulting from the Health Check and which has a compulsory character. This new standard

[13] Directive 91/676/EEC

clearly relates to the second objective of the new issue on water i.e. the management of the use of water. The wording here is somehow less open to further development by national authorities than other standards since there is a clear link with the national procedures for the authorisation of using water for irrigation. It means also that when there are no restrictions for this use in the national law, this standard is irrelevant.

In term of control, the questions are linked to the way the national law foresees the authorisation procedures. When there are geographical components (e.g. if the restriction apply to a geographical zone) the geographical tools are relevant for checking this standard. The controls may also include tools for measuring the water consumption such as water meters. In any case there is a strong logic to fully use the existing control system of the national authorisation procedures (if these are efficient of course) and add, through the GAEC instrument, the calculation of reductions of CAP payments in case of infringement. In this context, the main challenge for the national authorities would be to define reduction matrices to be used under cross compliance.

In general, the definition of national requirements should also take into account very important principle underlying to cross compliance. First the requirements shall take fully into account that cross compliance deals with the individual responsibility of the farmer himself: the infringement is deemed committed only in case this responsibility is involved. Secondly the requirement must concern the farming activity and/or the farm land only (possibly the forest areas also when these areas receive support under rural development). Thirdly these requirements should be clearly understandable and communicated to the farmers. These elements are keys to ensure a successful implementation of the GAEC standards by farmers and allow controls, included for the new standards originating in the Health Check.

3. REFERENCES AND SELECTED BIBLIOGRAPHY

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Conference Programme

Agenda Day 1 (18 November 2009)

11.00-13.00	Registration
13.00-14.00	Buffet Lunch
Plenary 1 (chair: Giancarlo Nanni, AGEA, IT / Co-chair: Paolo Pizziol, JRC)	
14.00-14.15	Opening Session - Conference Program (Franco Contarin, AGEA, IT)
14.15-14.35	**PA-1**: JRC/IPSC and agriculture challenge (Simon Kay, JRC)
14.35-15.05	**PA-2**: CAP and its perspectives (Prosper De Winne, DG AGRI)
15.05-15.35	**PA-3**: Future challenges of agriculture (Peter Nowicki, LEI – NL)
15.35-15.55	Coffee Break
15.55-16.25	**PA-4**: GAEC controls by satellite imagery: the Italian study (Livio Rossi, Paolo Tosi, AGEA-SIN, IT)
16.25-16.55	**PA-5**: The Italian GIS refresh (Maurizio Piomponi, Pierpaolo Guerra, AGEA-SIN, IT)
16.55-17.15	**PA-6**: The EGNOS system status (Michael Mastier, DG TREN G4)
17.15-18.15	**Session restricted to MS Administrations** on LPIS quality assurance 2010 **Discussion paper** (11164): LPIS quality inspection: EU requirements and methodology Chair: Prosper De Winne, DG AGRI
19.15 - ***	Welcome Cocktail

Agenda Day 2 (19 November 2009)

	Parallel session 1 (with translation) **LPIS Quality Assurance and geodatabases features** Chair: Ahti Bleive, ARIB, EE / co-chair: Wim Devos, JRC	Parallel session 2 **New Sensors, new software, and their use within the CAP** Chair: Bruno Biagini, eGEOS, IT / co-chair: Joanna Nowak, JRC
09.00-09.10	**P1-1**: Findings of the 2009 LPIS workshop in Tallinn (Wim Devos, JRC)	**P2-1**: THEOS available for European Users (Damrongrit Niammuad, GISTDA, TH)
09.10-09.30	**P1-2**: LPIS upgrade in Denmark (Hendrik Friis, DK)	
09.30-10.00	**P1-3**: Quality improvements in the Hungarian LPIS: control of non declared areas and retroactive procedures (Gabor Csornai, FOMI, HU)	**P2-2**: Ortho rectification, fusion and CAPI of GEOEYE-1 and KOMPSAT-2 sensors for the CwRS program (Pedro Miguelsanz Muñoz ,Tragsatec, SP)
10.00-10.30	Coffee break	
10.30-11.00	**P1-4**: LPIS Portugal - Quality assurance strategy (Odete Serra, IFAP, PT)	**P2-3**: UK-DMC 2 and Deimos-1, New DMC Sensors for Agricultural Monitoring (Owen Hawkins, DMC2, UK)
11.00-11.30	**P1-5**: Integrating external registers within LPIS (Alenka Rotter, MoA, SI)	**P2-4**: The Next Generation System WorldView-2 for CwRS: Transferring 7 years of local tasking success from IKONOS to WorldView-2 (George Ellis (European Space Imaging) and Maher Khoury (DigitalGlobe)
11.30-12.00	**P1-6**: New LPIS data and their quality control in Macedonia (Pavel Trojacek, Ekotoxa, CZ)	**P2-5**: Evaluating the RapidEye, GeoEye-1, Cartosat-2 and KOMPSAT-2 Imagery For Use In the CwRS (Joanna Nowak, JRC)
12.00-14.00	Buffet Lunch Poster Session (Piotr Wojda, JRC)	

