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Front Cover –Pictures related to the EARSeL Workshops in Prague, June 2011

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Contents

The Newsletter is a forum for an exchange of news and views among the members of the Association. The opinions expressed in the Newsletter do not necessarily reflect the views of the editor, the EARSeL Bureau or the other members of the Association.

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Editorial

Dear EARSeL members,

Now, after the summer break, we would like to give you some news about recent EARSeL activities.

In this issue of our newsletter you will find some information about EARSeL's participation in the Semana de Geomática 2011, Bogotá (Colombia).

On 13 September Rainer Reuter (Chairman) and Ioannis Manakos (Secretary General) met with Geoff Sawyer, Secretary General of EARSC, the European Association of Remote Sensing Companies to evaluate fields of mutual interest and initiating closer cooperation between both associations.

You can also enjoy reports related to the workshops of the Special Interest Groups on Land Use/Land Cover, on Coastal Zones and on Operational Remote Sensing in Forest Management which were held in framework of the EARSeL Symposium 2011 in Prague, Czech Republic.

Moreover, we would like to draw your attention to two contributions for the Symposium 2011 Proceedings, published as preprints in this Newsletter: "European Validation of Land Cover Changes in CLC2006 Project" by György Büttner, Gergely Maucha and Barbara Kosztra, and "Combined Use of Satellite Remote Sensing, GIS, and Geophysical Data for Archaeological Research in Europos Area, Macedonia (Northern Greece)" by Dimitrios Oikonomidis, Alexandra Karamitrou , Gregory N. Tsokas and Theodore Astaras.

We are pleased to highlight a first series of publications in EARSeL eProceedings Vol. 10(2), 2011 and we invite you to submit your papers to be considered for publication in our peer-reviewed journal.

Finally, as usual, there is the list of relevant meetings, conferences, symposia and workshops which we recommend you to attend in the near future.

We hope to meet you at future EARSeL events.

Wishes for a productive autumn.

Sincerely,

Editorial Team

News from EARSeL

Participation in the Semana de Geomática 2011, Bogotá (Colombia)

From 8-12 August 2011 the Colombian Space Commission celebrated the Semana de Geomática 2011 in Bogotá, Columbia. Titled *Satellite Information in Service of Territorial Development* the event offered a platform for learning about the national and international progress in development of geomatics technology, methodologies and applications, focussing on planning and management issues, risk management and knowledge management in geospatial technologies.

Internet: http://www.cce.gov.co/web/semana-geomatica-2011/

During the Geomatics Week 2011 a symposium on Remote Sensing and GIS in Education was organised. Luis Joel Martinez, Director at the Agronomy Department of the National University of Colom and co-chairman of the symposium, invited Rainer Reuter (EARSeL Chairman) to present EARSeL's educational activities by means of a video conference.

Following a short overview about the general activities of EARSeL, Reuter reported on the *Science Education through Earth Observation for High Schools* (SEOS) project which had been conducted in 2007-09 with funding from the European Union. Following a presentation of the education concept behind the 17 internet-based e-learning tutorials, the participants were invited to have a closer look at some worksheets as part of the *Marine Pollution* tutorial, reporting on various mission scenarios in maritime surveillance of oil spills using modern remote sensing methods.

Although formally completed in 2009, new contributions are continuously added to the SEOS tutorials, thus keeping their contents most actual. Moreover, translations into other languages are underway, such as versions in Turkish, Spanish and Czech.

SEOS on the internet: http://lms.seos-project.eu

Future cooperation with EARSC

On 13 September Rainer Reuter (Chairman) and Ioannis Manakos (Secretary General) met with Geoff Sawyer, Secretary General of EARSC, the **European Association of Remote Sensing Companies**. The intention was to evaluate fields of mutual interest and initiating closer cooperation between both associations.

EARSC coordinates and promotes the activities of its members in the area of geo-information services. Established in 1989, EARSC's objective is to foster an increasing use of Earth Observation, thus improving the profile of its about 70 members from most European countries. Geoff Sawyer, Secretary General of EARSC, has held several management positions in space industry and has been member of EU consultative bodies. He spent three years working for the European Commission where he initiated the GMES Programme.

The discussions aimed at bringing research and industry closer together thus arriving at a more efficient transfer of scientific results towards products which are available on the market. This shall be facilitated by initiating several joint activities in the near future:

- Information shall be provided on activities in EARSC and EARSeL through reports and interviews in EOMag and the EARSeL Newsletter
- The homepages of both associations shall include sites presenting the fields of activity of the partner association, information on partner search for planned projects and reports on ongoing joint projects
- EARSC will participate in the EARSeL Symposium in 2012. This will include a keynote on its activities and a symposium session presenting projects with partners from research and industry. A round-table meeting with Council members will be organised to jointly discuss and prepare a roadmap of future initiatives.

The participants of the meeting are very confident that these suggestions will be highly welcomed by the Boards and members of EARSeL and EARSC, thus opening a way for a very fruitful future cooperation.

EARSC on the internet: http://www.earsc.eu/

EARSeL Workshop Reports

4th Workshop on Land Use/Land Cover

Following successful Workshops in Dubrovnik (2004), and Bonn (2006, 2009) the 4th Workshop of the Special Interest Group on Landuse/Landcover was hosted by the Technical University of Prague on 1-3 June 2011, attached to the annual EARSeL Symposium. The Workshop was attended by about 90 participants originating from over 20 countries. In contrast to the previous events, the 2011 Workshop was organized in five sessions along predefined themes, where invited keynote speakers gave oral talks followed by short oral introductions to the posters presented in each session. All keynote speakers presented current state-of-the-art research and pointed to future directions. They also highlighted still existing limitations and gave provocative thoughts to stimulate discussions afterwards. Participants presented their work in four posters and very intense discussions occurred in front of the posters.

Wrap-up discussions at the end of each half-day sessions were guided by the keynote speakers and fostered intensive exchange of experience, open questions, but also addressed major issues of concern, as well as unsolved problems. Participants very actively engaged in the discussions with quite different views. In particular the representation from science, operational service provider, and administration stimulated the open exchange. The Workshop was closed by a hands-on tutorial on support vector regression and classification. With this Workshop concept, the organizers intended to avoid the always unsatisfying task to select contributions for oral or posters. All submissions were handled equally and the posters receive already in previous events very much attention and often led to more feedback than talks. It was also the intension of the organizers to leave more room for discussion. By adopting such a clear Workshop character a distinguished event was achieved in comparison to other conference style meetings.

The National Technical Library in Prague, venue of the workshop.

In the opening session, two keynote presentations were given by Hans Dufourmont from the European Environmental Agency (EEA). His talks were titled "*Contributions to LULC mapping from the GMES Land Monitoring Service*" and "*Requirements in LULC monitoring in Europe*". They provided a focused elaboration on the GMES Initial Operations (GIO) program from a GMES programmatic point of view and on the requirements, the usage and role that the European Environmental Agency (EEA) takes up for the GIO land activities. The first keynote addressed the overall GMES program, how the user consultations led to the proposed portfolio for the land services, and how the programmatic framework has been elaborated by the GMES bureau, and finally some key examples of expected services. The second keynote addressed the requirements of the EEA in terms of land use and land cover data and information. The requirements have been illustrated by the evolution of usage of land cover data in the EEA, keeping the pace of policy requirements and the technological evolution. Furthermore the overall planning for the technical coordination of the upcoming GIO land services has been highlighted.

The following discussion was very active and controversial. Major issues raised among others were e.g. *Why an EU-wide urban atlas is generated while most cities have much more detailed data at hand?* Hans Defournment (H.D.) responded that a homogeneous database is required. Efforts to get and compile it from different European and administrative sources as well as data formats are a main obstacle. In order to have something put forward he pronounced that it is sometimes easier to do a new product. Martin Herold (Wageningen Univ.) was concerned that the science community is supposed to be a major stakeholder in GMES and how this is handled in practice. H.D. mentioned that access via EU projects, as well as new FP7 projects in e.g. the space call, addressed to this community will enable this. Giles Foody rose the points (a) how much of the GMES budget is actually dedicated to quality check, and (b) if the increased quality demands for the high resolution layers are still in line with the costs. He was responded that it is expected to be a few percent of the budget (e.g. as for the soil sealing layer), and that quality/price issue will be a subject of the tendering process. Pavel Milenov asked if national orthophotos that are anyway acquired would not be a better alternative than space imagery. They are already successfully used. The difficulty for pan-European products are the different acquisitions dates for production, while on the other hand they are very valuable for QA. Another topic addressed the Corine Land Cover (CLC) compatibility with FAO Land Cover Classification System (LCCS). H.D. responded that EEA is directly involved in the discussions with FAO, and with UNSD on the SEEA methodology. A recent meeting between these stakeholders has yielded an agreement on how to best link the various approaches on LC/LU, and it will be possible to make a CLC derivative that fits the future commonly agreed approach.



Finally, H.D. asked the auditorium if there are other methods and techniques out in the science community that might be used for production and potentially reduce costs. There was not a clear response, however, it was highlighted that there exist many techniques. Most science labs do not focus on production over different physiographic regions and large areas. It is also a matter of access to the data used in operational production, e.g. image2006, image2009. The available methods cannot be easily tested or adapted for operational use. This fact strongly limits development and potential cost reduction. A comprehensive inter-comparison exercise for methods on different data sets and rigorous independent accuracy assessment should be targeted.



In a dedicated session on classification and change detection the first keynote was given by Lorenzo Bruzzone (Trento Univ.) on the topic of "*Current and future trends in automatic classification of remote sensing images*". He focused on modern classification techniques and how they can advance the field in land cover. Various classification algorithms and active learning strategies were presented with example case studies for their applications. In a second talk given by Gunter Menz (Bonn University) *techniques and challenges in change detection* were reviewed. He first outlined how change detection research has developed since the launch of the first earth observation platforms from space by a comprehensive literature review. In subsequent part of the presentation, he provided case studies on various change detection approaches, and pinpointed where still difficulties and unsolved problems exist.