	Parallel session 3 (with translation) **GAEC: control methods and implementing measures** Chair: Al Grogan, Department of Agriculture, IE / co-chair: Vincenzo Angileri, JRC	Parallel session 4 **New Sensors, new software, and their use within the CAP** Chair: Gàbor Csornai, FÖMI, HU / co-chair: Pavel Milenov, JRC
14.00-14.30	**P3-1**: The new GAEC framework after the Health Check (Aymeric Berling, DG AGRI)	**P4-1**: GIS-oriented control point measurement (Lars Edgardh, Spacemetric, SE)
14.30-15.00	**P3-2**: Dublin workshop (Vincenzo Angileri, JRC)	**P4-2**: "ORFEO Toolbox: open source information extraction tools for high resolution remote sensing images (Cyrille Valladeau, Eric Guzzonato, CS, FR)
15.00-15.30	**P3-3**: Management of Landscape features in the frame of GAEC (Philippe Loudjani, JRC)	**P4-3**: New SAR processing capabilities: COSMO-SkyMed high resolution data applied to agro-environment analysis and monitoring (Filippo Britti, AGEA-SIN, IT) part 1 and part 2
15.30-16.00	Coffee break SINERGISE	
16.00-16.30	**P3-4**: Best practices for buffer zone implementation at watershed scale (Jean-Joël Gril, CEMAGREF, FR) **Call for an European network concerning buffer zones for water protection** The non point source pollution team from the Cemagref in Lyon (France) intends to organize a network gathering European scientists, engineers and technicians having a field experience concerning buffer zones for water protection. We would like to take advantage of these GeoCAP proceedings to call for names of persons with field engineers and technicians' profiles coming from European countries, and who may be interested by this proposal. If you are or know such persons, **please contact**: Jean-Joel Gril Cemagref, Freshwater Pollution Unit, Lyon Centre 3 bis quai Chauveau F-69336 Lyon cedex 09 jean-joel.gril@cemagref.fr	**P4-4**: Overview of Rapid Eye data processing and use within CwRS campaign in the Czech Republic (Katerina Jupova, GISAT, CZ)
16.30-17.00	**P3-5**: Automatic Detection of Hedges and Orchards Using Very High Spatial Resolution Imagery (Selim Aksoy, Bilkent, TK)	**P4-5**: Assessment the potential use of RapidEye for annual evaluation of the land eligible for payment (Brooke Tapsall, Pavel Milenov, JRC)
17.00-17.30	**P3-6**: Sustainable criteria within biofuel directive (Simon Kay, JRC)	**P4-6**: 3D data extraction techniques and validation methods, prior to the integration in the LPIS (Fabio Slaviero, Abaco, IT)
		P4-7: Updates on Leica - Airborne Digital Sensors: ADS80 and ALS60 (Arthur Rohrbach, Leica)
17.30-19.00	Exhibition and Demo Sessions	

20.00-***	Gala Dinner (Speech J. Delincé and G. Nanni)

Agenda Day 3 (20 November 2009)

Plenary 2: Campaigns 2009 and 2010 Chair: Philippe Loudjani, JRC	
09.00-10:30	**PB-1**: Review campaign 2009 (Mihaela Fotin, JRC) **PB-2**: Statistics 2009, Outline Campaign 2010 (Hervé Kerdiles, JRC) **PB-3**: GPS tests (Krasimira Galabova, JRC) **PB-4**: LPIS quality assessment in 2010 (Wim Devos, JRC) **Discussion paper** (11164): LPIS quality inspection: EU requirements and methodology
10.30-11.00	Coffee Break
Plenary 2: Concluding session Chair: Simon Kay, JRC	
11.00-12.00	Reporting on parallel sessions (4 chairmen of parallel sessions)
12.00-12.30	Reporting of selection committee + awards (Jacques Delincé, JRC-IPTS)
12.30-12.45	Concluding remarks (AGEA-JRC)
12.45-14.00	Buffet lunch
14.00-16.00	Social event: Visit to the Taormina Ancient Theatre

List of Posters and Poster Presenters

	Title	Name
1	LPIS tp manage GM/conventional maize coexistence in Lombardy	**Paolo Pizziol (JRC)**
2	Implementation of a land registry system showing erosion risk on LPIS	**Alfred Hoffmann (LAL, DE)**
3	Convergence of SIGPAC and Cadastre	**Marcos De Antón Molina (TRAGSA, SP)**
4	The IACS system simplification - the CAP reforms	**Lucie SAVELKOVA (SZIF, SP)**
5	Design and functioning of the IACS and LPIS in Turkey	**Ismail Hakan ERDEN**
6	Review of CwRS Campaign 2009 in Slovenia	**Katja Oven & Aleksandra Žigo (SL)**
7	Review of area based OTS checks in Slovenia	**Dejan Jevsnik (GZ-CE, SL)**
8	How geotracability can improve the transparency of food traceability	**Michel DEBORD (FR)**
9	Evaluating the RapidEye, GeoEye-1, Cartosat-2 and KOMPSAT-2 Imagery For Use In the Common Agricultural Policy Control with Remote Sensing Programme	**Joanna Krystyna Nowak Da Costa (JRC**

All abstracts and presentations may be found on-line at:

http://mars.jrc.it/mars/News-Events/15th-GeoCAP-Conference-GeoCAP/Presentations

European Commission

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Abstract
The 2009 Annual Conference was the 15th organised by GeoCAP action of the Joint Research Centre in ISPRA. It was jointly organised with the Italian Agenzia per le erogazioni in agricoltura (AGEA, coordinating organism of the Italian agricultural paying agencies).
The Conference covered the 2009 Control with Remote sensing campaign activities and ortho-imagery use in all the CAP management and control procedures. There has been a specific focus on the Land Parcel Identification Systems quality assessment process.

The conference was structured over three days – 18th to 20th November. The first day was mainly dedicated to future Common Agriculture Policy perspectives and futures challenges in Agriculture. The second was shared in technical parallel sessions addressing topics like: LPIS Quality Assurance and geodatabases features; new sensors, new software, and their use within the CAP; and Good Agriculture and Environmental Conditions (GAEC) control methods and implementing measures. The last day was dedicated to the review of the 2009 CwRS campaign and the preparation of the 2010 one.

The presentations were made available on line, and this publication represents the best presentations judged worthy of inclusion in a conference proceedings aimed at recording the state of the art of technology and practice of that time.

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