Questions addressed in the subsequent discussions covered e.g. the main limitations of current classifiers available in commercial software. The response by Prof. Bruzzone demonstrated that many methods do not take into account the data properties, e.g. when using high resolution or very high resolution data, multi-level object oriented approaches that properly model the semantics of the class would be appropriate. Many techniques have been developed in the research field but transformation into commercial software and hence application is lacking. In general, a large gap between the community that develops techniques and algorithms, and the application community was identified by the Workshop participants.

Other topics of concern were that a very clear legend and goals have to be predefined prior the classification, since often land cover and land use classes are merged. In this discussion also the issue of access to data came up again. Some contributions were in favour of constellations in order to ensure access to data, while others saw a main problem for research in accessibility of existing resources (e.g. Image2006, Image2009). From the responses it seemed to be more important to push for funds in the field of transfer of methodologies, rather than for new missions, in particular with the Sentinels in view. For change detection it was highlighted by J. Hill (Trier Univ.) that meanwhile time series are available to detect changes and that such approaches can provide more robust results also with slighter changes. The community is still very much focused on bi-temporal approaches, and should explore the available archives much more. One participant suggested that a web forum related to the EARSeL interest group should be established. It emerged that the community has some needs to exchange on these topics. Such a platform could certainly be extended to other topics that came up during other discussions of the Workshop.



The morning session on Thursday covered European and global land cover monitoring as well as pre-processing, accuracy and quality issues. In the morning Steffen Kuntz from Astrium Services / Infoterra GmbH gave a first keynote on *European and global land cover monitoring: operational approaches and research demands*. He was followed by Martin Herold (Wageningen Univ.) with his talk on *Global land cover monitoring: where are we now and what is the way ahead?* Following both presentations a lively discussion was initiated. A general feeling among the attending scientists was that while the GMES activities for European land monitoring are making progress on developing and implementing services in cooperation with the EC, Member States and the EEA, GMES seems to be an encapsulated process, not necessarily driven by research and innovation, and science user involvement. As a consequence various issues of concern were addressed in the discussion, which can be summarized in the following:

- Many attendees of the Workshop showed the impression that GMES is still a distant, more political process with a strong engagement by some value adding industry. It seems to be difficult for many scientists to follow the process. Involvement of the science community, and drawing full advantage of European scientific capacities, seemed not to be fully developed. Much more consultation and interaction between production, users, and the available scientific expertise is necessary. Several complaints from the audience expressed that an early stage science involvement in the process was lacking, and now it seems to be showing up in some of the requests for alternative or improved methodologies.
- Some members of the audience also saw that the needs of the scientific community as key user of GMES seem to be not properly considered nor assessed. They also pointed out the need for a well-funded, independent scientific assessment of GMES Land service products.

Geoland2, as FP7 project, advancing methodologies for a GMES land service has some feed-back mechanisms for users, but they also see that GMES was not designed for the scientific community. EARSeL is currently carrying out scientific soundness reviews for some of the approaches used in geoland2, but this does not include any aspects of scientific use of the products nor the testing of alternative approaches. For this, the products and databases would have to be made accessible to the broader scientific community and additional funding would have to be brought up. For instance, today access to Image2000, Image2006,Image2009 and the thematic products is either limited or complex or restricted to FP7 projects only, and thus limits even voluntary participation of scientific partners.

- Another issue covered in the discussion was that Calibration/ Validation (Cal/Val) activities are currently still largely understood as ad-hoc add-ons to products and service development; not as an integral part of an operational monitoring system. The lack of substantial investments into Cal/Val becomes the largest stumbling block to large area land cover Earth Observation progress beyond state of the art.
- In a similar way some aspects of the Sentinel missions were considered critically. They are defined as operational missions, but address important scientific challenges as well. Many science partners and user needs are not involved in GMES activities at this point, and hence have difficulties entering into the system. Thus, the sole focus of specific user/service needs, and service cost constraints creates a steadily growing innovation gap and limits European leadership and innovation in the field, as well as more research-driven approaches.
- In regard to global land monitoring, research needs are in a consistent global and large area time series processing and analysis (for Sentinels), and investigations into synergies between multiple Sentinel satellite observations with consideration of the Land Data Continuity Mission (LDCM). Robust Cal/Val networks need to be established as an integral part of an observing system. Additionally, the historical data archives are still lacking full exploitation, and are expected to contain very valuable information from a global perspective.

Overall, the discussion strongly reflected the statements and discussion outcome from the previous day. There seemed to be an evolving mismatch between the need of industry and administration for scientific involvement and contributions, while at the same time very limited investments are being made into related R&D. Joint efforts should be undertaken to close this discrepancy. The discussion also revealed that more benchmarking of algorithms and products is needed, however, with clear, predefined definitions of products and procedures for evaluation. In this regard, proposals to ESA/EU should be considered or addressed in scientific networks proposals to EC.



In the <u>Thursday afternoon session, focus was laid on data pre-processing and accuracy assessment</u>. Michael Schaepman (Zürich Univ.) opened the session with a talk on "*Advances in quantitative, physically based processing of optical data*". He was followed by Giles Foody (Nottingham Univ.) focusing in his talk on "*Accuracy assessment for LULC products*". He pointed out that remote sensing scientists are perhaps sometimes overcritical with the quality of their products in comparison to other approaches. Also maps are subject to generalization and have errors.

As expected, a very intense discussion developed around the quality issues as almost any project has to struggle with this. The question was posed, if there is any remedy to overcome ground data imperfections. Giles Foody pointed towards his talk, where he outlined possibilities to include (estimated) errors of the ground truth data in the accuracy assessment as there is always a bias in ground truth data. He also recommended to focus on better higher quality data, than many. Michael Schaepman pointed out to start a different view on ground truth as there are cases, where ground truth data are more wrong than the earth observation data. Lorenzo Bruzzone added that different classification algorithms have different sensitivities to ground truth errors and hence the selection of an appropriate method for approach needs to go in hand with the selection of Cal/Val data. It was also mentioned that the product users should be more explicit on their purpose for the product in advance as it might influence the chosen approach. In a similar way, the minimum mapping unit of the product needs to be considered in advance by equivalent areas. When using object-oriented approaches that are strongly associated with spatial patterns, those also need to be reflected by the validation data.

Based on this, Martin Herold asked how we do actually best generate reference data. This is becoming a very important topic for large-scale and global studies. Answers were that no ideal way may exist, but that systematic acquisition might be best, as errors can then be easiest removed. Moreover, standardization was suggested for ground truth data in order to be more comparable in the community. This was considered a very important point although very difficult to achieve. Micheal Schaepman pointed out that very often it is not the measurement itself, but the protocol used for acquisition, as well as the documentation. He suggested to look at e.g. the INSPIRE initiative that has gone through this issue very extensively. It was concluded that it is better to have a poorer product, but a better and thoroughly validated one, rather than potentially excellent data validated in a poor process. Hence, it was advised that 1/3 of the budget should be spent on validation, and 2/3 on data acquisition and processing.

The last session of the Workshop on Friday June 3rd targeted a broader perspective from the so far very remote sensing concentrated view. The session was title "*Beyond mapping: socio-economic dimensions and drivers for LUCC*" and was kicked-off by a very stimulating keynote by Patrick Hostert (Humboldt University Berlin) on "*LUCC - mapping, causes, drivers, implications*". He nicely showed the link between our remote sensing observations and the various components leading to land use and land cover change. With various examples from Eastern Europe, Africa, and South America he clearly demonstrated that observing the patterns of change is one thing, but explaining them and making full use of their content requires much more efforts. It also encouraged participants not to stop with their research at the pure remote sensing analysis and product, but interdisciplinary work with other science groups.



In the lively discussion in this session, one of the major issues raised was how are we going to differentiate between modification and transition, how much can classification contribute here, and how many other approaches do we need. Replies by e.g. Stefan Arnold, from the German Federal Agency for Cartography and Geodesy, mentioned that precise and detailed information is required in first order, from which subsequent other products may be derived. Novel, object-oriented data models can provide a better base for this. Matthias Braun (Univ. Alaska Fairbanks) mentioned that, in his view, continuous products based on physical correct algorithms, such as e.g. vegetation continuous fields or albedo products, will play a stronger role in the future. He also suggested that then more documentation on (pre-)processing is required. Such products might facilitate a better discrimination of subtle changes. Michael Förstner added that a global standardization might be difficult, but solutions tuned to the problem are required. Similar discussions were happening in ecology in the 1990's.

Other contributions added that the problem might be tackled at different scales and that more metadata need to be provided with the land cover classifications. The FAO Land Cover Classification System was also mentioned in this context having the potential to guide such meta information needs to a standardized product.

At the end of the Workshop a "*Tutorial on Support Vector Regression for Satellite Imagery using imageSVM in the EnMAP-Box*" was given by Sebastian van der Linden and colleagues from the Geomatics Lab of Humboldt University Berlin. He introduced the audience to their implementation of various classification and regression tools, and in particular to support vector regression. The toolbox is designed in the software framework of the upcoming German hyperspectral satellite EnMAP. It is a plugin for the commercial ITT ENVI distribution or can also be used with the freely available ITT ENVI virtual machine. Sebastian van der Linden explained the methodological background of the techniques, and demonstrated how to effectively make use of the software and how products can be generated with the software.

At the closing session, the overall feedback from the audience, as well as based on the intense discussions, the chairmen's impression was that the new Workshop concept with invited talks only and contributed posters by the participant was positively received. They will ensure that for the upcoming SIG events posters can be displayed for the entire Workshop time to provide even more attention to them. Tobias Kümmerle (Department of Earth System Analysis of the Potsdam Institute for Climate Impact Research), and Sebastian van der Linden (Geomatics Department of Humboldt University in Berlin) kindly offered to host the next Workshop in Berlin. It is currently scheduled to take place in 2013; details will be announced with sufficient time in advance.

geoland2 EARSeL

The SIG chairmen would like to thank the local organizers, Lena Halounova and her team for their very active support. We will certainly remember the hearty welcoming smile of our hosts, and the wonderful icebreaker and dinner, which settle down in every ones memory.

The Workshop was financially supported by the EU FP7 geoland2 project. Both for the geoland2 project and the EARSeL Community the Workshop was an excellent opportunity for live interaction and feedback on contemporary developments and trends. The high quality contributions by the Workshop participants, as well as the stimulating keynotes lead to very intense and vivid discussions.

Engaged participants and high quality level discussions form the backbone of our SIG, and guarantee the success of the SIGs role within the scientific and European community.

On behalf of the organizing team and the participants,
Matthias Braun & Ioannis Manakos, with contributions by the keynote speakers.

The SIG Land Use / Land Cover on the internet: http://www.earsel.org/SIG/LULC/

1st Workshop on Forestry

Operational remote sensing in forest management

The first European Association of Remote Sensing Laboratories workshop of the Special Interest group on Forestry was held in framework of the EARSeL symposium 2011, 2 – 3 June 2011 in Prague, Czech Republic. It was jointly organized by the Czech Forest Management Institute and the Forestry faculty in Krakow. The event was hosted by the Czech Technical University in Prague, in the new building of National Technical Library (NTK).

The workshop aimed at setting up the common forum for the research community and people from the forestry sector, where both the operational techniques as well as developing methodologies can be presented and understood in order to improve the forest management and protection practices in Europe. Further, the providing the continuity of the successful events organised by the previous Forestry SIG chairman Håkan Olsson from Sweden was of the main concern. The two days workshop programme included 40 oral presentations in 7 thematic sessions and 13 shorted presentations in the poster session.

The event program started with the session Ecology, vegetation studies. The results of the vegetation analyses, the status and the reactions to the stress factors in changing environment were presented for example by Joachim Hill from the Trier University in Germany, or Mathias Schardt from Technical University in Graz. After the poster session with the talks on various forestry topics, the sessions in LIDAR applications was on programme. The utilisation of the laser scanning in forestry applications represents an important topic. Several results of measuring with the terrestrial and airborne scanners, modelling of the dendrometric and stand characteristics were presented (Magnus Bremer from Institute of Geography in Innsbruck, Piotr Wezyk from Faculty of Forestry in Krakow, or Géza Király from Sopron University in Hungary). An interesting talk was given by Yasumasa Hirata from Forestry and Forest Products Research Institute in Japan presented the method of mapping tropical forest structures using the space born laser GLAS onboard of the ICEsat satellite.

The afternoon programme continued with the two sessions. In the Forest monitoring using coarse spatial resolution data, the modern techniques of the large areas forest ecosystems mapping were presented for instance by Mr. Azzi from MAICh in Greece, or Ivan Barka from the National Forest Centre in Slovakia. The analyses of the hyperspectral satellite data such as from MODIS are recently turning operational thanks to the continental coverage and the high temporal resolution (monitoring of the forest health status, forest fires, …). The Thursday workshop programme was closed with the session on Forest protection, REDD. The rapid deforestation is still being an important issue (especially in tropical regions). Together with the topic of Reducing Emissions from Deforestation and Forest Degradation represent an interesting and very practical application field for the remote sensing. In this session the up-to-date processing methods using data from the different sensors (LIDAR, optical data from the DMC satellite constellation) to enhance the monitoring of deforestation were presented.

The workshop continued with no less interesting content on Friday morning. The first session Hyperspectral, Radar, Modelling focused mainly onto the advanced in the field of quantitative remote sensing. Here, the data analyses lead to the extraction of quantitative (bio) chemical or structural parameters of the vegetation surface. Then the parameters are complexly assessed and related to the current health status, biomass, etc. Such applications were presented by Petr Lukeš from Global Change Research Centre in Brno, or by Reza Amiri from Monash University in Australia. The radar remote sensing where the stand heights and structural forest characteristics are assessed based on InSAR and polarimetric methods, posed the second crucial topic of the session.

The next session on Forest Inventory brought several interesting presentations from the National Forest Inventory (NFI) centres in Europe The results of crown canopy cover modelling using the nDSM stereo-matching technique and the automated tree species identification from ADS40/80 digital aerial photos (Christian Ginzler with his colleague Lars Waser from Swiss WSL) represented one of the workshop highlights. Filip Hájek from Forest Management Institute presented the utilisation of digital photogrammetry and satellite remote sensing in the 2nd period of the Czech NFI. The two days workshop finished with the afternoon session about Ecology, biodiversity and forest protection. Several interesting presentations about different topics such as detection of the forest succession after the fire burn (Shannon Franks from NASA), or biotop mapping using the object-based classification approach (Vincent Thierion from French research institute Cemagref) were given.

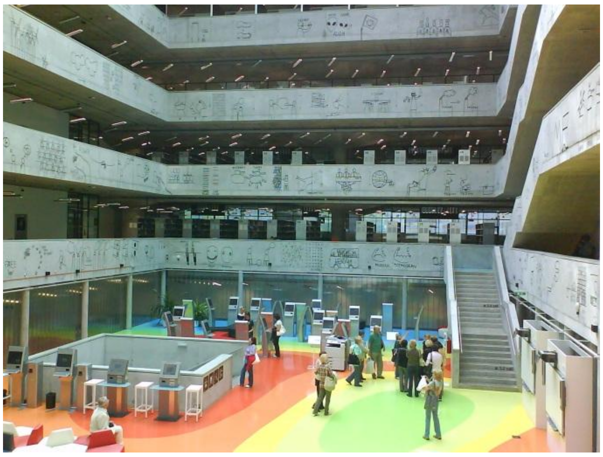
To conclude, the 1st EARSeL workshop on Forestry remote sensing turned our very well. The participants were satisfied with both technical level of the contributions as well as with the smooth organisation and the pleasant atmosphere of the National Technical Library. We will look forward to the workshop follow up - the next event is planned to be hosted at the Forestry faculty in Krakow in 2013.

On behalf of the organizing team and the participants, Filip Hájek and Piotr Wężyk.

The SIG Forestry on the internet: http://www.earsel.org/SIG/Forestry/

5th Workshop on Coastal Zones

A *Krásná Praha* (Beautiful Praha) has been discovered by the attendees at the 5th Workshop on Remote Sensing of the Coastal Zone, which was held in the modern and fashionable venue of the National Technical Library from June 1st to 3rd, 2011, in quasi overlapping with the Symposium.



Outside and inside view of the Praha's National Technical Library. Courtesy: Martin Montes and Luca Fiorani

In a sort of interchange between sea's and river's waters with previous past editions, we exploited news and updates from colleagues coming not only from Europe but also from USA, Russia, Canada, Tunisia, Israel, Korea, Iran and Japan within a total of 19 countries represented and about 60 attendees. We had intense sessions on Ocean Colour, Optical Properties, Algorithms, Temperature, Multisensor Applications, Oil Pollution, Lake & Coastal Colour and Habitat, Land Remote Sensing.

The workshop opening session started with an interesting keynote lecture given by Vittorio Barale (JRC - EC) presenting the view of the European Commission on the new frontiers for remote sensing of Coastal Zones and marine regions in a future maritime spatial planning. The EC is particularly engaged in Integrated Coastal Management and already drafted a series of embryonic policies that rotate around an ensemble of ten so-called key principles, where at the bottom level there is an "ecosystem approach". Coastal zones represent a critical factor in this context, due to its interaction between atmosphere, land and sea clearly not bounded by evident geographic markers, except the coastline itself.

Ocean Colour, Optical Properties and Algorithms

Monitoring and understanding the dynamics and variability of marine ecosystems in coastal zones requires a diversity of properties measured. During the last two decades, ocean colour remote sensing has played an important role in this monitoring effort by observing both physical and biological variables with regular space-time sampling providing several optical (or optically derived) properties of the ocean

Two section of the 5th Workshop on Remote Sensing of the Coastal Zone were dedicated to discuss the capabilities of the remote sensing to operate in coastal zones to detect key coastal environmental parameters: the first focused on ocean colour applications and experiments while the second was more dedicated to optical properties of coastal ocean waters and algorithms.

The results of several field experiments performed in the Tyrrhenian Sea and near the Svalbard Islands (Marullo et al., Fiorani et al.) have contributed to an understanding of the main mechanisms that drive the marine ecosystem functioning in the coastal areas and to validate/calibrate satellite estimates of ocean colour derived parameters in Case I and II waters. During the TYR01 cruise in the

Tyrrhenian Sea, the strategy adopted to achieve the cruise objectives included the acquisition of hyperspectral radiation profile data, marine biochemical and biological data through water sample collection and analysis, and specific experiments, standard hydrographical data and in situ Lidar marine data. Lidar data were also acquired during the Arctic experiment near the Svalbard Island. Both experiments confirmed that, while satellite estimates of chl-a for case I water already matches the error maximum limits in the range proposed by the space agencies measurements in coastal zones are still affected by non-negligible uncertainties.

Antonio Palucci (right), Chairman of the Workshop on Remote Sensing of the Coastal Zone, together with the EARSeL chairman (middle) and Russian colleagues (from left to right) Daria Khundzhuia, Tatiana Dolenko and Svetlana Patsaeva. Courtesy: Svetlana Patsaeva.

Particular attention was also devoted to the effects of river runoff on coastal waters. Dogliotti et al. discussed the case of La Plata River plume, highlighting problems in estimating suspended matter concentrations from satellite due to limitations of the atmospheric correction algorithms, which usually relies in the assumption of zero water-leaving reflectance in the NIR or SWIR part of the spectrum, in the very turbid waters of estuarine regions. However, they tested some TSM algorithms that use the red and near infrared bands of MODIS obtaining results consistent with known values and their spatial distribution in the region. The distribution of total suspended particulate matter (SPM) in the St Lawrence estuary (North Atlantic Ocean) has been discussed by Montes et al. Their data do not suggest a simple relationship between freshwater discharge and average SPM concentration, and highlight the importance of additional environmental factors other than river runoff (e.g., wind) explaining the variability of SPM in the St Lawrence estuary.

Terrigenous carbon export into the Arctic shelf systems is a major component of the Arctic Organic Carbon (OC) cycle. Heim et al. studied the Laptev Sea, an area characterized by a very shallow topography and considerable regions of fresh water influence. This area is a highly dynamic mainly sedimentary ice-rich system that delivers vast amounts of interstorage carbon and old carbon from syncryogenic deposits. They found that MERIS-C2R optical parameters such as the first attenuation depth, ’Z90’, seem adequately to represent true conditions. Whereas the derived concentration parameters seem to be overestimated.

The problem of determining the chl-a distribution in case II waters has also been discussed by Vilas et al. In this study a series of algorithms for the retrieval of chlorophyll a in the Galician rias (NW Spain) from MERIS full resolution data were developed based on Multilayer perceptron (MLP) artificial neural networks and fuzzy c-mean clustering techniques (FCM) using different quality levels. The algorithms were applied to MERIS images of July 2008. They concluded that a local-based algorithm for the chl-a retrieval from an ocean colour sensor with the characteristics of MERIS can be a great support in quantitative monitoring of chl-a and study of harmful algal events in Galician rias.

Another key parameter to understand physical processes in the upper layer of the ocean and biological processes such as phytoplankton photosynthesis in the ocean euphotic zone is the diffuse attenuation coefficient. Saulquin et al. noticed that although several empirical and semi-analytical models are commonly used to map downwelling spectral irradiance at wavelength 490 nm (Kd490) or the downwelling photosynthetically available radiation (KdPAR), most of them have been calibrated on open ocean waters and then provide good results in the high seas, but tend to underestimate the attenuation of light in coastal turbid waters. For this reason they proposed a new estimation of

KdPAR and the euphotic depth for both European clear and turbid waters using MERIS reflectance at full resolution of 250 m.

The problem of achieving a good ecological status in European waters by 2015 is the intent of the Water Framework Directive 2000/60. Rinaldi et al. presented the results of the analysis of twelve years (1997 to 2009) of OC Mediterranean SeaWiFS re-analysis product (from MyOcean & CNR-ISAC) and in-situ observations (from the EEA database) to develop environmental indicators from Ocean Colour data over the Mediterranean Sea suitable for environmental state assessment and for eu-trophication monitoring. The application of the selected method to the entire Mediterranean Sea reveals that significant trends are present only in the coastal area of basin and in particular in the region affected by the major river outflows

The ability of ocean colour measurements to determine phytoplankton size distribution (PSD) and, in particular, to discriminate diatoms and flagellates has been investigated by and by Corinne et al. and by Marullo et al. They both pointed out the need of validate algorithms. Corinne et al. showed the results of their Phytoplankton light absorption spectra measurements in the Canadian arctic seas to evaluate diatom-flagellate discrimination algorithms. During the fall period, highest blue-to-red ratios were found in the Hudson Bay which were associated with the dominance of green algae containing Chl b (microphytoplankton > 2 µm). In arctic regions however, the yellow-brown algae of nano and micrometre sizes containing Chl c was associated with lower blue-to-red ratios. In the eastern side (northern Baffin Bay), microphytoplankton was dominant whereas nanophytoplankton (< 2 µm) was predominant in the western Canadian Arctic (Amundsen Gulf).

Spectroscopy of chromophoric organic substances released by soil fungi into water was discussed by Khundzhua et al. They analysed spectral properties of organic matter released by differently coloured fungi strains grown in aqueous medium to define the possible contribution of microscopic fungi to the pool of chromophoric organic matter naturally occurring in water. Peaks observed in the absorption spectra were attributed to phenolics or quinones (maximum located around 290 nm) and to carotenoids or melanin pigments (the band spreading from 400 to 500 nm). Their experiments revealed microbial degradation of coal-originated humate to chromophoric organic matter of smaller molecular size. They concluded that transformations of humic substances by fungal cultures can be measured and characterised using spectral measurements.

Multisensor Applications, Oil Pollution

The session on Multisensor Applications was full of precious hints and received a fundamental contribution from Asia: among the four presentations, one was from Japan and another one from Korea. Y. Saito (Japan) provided the attendees with a comprehensive review on lidar fluorosensor quality monitoring of lake and river, reporting on the lidar activities in Shinshu University (Laser-induced fluorescence spectrum lidar) and National Maritime Research Institute (Multi-platform oceanographic lidar). At the end, he discussed a prospective management system of water-related environment.

J.-H. Ryu and J.-K. Choi (Korea) examined the applicability of the geostationary ocean colour imager (GOCI) to the detection of temporal and daily variation in suspended sediment on the coastal water in the west coast of Korea. GOCI is the world's first ocean colour observation satellite positioned at the geostationary orbit. It has been launched in June, 2010 and is planned for use in real-time monitoring of the ocean environment around Korean Peninsula by daily analysis of ocean environment measurements of chlorophyll concentration, dissolved organic matter, and suspended sediment for seven years.

K. Stelzer et al. pointed out that the use of multisensor techniques can provide additional valuable information about intertidal flats. On the one hand, optical remote sensing data provide information about the spectral reflectance of the different surface types such as different sediment types (sand, mud), mussel or oyster beds, sea grass or macro algae. On the other hand, radar techniques are used to gain information about the surface roughness of the different areas.

F. Palazzo et al. used remote sensing as a tool to monitor and analyse Abruzzo coastal changes. In their presentation, they summarized the results of the COSMOCoast project, carried within the framework of an ASI contract (I/067/09/0): standard image processing, object-oriented approaches and neural nets were applied for boundary detection along the Abruzzo coast from high to very high resolution actual satellite data (e.g. COSMO-SkyMed, Formosat-2, IKONOS, Kompsat 2, Prism, Quickbird).

Lidar and SAR techniques dominated the session on Oil Pollution. N. Evtushenko and A. Ivanov addressed the oil seep in the Black Sea, Georgian section, imaged and studied with the ERS-1/2 and Envisat SARs. This seep has been mapped using the geoinformation approach, when all oil slicks visible on the SAR images of the sea surface were collected in a geographic information system (GIS), thus revealing a relationship of detected oil slicks with the oil and gas seeps on the sea floor at the underwater Kobuleti ridge, and providing estimates of seep rate in the SE part of the Black Sea.

J. M. Torres Palenzuela et al. studied oil pollution detection using shipborne LIF/LIDAR in the framework of the DEOSOM (AMPERA) project. The lidar system was utilized onboard different vessels for monitoring of coastal waters and detection of oil spills and organic pollutants. Field tests were carried out by University of Vigo and Galician Coast Guard. Several biologically innocuous dyes were used to simulate an oil spill in the Ria de Vigo waters. The results were integrated into web-GIS-application for visualization.

S. Babichenko et al. discussed the application of LIF lidar as an early warning tool for oil pipeline integrity monitoring. The Fluorescence Lidar Systems (FLS-Lidar) they developed were initially employed for environmental monitoring of marine and coastal environments. They proved the capability of minor oil pollution detection in water and on land. A dedicated FLS-AI (Airborne, Integrity) lidar has been developed for surveillance of ground, underground and underwater pipelines. The pilot experiments showed good potential of the technology. Also the last presentation by A. B. Utkin et al. dealt with lidar. The authors showed experimental results obtained with typical crude brands, transported and processed in the Mediterranean region, which include: (i) investigation of dynamics of oil film on the water surface; (ii) study of LIF spectra of spills depending on the oil type and film thickness; (iii) detection of a an experimental spill in the Atlantic Ocean coastal waters; (iv) LIF spectra calibration using water Raman scattering; (v) detection of the LIF spectra of dissolved organic matter.

Lake surface water temperature (LSWT) and lake ice-cover (LIC) observations are key parameters for determining ecological conditions thus to have strong potential environmental and meteorological applications for inland water management and numerical weather prediction (NWP). The new LSWT observations and the EOF-based reconstructions, presented by MacCallum et al., offered benefits to numerical weather prediction (NWP), lake model validation, and improve our knowledge of the climatology of lakes globally.

The merging of three data sources, from optical remote sensing, radar techniques and different surface types enables a classification of intertidal flats covering a large area. Stelzer at al. validated the proposed synergetic classification with in-situ data obtaining a good understanding of the data and their potential application for the ecological and economical impact of intertidal flats areas.

The audience remained very interested, on the possibility of uranium detection in natural waters with the use of laser spectroscopy technique due to the recent remember of the Fukushima disaster and successive nuclear contamination. Shirshin at al. suggested a novel approach to speciation of uranyl complexes in waters based on simultaneous application of the time-resolved and non-linear fluorimetry technique.

A significant presence of posters stimulated the discussion among the attendees during the afternoon, when portable fluorometers could also be examined in operation.

The social programme included a welcome party on Wednesday evening, followed by a pleasant travel excursion over the Vltava River where the attendees enjoyed the dinner onboard the boat. The view of the Castel emerged with all its imperiousness on top of the hill during the sunset.

On behalf of the organizing team and the participants, Antonio Palucci.

The SIG Coastal Zones on the internet: http://www.earsel.org/SIG/CZ/

Symposium 2011 Proceedings Preprints

European Validation of Land Cover Changes in CLC2006 Project

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Abstract. CORINE Land Cover 2006 is the third European Land Cover inventory (1990s, 2000 and 2006). The number of participating countries is increasing, at present being 38. Countries (CH, IS, NO, TR) not participating previous CLC inventories have joined the CLC2006 project. The project is co-financed by the EEA and the member countries and covers 5,8 million km^2 of the European continent. Project was implemented by national teams. A Technical Team under ETC-LUSI was responsible for technical follow-up of the project. For production of CLC-Change$_{2000-2006}$ database "change-mapping first" visual photo-interpretation technology was applied by majority of countries. Scandinavian countries replaced part of labour-intensive photo-interpretation with GIS and image processing. CLC2006 database was usually produced in GIS by adding together revised CLC2000 and CLC-Change$_{2000-2006}$. National teams used multi-temporal (two coverages) SPOT-4/5 and/or IRS-P6 imagery to derive the minimum 5 ha land cover changes that occurred between 2000 and 2006. Ortho-corrected satellite images provided a solid geometrical basis for mapping land cover changes based on the standard CLC nomenclature. Results show that land cover changed on 1.25% of the surface of Europe between 2000 and 2006, which is equivalent to the size of Lithuania. Forestry changes (forest felling and growth) constitute the largest change area as well as they provide the highest number of change polygons. Stratified random sampling was used for validating the database of CLC-Change$_{2000-2006}$, being the first change validation exercise in the history of CLC. The obtained 87,8%±3,3% overall accuracy (calculated using commission error only) based on 2405 samples is satisfying. Omission error was not possible to measure due to the very large sample size required, being the consequence of small change percentage.

1. Introduction

From 1985 to 1990, the European Commission implemented the CORINE Programme (Co-ordination of Information on the Environment). During this programme an information system on the state of the European environment was established, nomenclatures and methodologies were developed and agreed at European level. The first CORINE Land Cover (CLC) project was implemented in most of the EU countries, as well as in the 13 partner countries in Central and Eastern Europe [1]. CLC data provide information on the physical characteristics of the earth surface. Images acquired by earth observation satellites are used as the main source data to derive land cover information.

Since the setting up of the European Environment Agency (EEA) and the establishment of the European Environment Information and Observation Network (EIONET), the responsibilities of the CORINE databases have been lying with the EEA.

The second CLC inventory was implemented within the IMAGE&CLC2000 project, based upon lessons learnt from the first CLC inventory, a list of user needs and the available satellite images. The overall aim was to produce an updated CLC database (CLC2000) and the database of land cover changes (LCC) between the first CLC inventory and 2000 (CLC-Change$_{1990-2000}$) [2].

The third CLC inventory (CLC2006) was the result of EEA's collaboration with the European Commission (EC) and the European Space Agency (ESA) on the implementation of the Fast Track Service on Land Monitoring (FTS LM) in line with the communication: "Global Monitoring for Environment and Security (GMES): From Concept to Reality" [3].

In its more than 20 years history CORINE Land Cover has maintained its basic technical specifications (e.g. nomenclature, geometric resolution [6]), but the way of technical implementation has significantly changed since the beginning. In CLC1990 photo-interpretation was carried out on plastic overlays placed on 1:100.000 scale satellite image printouts. Drawings on the plastic overlay had to be digitized in order to create a database. Deformation of the plastic often caused geometric distortion of land cover data. Today, "drawing" is done on screen - with a geo-referenced satellite image in the background - at a suitable scale selected by the interpreter, creating digital data in one step.

In CLC1990 ortho-correction was not routinely applied in producing the base image map for photo-interpretation. Today, with the availability of DEM at the appropriate resolution ortho-correction of satellite imagery is a standard process, providing higher geometric precision of the imagery.

Ancillary data in CLC1990 were mainly topographic maps and black-and-white photographs as hard-copy. Today, scanned topographic maps are commonly available, and national coverages of digital colour aerial photography are also frequently accessible.

Quality assurance was a difficult task in CLC1990 as checking of photo-interpretation had to carried out on the plastic overlay. Today, computer-assisted quality control – applied since the CLC2000 project – provides written, geo-located explanations regarding the problems. This is an efficient tool of standardizing / harmonizing production and understanding all over Europe.

Data dissemination has also been improved. Since CLC2000 data have had dual ownership (EEA and the country). Today CLC data are freely accessible from the EEA to any person or legal entity.

Chapter 2 introduces CLC2006 as part of the GMES FTS Land Monitoring. As the main purpose of this paper the methodology and results of validation of the European CLC-Change$_{2000\text{-}2006}$ product are presented in Chapter 3 and Chapter 4, respectively.

2. CLC2006 in the frames of GMES

In 2006, based on requirements of DG Environment, DG Agriculture and other users EEA started collaboration with the European Space Agency (ESA) and the European Commission (EC) in the implementation of the Fast Track Service on Land Monitoring under the umbrella of GMES [3]. CLC2006 is one of the components of GMES FTS LM [4] (Figure 1, Table 1). DG JRC and ESA have defined and implemented the satellite data procurement and processing (IMAGE2006).

2.1 IMAGE2006

Imagery from Landsat-7 satellite, used in CLC2000 project being unavailable at the time of project (due to malfunction), new sources of suitable satellite imagery had to be found for purposes of the GMES FTS Land Monitoring. As a result of agreements between satellite operators and ESA, imagery from two types of satellite has been acquired for purposes of CLC2006:

- SPOT-4&5 (French, 60 km swath width, 20 m pixels; VIS, NIR and SWIR bands), and
- IRS P6 (Indian, 141 km swath width, 23 m pixels; VIS, NIR and SWIR bands).

IMAGE2006 is a multi-temporal satellite image coverage with coverage-1 usually taken in summer, while coverage-2 in spring or autumn. According to specifications, the acquisition date of coverage-2 should be more than 6 weeks away from that of coverage-1 in order to provide an optimal basis for photo-interpretation. Altogether 2416 SPOT 4 and 5 images and 1283 IRS P6 images were acquired and ortho-rectified for the project [5]. Ortho-rectification was executed by DLR and Metria.

2.2 Geographical Coverage

The GMES FTS Land Monitoring aimed to cover the EU27, neighbouring countries and all EEA Member countries, namely:

- Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom,

as well as the West Balkan countries, namely

- Albania, Bosnia and Herzegovina, Croatia, FYR of Macedonia, Montenegro, Serbia.
- Kosovo joined the project following her independence.

Four countries not participating previous CLC inventories joined the project (CH, IS, NO and TR). Greece did not participate. Thus altogether 38 countries were involved, covering 5,7 million km^2 of land area (Figure 2).

National organisations responsible for technical implementation and technical project managers of the participating countries are listed in Annex 1

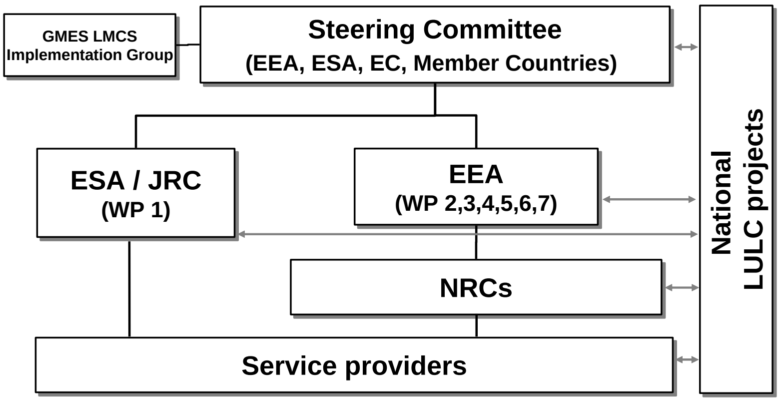

Figure 1: Organisational chart of GMES FTS Land Monitoring [4].

Table 1. GMES FTS Land Monitoring work packages and the overview of the role of partners [4].

Tasks	NRC	EEA	ESA	JRC	Data & service providers
WP1.1 Satellite data acquisition	x		O	x	O
WP1.2 Ortho-correction			O		O
WP1.3 Satellite image mosaic				O	O
WP2 In-situ and ancillary data collection	x	O			O
WP3.1 CORINE land cover change mapping 2000-2006	O	O			
WP4.1 Built-up areas and degree of soil sealing 2006	x	O			O
WP4.2 Forest area mapping (not implemented)					
WP5 Validation	x	O			
WP6 Data dissemination	x	O	x	x	
WP7 Project management	x	O	x	x	
O = leading organization x = organisation involved NRC = National Reference Centre					

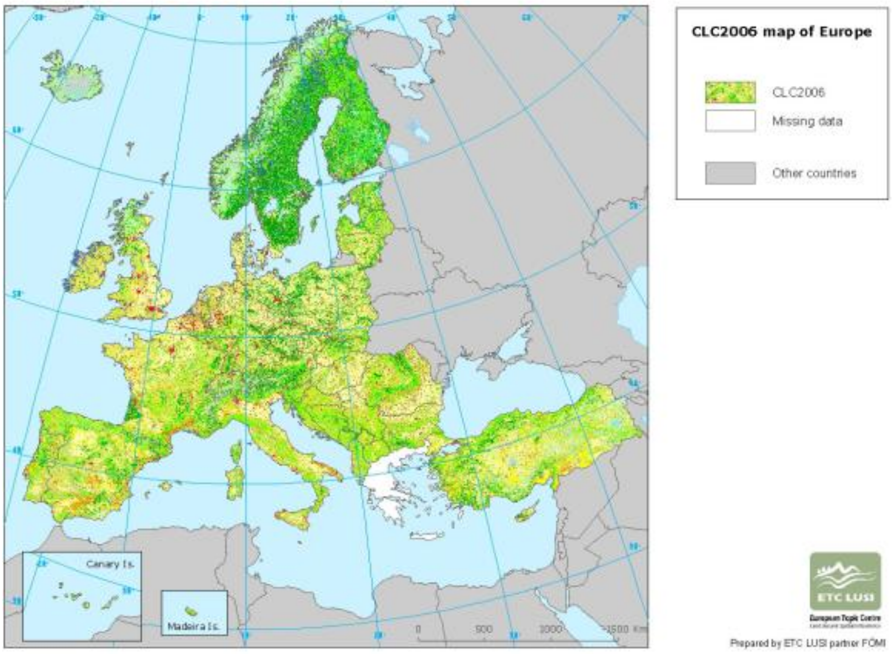

Figure 2: Coverage of the CLC2006 database

2.3 Mapping methodology

Basic parameters of CLC2006 are the same as those of previous CLC inventories [7] thus continuity with CLC1990 and CLC2000 is maintained:

- minimum mapping unit (MMU) is 25 hectares;
- minimum width of linear elements is 100 metres;
- standard CLC nomenclature, which includes 44 land cover classes on level 3. The five level-1 categories are: 1) artificial surfaces, 2) agricultural areas, 3) forests and semi-natural areas, 4) wetlands, 5) water bodies [7]. The list of standard CLC classes is presented in Annex 2.

CLC-Change$_{2000\text{-}2006}$ was the primary product of the CLC2006 project. The aim was to produce the European coverage of real land cover changes that

- are larger than 5 ha and wider than 100 m;
- occurred between 2000 and 2006;
- reflect real evolution process (e.g. urban sprawl, new forest plantation, new water reservoir).

The proposed method was computer-aided visual interpretation of satellite images [8]. Image classification based methods, as alternatives of visual interpretation, were not considered mature enough to handle the large number of CLC classes in the diverse geographic environment of Europe. National experts interpreted CLC changes directly on screen, by comparing IMAGE2000 and IMAGE2006 data in a dual-window environment. Delineation of changes was based on CLC2000 polygons in order to avoid creating sliver polygons and consequently false changes when producing CLC2006 database. Interpreters gave two CLC codes to each change polygon: code2000 and code2006. Change code pair thus shows the process that occurred in reality and thus may be different from the codes occurring on the CLC2000 map and / or in the final CLC2006 map, due to generalization applied in producing CLC2000 and CLC2006 [8]. The main benefits of this direct change-mapping approach are: (1) changes are interpreted directly (the interpreter has to think about what the real process was), (2) all changes larger than 5 ha can be easily delineated regardless of their geometric position (attached to an existing CLC2000 polygon or not). The weakness is that some small (< 5 ha) deficiencies of CLC2006 cannot be avoided [9].

In some countries (especially in Scandinavia) procedures different from visual photo-interpretation were used for deriving CORINE Land Cover data [10, 11, 12, 13]. These solutions combine national GIS datasets, satellite image processing, on-screen digitization (visual photo-interpretation) and GIS-based generalisation.

Table 2 summarises the main features of CLC-Change$_{2000\text{-}2006}$ database. Having the CLC-Change$_{2000\text{-}2006}$ database completed, CLC2006 is generated in an automated process [8]:

$$\text{CLC2006} = \text{CLC2000 } (+) \text{ CLC-Change}_{2000\text{-}2006}$$

Where (+) means the following operation: CLC2000 (revised) and CLC-Change$_{2000\text{-}2006}$ databases are intersected, then CLC-Change$_{2000\text{-}2006}$ polygons' code2000 is replaced by code2006. Finally, neighbours with identical code are unified and small (<25 ha) polygons are generalized according to a priority table [14].

Table 2. Figures characterising the CLC-Change$_{2000\text{-}2006}$ Europe database (V14)

Total changed area:	68 645 km^2
Part of Europe (without sea and ocean) that changed in 6 years	1.25 percent
Number of change polygons	352 987
Number of change types occurring	924
Number of change types providing 90% of total change area	73
Number of sporadic change types (each giving less than 0.1% of total change area)	845
Change types providing 50% of total change area	312-324, 23 473 km^2 311-324, 5 726 km^2 324-312, 5 702 km^2
Change types with the largest number of change polygons	312-324, 143 552 polygons 324-312, 33 429 polygons 311-324, 24 618 polygons

3. Validation strategy

After completing the previous CLC inventory, ETC-TE validated CLC2000 database by using LUCAS data, which provided results better than the 85% accuracy specification [15]. As the percentage of CLC changes between 2000 and 2006 is small, similar accuracy can be expected for CLC2006. Therefore in the CLC2006 project it was decided to validate only the database of CLC-Change$_{2000\text{-}2006}$, being the first change validation exercise in the history of CLC. Stratified random point sampling was chosen to select locations for independent visual photo-interpretation and comparison with the CLC-Change layer. This solution is considered to provide relevant information on the database quality with affordable effort. Some of the participating countries validated their national results independently using a similar method [16].

3.1 Sampling strategy

By validation of land cover changes we are looking for answer to the following basic questions:

a) Do the mapped changes represent real change process? (This is measured by commission error.)

b) Have all the changes been found? (This is measured by omission error.)

While commission error is relatively easy to estimate by sampling within CLC change polygons, reliable estimation of omission errors would require an enormous number of samples (Table 3) and effort.

Table 3. Number of samples required to estimate 15% omissions (with ± 5% standard deviation)

Selected change type in CLC-Change$_{2000\text{-}2006}$	Percent changes relative to CLC2000	Number of necessary samples	Number of samples expected to find the 15% omission error	Calculated omission error (related to class area)
133-112	40.5	100	10	14.7%± 4.4%
312-324	3.28	1 800	9	14.7%± 4.9%
231-211	0.24	25 000	9	15.0%± 5.0%
312-334	0.05	120 000	9	15.0%± 5.0%
211-512	0.01	600 000	9	15.0%± 5.0%
All changes	1.25	5 000	10	15.7%± 5.0%

Table 3 provides some representative change rates based on CLC-Change$_{2000\text{-}2006}$ statistics. There is only one level-3 class with high rate of changes: 40,5% of the CLC2000 class 133 changed to 112 class during the 2000-2006 period (meaning construction site changed to residential area). In this case an omission error around 15% could have been estimated with ± 4,4% standard deviation using only 100 samples. For all other cases the number of samples required for a meaningful result, obviously made the exercise difficult or not accomplishable. However, the practical evaluation of omitted changes of CLC2000 class 133 failed, due to unavailability of revised CLC2000 data in most of the countries.

Commission error is estimated by distributing random point samples within CLC change polygons. By this sampling design a further question on database quality can be answered, namely if the type of the change mapped is correct.

There are over 900 level-3 change types in the European CLC-Change$_{2000\text{-}2006}$ database (Table 2). As it is not possible to test all change types, some kind of selection or grouping of level-3 changes had to be done in order to provide an overall picture of accuracy of CLC-Change$_{2000\text{-}2006}$.

Therefore two kinds of sampling exercises were implemented:

- Sampling of level-1 changes. There are 25 different level-1 changes in CLC coming from the five level-1 CLC classes (Table 4). Maximum 100 randomly placed sampling points were selected for each level-1 change type. This makes up altogether 2405 samples. (The smallest change type (from class 1 to class 4 - abbreviated as 1-4) included only 5 small polygons.) These samples were used to estimate the commission error of CLC-Change$_{2000\text{-}2006}$ (level 3), grouped according to level-1 change types. In this exercise the whole population of CLC change polygons was sampled. Assigning the same number of samples to frequent change types (e.g. 2-1, 3-3), as to rare changes (e.g. 4-4, 5-5) provided a good statistical basis to avoid bias due to different population sizes of change types. In case of rare change types several sampling points could be placed into a single polygon.

- Additional samples (about 100 samples for each case) for a number of level-3 change types of special interest were selected. The Land Cover Flow (LCF) scheme [17] was used to select which level-3 changes are to be considered. Based on CLC-Change$_{2000\text{-}2006}$ statistics, the largest constituents of each major LCF were identified (Table 5). In this exercise about half of all CLC change polygons were sampled. In two cases (LCF4 and LCF7) we have selected two change types under the same Land Cover Flow. These are balancing processes, which cause a close to equilibrium status in agriculture and forestry. In case of LCF4 (agriculture internal conversions) these are 231-211 and 211-231 (pasture changing to arable land and reverse, respectively). In case of LCF7 (forest creation and management) these are 312-324 and 324-312 (felling and growth of coniferous forest, respectively), the first being the most frequent change type of all. In LCF5 (new agricultural land) the largest constituent (324-244) has an uneven European coverage: CLC class 244 (agroforestry) being limited to practically the Iberian Peninsula, and its interpretation is usually not possible without local knowledge / high-resolution ancillary data. Therefore this change type was not examined.

Table 4. Number of CLC change polygons (upper figures) and percent of total area of CLC change types (lower figures) grouped on level 1 of the CLC nomenclature

		Year 2006					
		1	2	3	4	5	Sum
Year 2000	1	5573	834	651	5	287	7 350
		1.8%	0.36%	0.38%	0.00%	0.15%	2.70%
	2	3496	16 137	7 748	124	1 870	60 835
		7.6%	8.33%	2.65%	0.08%	0.57%	19.30%
	3	1091	7 748	261 572	422	1 038	281 741
		2.3%	2.48%	70.92%	0.13%	0.66%	76.51%
	4	147	1 010	1 090	11	86	2 344
		0.03%	0.34%	0.48%	0.06%	0.04%	0.95%
	5	243	85	294	62	33	717
		0.06%	0.05%	0.34%	0.04%	0.05%	0.55%
	Sum	51 880	25 814	271 355	624	3 314	352 987
		11.90%	11.56%	74.77%	0.31%	1.47%	100.0%

1: Artificial surfaces; 2: Agriculture; 3: Forests and semi-natural vegetation; 4: Wetlands; 5: Water

Table 5. The nine main LCFs and their most dynamic level-3 CLC-Change constituents

Land Cover Flow	Name of the Land Cover Flow [17]	Sampled change	Percentage of change compared to CLC2000 class area
LCF1	Internal transformation of urban areas	133-112	40.5% of all 133
LCF2	Urban residential sprawl	211-112	0.06% of all 211
LCF3	Sprawl of economic sites and infrastructure	211-133	0.07% of all 211
LCF4	Agriculture internal conversions	231-211	0.24% of all 231
LCF4	Agriculture internal conversions	211-231	0.08% of all 211
LCF5	New agriculture land	324-244	0.09% of all 324
LCF6	Withdrawal of farming	211-324	0.07% of all 211
LCF7	Forest creation and management	312-324	3.28% of all 312
LCF7	Forest creation and management	324-312	2.24% of all 324
LCF8	Creation of new water bodies	211-512	0.01% of all 211
LCF9	Changes of land cover due to natural and multiple causes	312-334	0.05% of all 312

Based on the above considerations ten level-3 change types were selected for additional sampling (100 samples for each). This selection represents 49,7% of total CLC change area.

3.2 Materials used

In an optimal case reference data for validation consist of:

- Very high resolution (VHR) satellite imagery or orthophotos taken in years 1999-2001 at resolution better than resolution of IMAGE2000;
- VHR satellite imagery or orthophotos taken in years 2005-2007 at resolution better than resolution of IMAGE2006;
- Topographic maps at scale 1:50.000 or finer.

Field photographs from Eurostat LUCAS2006 project would have been very useful for the validation of 2006 status, but as they were used by some of the countries during the production (thus being not independent), they were not relevant for the validation. The large number of participating countries made it unrealistic to collect very-high-resolution orthophotos or satellite imagery and even topographic maps for the purposes of validation. Therefore validation was executed by re-interpretation of IMAGE2000 and IMAGE2006, supported by use of Google Earth (GE) imagery. Multi-temporal 5x5 km imagettes around each sample point were extracted from IMAGE2006 as well as from IMAGE2000. The date of each imagette was precisely known, as this was mandatory for the re-interpretation. GE proved to be an extremely useful support, especially due to its time-series feature. In many parts of Europe GE provided the required very-high-resolution data for the validation (Figure 3).

Figure 3: High resolution Google Earth (GE) images are often perfect data sources for validation.
Left: September 2003, Right: September 2006. Arable land changed to construction site (Turkey).

3.3 Way of validation

The enhanced plausibility approach was selected to validate CLC-Change$_{2000\text{-}2006}$. In the first step the validation point was blindly interpreted by the validation expert, i.e. without knowing the delineation and CLC-Change attributes of the area. Interpretation meant answering: what type of valid (at least 5 ha) CLC change was visible in the surroundings of the sample point? In the second step outlines the CLC-Change database were displayed on the area and a new validation code should have been provided. In the second step the validating expert had to decide whether the mapped change was correct (OK) or not correct (NOK). Decision “Other” could be chosen if it was not possible to make a decision (i.e. missing or bad quality images). For the NOK case one of the following standard explanations could have been provided:

- No change
- No change, temporal difference only

- No change and CLC2000 code is not corrected
- Change exists, but with different attributes

4. Results of validation

Results of validation of CLC-Change$_{2000-2006}$ are presented in Tables 6 and 8. In both tables the accuracy figure is followed by standard deviation of accuracy figure. In Table 6 the figure of accuracy refers to percentage of cases when the change was found by the original photo-interpreter and the given attributes were correct. The last column shows the "importance" of the change type by providing the percent of the area of given change type relative to the total area of changes.

The overall accuracy was calculated as a weighted sum: change type accuracies were weighted with the relative area, meaning the share of change type within all changes. The overall accuracy of CLC-Change$_{2000-2006}$ database (based on commission error only) is 87.8%, i.e. exceeds the target value of 85%.

Table 6. Accuracy figures for CLC-Change$_{2000-2006}$ grouped on level 1 (based on commission error only)

Level-1 class CLC2000	Level-1 class CLC2006	No. of samples used	Accuracy (%)	Standard deviation (%)	Size of the change type (% of total changes)
5	5	84	97.6	1.7	0.05
2	5	100	97.0	1.7	0.57
4	4	57	94.7	3.0	0.06
1	5	100	94.0	2.4	0.15
5	1	100	93.0	2.6	0.06
3	5	96	91.7	2.8	0.66
3	3	95	89.5	3.2	70.92
3	4	100	88.0	3.4	0.13
1	1	92	88.0	3.3	1.81
2	3	99	87.9	3.3	2.65
4	1	95	87.4	3.4	0.03
4	2	85	87.1	3.6	0.34
4	3	98	86.7	3.4	0.48
1	2	99	84.9	3.6	0.36
2	1	98	83.7	3.7	7.67
2	2	97	83.5	3.8	8.33
4	5	95	82.1	3.9	0.04
3	1	98	80.6	4.0	2.32
5	3	99	79.8	4.0	0.34
3	2	95	77.9	4.3	2.48
2	4	93	74.2	4.5	0.08
1	3	98	66.3	4.8	0.38
1	4	5	60.0	21.9	0.00
5	2	93	59.1	5.1	0.05
5	4	89	21.4	4.3	0.04
Overall Accuracy		2 260	87.8	3.3	100.00

More than 2/3 of the level-1 change types have accuracy higher than 85% (with standard deviation taken into account). In Table 6 these change types are listed above the bold line. The most frequent of these successfully mapped change types are emphasized here:

- The far largest change types are the internal changes in level-1 class forest / semi-natural (3-3; dominated by forest clearcut and forest growth). Almost ¾ of all changes belong to this type, therefore its 89,5% accuracy is very important.
- Agricultural area changed to forest / semi-natural area (2-3; e.g. afforestation).

- Internal changes within artificial areas (1-1; e.g. construction site changed to residential area).
- Agricultural area changed to water (2-5; e.g. new reservoir on agricultural land).
- Forest / semi-natural area changed to water (3-5; e.g. new reservoir on area originally covered by sclerophyllous shrub).
- Wetland changed to forest / semi-natural class (4-3; e.g. afforestation on peatland).
- Wetland changed to agriculture (4-2; e.g. peatland converted to arable land).
- Artificial areas changed to agricultural land (1-2; e.g. reclamation of mineral extraction sites).
- Agricultural area turned to artificial surface (2-1; e.g. highway construction on agricultural land).
- Internal conversions within agriculture (2-2; e.g. arable land turned to olive plantation).

There are eight change types on the lower end of the accuracy list (below bold line in Table 6). Two of them almost reached the 85% accuracy; 2 others are between 70-80%, while four change types have accuracy below 70%. In this latter group three change types have marginal frequency.

Remarkable change types with accuracies below 85%:

- Forest-semi-natural area changed to artificial surface (3-1; e.g. new highway replacing former forest, almost reached the 85% limit).
- Water changed to forest / semi-natural area (5-3; e.g. changes of unregulated rivers, almost reached the 85% limit).
- Forest / semi-natural area changed to agriculture (3-2; e.g. forest changed to arable land).
- Artificial area changed to forest / semi-natural area (1-3; e.g. reclamation of mineral extraction site by forest) is the least accurately mapped significant level-1 change type.

Table 7. Summary statistics of samples used in validation

Validation case	Explanation of error	Not OK; no-change samples	No. of samples
OK			1859
Not OK; no change			229
	Temporal difference only	51	
	CLC2000 code not correct	28	
	No specific explanation	150	
Not OK; Change exists, but wrong attributes			172
Other (not interpretable)			145
Total:		229	2405

The summary statistics of samples in Table 7 show that:

- 1859 samples (77,3 %) were proved to be correctly mapped by the validation, 401 (16,7%) were found not to be correct, while 145 (6 %) were not interpretable.
- Considering not-correct cases, 229 were judged as “no-change” (57,1%), while 172 (42,9%) were evaluated as “change exists but wrong attributes”.
- A significant number of errors (51 out of 229) refer to short-term (seasonal or shorter) differences in land cover misinterpreted as CLC change. This fact underlines the need of further training on mapping CLC changes.
- Still there are errors (28 out of 229) related to mistakes of CLC2000. Because these mistakes are usually inherited by CLC2006, the “retrospective” correction is important in the next CLC update.

Considering the ten level-3 changes selected as “flagships” of major land cover flows we found that all but two change types were above the 85% accuracy limit (with standard deviation taken into account). The following five change types have extra high accuracy (above 90%):

- Arable land converted to construction site (belonging to "urban residential sprawl").
- Arable land converted to water body (belonging to "creation of new water bodies").
- Coniferous forest burnt (belonging to "changes of land cover due to natural and multiple causes").
- Construction of residential area finished (belonging to "internal transformation of urban areas").
- Coniferous forest changed to transitional woodland-shrub (felling) (belonging to "forest creation and management"). This is the largest level-3 change, providing more than 1/3 of area of all CLC changes.

Two change types were mapped with accuracy lower than 85%:

- Growth of coniferous forests (belonging to "forest creation and management"). This change type concerns rather significant area in Europe. Mapping it consistently is difficult without in-situ data.
- Pasture/set-aside land changed to arable land (belonging to "agriculture internal conversions"). Its consistent mapping is difficult without in-situ / more multi-temporal data.

Table 8. Accuracy figures for selected level-3 CLC changes (based on commission error only)

CLC2000 class	CLC2006 class	No. of samples	Accuracy (%)	St.dev. (%)	Size of the change class (% of total change area)	Represented Land Cover Flow
211	133	101	96.0	1.9	1.08	LCF3
211	512	100	96.0	2.0	0.20	LCF8
312	334	96	93.8	2.5	0.50	LCF9
133	112	100	93.0	2.6	0.71	LCF1
312	324	110	92.7	2.5	34.21	LCF7
211	324	100	83.0	3.8	1.11	LCF6
211	112	96	82.3	3.9	0.97	LCF2
211	231	100	82.0	3.8	1.30	LCF4
324	312	99	76.8	4.2	8.25	LCF7
231	211	97	76.3	4.2	1.34	LCF4
Total:	-	999	-	-	49.67	-

Level-3 changes presented in Table 8 constitute almost 50% of all CLC change area. As not the whole CLC change polygon population was sampled in this second exercise, overall accuracy was not calculated.

5. Conclusion

Executed under the GMES FTS Land Monitoring program, CLC2006 was the third land cover mapping project of the European territory. It has provided updated, harmonized land cover and land cover change information for 5,7 million km^2 of the European continent. Good quality multi-temporal satellite imagery, adequate reference data (topographic maps, orthophotos, LUCAS-2006 data etc.), national expertise from the 38 participating countries and strong coordination on behalf of EEA were key elements of the successful implementation. The proposed "change-mapping first" photo-interpretation technology was applied by the majority of countries. Scandinavian countries used more GIS-based data compilation and image processing and less labour-intensive photo-interpretation. Land cover changed on 1,25 % of the surface of Europe between 2000 and 2006, changed area thus being equivalent to the size of Lithuania. Forestry changes (forest felling and growth) occupy the largest area among the changes, providing also the highest number of change polygons.

Validation exercise, deriving commission error of the CLC-Change$_{2000\text{-}2006}$ database was executed by ETC-LUSI. This was the first time a CLC-Change layer was validated. Due the low percentage of changes, deriving omission errors would have required extremely large number of samples and consequently much labour. Therefore deriving omission errors was out of the scope of this study.

Method of stratified random sampling was applied to select samples for validating CLC-Change$_{2000\text{-}2006}$ database. This solution is considered to provide relevant information on the database quality with affordable effort. Samples were interpreted using IMAGE2000, IMAGE2006 and Google Earth imagery. Samples were selected based on two different arrangements of the change population.

(1) 100 sample points were selected from inside each of the 25 level-1 change types, thus representing the whole change polygon population.

(2) 100 samples were selected from each of the 10 “highly important” level-3 changes. The Land Cover Flow scheme was used to determine which changes are to be sampled. This sampling represents almost 50% of the whole change polygon population.

The overall accuracy (based on commission error only) of the CLC-Change$_{2000\text{-}2006}$ database is 87,8% ±3,3%, i.e. exceeds the target value of 85%. 17 of the 25 change type groups have accuracy higher than 85%, 13 types of which having accuracy higher than 90%, including the largest level-1 change class (internal changes in forest and semi-natural vegetation). Among the less accurate change types two almost reached the 85% accuracy; two others have accuracy between 70% and 80%, while four change types are below 70% accuracy. In this latter group three change types have marginal frequency.

Considering the ten level-3 changes selected as “flagships” of major land cover flows we found that all but two change types had more than 85% accuracy (based on commission error). Five change types have accuracy above 90%, including the largest level-3 change type (felling of coniferous forests). Two change types were mapped with accuracy lower than 85%: (1) growth of coniferous forests, and (2) conversion of pasture/set-aside land to arable land.

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Annex 1: Implementing organisations and project managers

country	implementing organisation	technical project manager
Albania	Centre of Agricultural Technology Transfer, Albania GeoVille Austria	Vangjo Kovaci Nina Schuldner
Austria	Umweltbundesamt (Enviroment Agency Austria)	Gebhard Banko
Belgium	IGN Belgium	Yvan Van der Vennet
Bosnia and Herzegovina	University of Sarajevo	Hamid Čustović
Bulgaria	Geomatics Department, Bulgaria Academy of Sciences	Anton Stoimenov
Croatia	GISDATA d.o.o. OIKON	Ivana Lampek Vladimir Kušan
Cyprus	MANRE, Environment Service	Nicos Siamarias
Czech Republic	Help Service – Remote Sensing spol. s.r.o.	Stanislav Holý
Denmark	National Environmental Research Institute (NERI)	Michael Stjernholm
Estonia	Regio AS	Helle Koppa
Finland	Finnish Environment Institute (SYKE)	Pekka Härmä
France	*Systèmes d'Information à Référence Spatiale (SIRS)*	Lionel Mequignon
Germany	Deutsches Zentrum für Luft- und Raumfahrt (DLR)	Manfred Keil
Hungary	Institute of Geodesy, Cartography and Remote Sensing (FÖMI)	Gergely Maucha
Iceland	National Land Survey of Iceland (LMI)	Kolbeinn Árnason
Ireland	ERA Maptec Ltd.	Martin Critchley
Italy	Università degli Studi del Molise	Gherardo Chirici
Kosovo	EvroGeomatika (Serbia)	Ivan Nestorov
Latvia	Envirotech	Harijs Baranovs
Liechtenstein	Umweltbundesamt (Enviroment Agency Austria)	Gebhard Banko
Lithuania	Institute of Ecology of Vilnius University	Daiva Vaitkuvienė
Luxemburg	GeoVille Luxemburg	Stefan Kleeschulte
Macedonia	GOVe d.o.o.	Zoran Velickov
Malta	Malta Environment and Planning Authority (MEPA)	Saviour Formosa
Montenegro	Geological Survey of Montenegro	Slobodan Radusinovic
The Netherlands	Alterra,Wageningen University and Research Centre	Gerard Hazeu
Norway	Norwegian Forest and Landscape Institute	Linda Aune-Lundberg
Poland	*Instytut Geodezji i Kartografii (IGiK)*	Elzbieta Bielecka
Portugal	Instituto Geográfico Portuguęs (IGP)	Mário Caeteno
Romania	Danube Delta National Institute (DDNI)	Jenica Hanganu
Serbia	EvroGeomatika	Ivan Nestorov
Slovak Republic	Slovak Environmental Agency (SAŽP)	Nada Machova
Slovenia	GISDATA d.o.o.	Sandra Radi Goljak
Spain	IGN Spain	Antonio Arozarena
Sweden	METRIA, National Land Survey of Sweden	Jan-Peter Mäki
Switzerland	*Bundesamt für Umwelt (BAFU)*	Tom Klingl
Turkey	Ministry of Forest and Environment	Ahmet Çivi
United Kingdom	Centre for Ecology and Hydrology (CEH)	Ian Simson

Annex 2: CORINE Land Cover nomenclature (European Commission, 1993)

LEVEL 1	LEVEL 2	LEVEL 3
1. ARTIFICIAL SURFACES	1.1. Urban fabric	1.1.1. Continuous urban fabric 1.1.2. Discontinuous urban fabric
	1.2. Industrial, commercial and transport units	1.2.1. Industrial or commercial units 1.2.2. Road and rail networks and associated land 1.2.3. Port areas 1.2.4. Airports
	1.3. Mine, dump and construction sites	1.3.1. Mineral extraction sites 1.3.2. Dump sites 1.3.3. Construction sites
	1.4. Artificial, non-agri-cultural vegetated areas	1.4.1. Green urban areas 1.4.2. Sport and leisure facilities
2. AGRICULTURAL AREAS	2.1. Arable land	2.1.1. Non-irrigated arable land 2.1.2. Permanently irrigated land 2.1.3. Rice fields
	2.2. Permanent crops	2.2.1. Vineyards 2.2.2. Fruit trees and berry plantations 2.2.3. Olive groves
	2.3. Pastures	2.3.1. Pastures
	2.4. Heterogeneous agricultural areas	2.4.1. Annual crops associated with permanent crops 2.4.2. Complex cultivation patterns 2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation 2.4.4. Agro-forestry areas
3. FOREST AND SEMI-NATURAL AREAS	3.1. Forests	3.1.1. Broad-leaved forest 3.1.2. Coniferous forest 3.1.3. Mixed forest
	3.2. Scrub and/or herbaceous associations	3.2.1. Natural grassland 3.2.2. Moors and heathland 3.2.3. Sclerophyllous vegetation 3.2.4. Transitional woodland-scrub
	3.3. Open spaces with little or no vegetation	3.3.1. Beaches, dunes, sands 3.3.2. Bare rocks 3.3.3. Sparsely vegetated areas 3.3.4. Burnt areas 3.3.5. Glaciers and perpetual snow
4. WETLANDS	4.1.Inland wetlands	4.1.1. Inland marshes 4.1.2. Peat bogs
	4.2.Marine wetlands	4.2.1. Salt marshes 4.2.2. Salines 4.2.3. Intertidal flats
5. WATER BODIES	5.1. Inland waters	5.1.1. Water courses 5.1.2. Water bodies
	5.2. Marine waters	5.2.1. Coastal lagoons 5.2.2. Estuaries 5.2.3. Sea and ocean

Combined Use of Satellite Remote Sensing, GIS, and Geophysical Data for Archaeological Research in Europos Area, Macedonia (Northern Greece)

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Abstract. The ancient city of Europos (or Evropos), is located in Central Macedonia (northern Greece), not far from the city of Thessaloniki. The purpose of this research project, is to detect and delineate buried potential archaeological remains, and propose them to archaeologists for further field work. QuickBird, IKONOS, SPOT and ALOS satellite imagery have been used for this purpose, along with geophysical (magnetic and electrical) measurements. QuickBird imagery showed the best results for the purpose of our study. Preliminary results of this research, indicate a number of promising target-areas for a more thorough investigation.

1. Introduction

The ancient town of Europos (figure 1), is the birthplace of Seleucus, one of the generals of Alexander the Great, and founder of the Seleucid Empire. Although the archaeological site is partly excavated (cemetery, parts of the Acropolis, a pottery kiln and a few more remnants/figure2), the urban area around the aforementioned ruins is still to be discovered.

Various satellite images but mostly Very High Resolution/VHR images have been used the last years in order to detect areas of archaeological interest (Lasaponara and Masini 2007, Lasaponara et. al 2008, Ciminale et al, 2008, Pavelka et al., 2008, Due Trier et al., 2008, Aiazzi et al., 2008). The purpose of the present research project –in progress-, supported with images by ESA, is to explore the surrounding promising area, for delineating unknown potential archaeological sites, with the aid of geophysical measurements in certain areas.

2. Materials

The following data have been collected for the needs of the Project:

1) 2 (two) ALOS radar images, with acquisition dates 24/07/2006 and 22/08/2006, 10 m spatial resolution (ESA/Cat-1 Project).
2) 2 (two) SPOT-4 optical XS images, with acquisition dates 05/07/2008 and 06/07/2008, 20 m spatial resolution (ESA/Cat-1 Project).
3) 1 (one) IKONOS optical XS and PAN image, acquisition date 23/09/2007, 4m and 1m spatial resolution (ESA/Cat-1 Project).
4) 1 (one) QuickBird (QB) satellite optical XS and PAN image, acquisition date 07/09/2004, covered at expenses of the “Laboratory of Applied Geophysics”, of the School of Geology of the Aristotle University of Thessaloniki/AUTH.
5) One air-photo of 13/07/1979 is available for our Project, from the archive of the “Laboratory of Remote Sensing and GIS Applications” of the School of Geology of the Aristotle University of Thessaloniki/AUTH. Initial source of the air-photo is the Hellenic Army Geographical Service/HAGS.
6) Geophysical (magnetic and electrical) measurements have been performed in 3 parts of the study area (Laboratory of Applied Geophysics).

ENVI 4.7, NEST 4A and ArcGIS 9.3 software have been used for the digital image processing of satellite images and GIS.

All the above data are georeferenced to the UTM/WGS84 34N projection system and have been entered to a Geographical Information System/GIS environment.

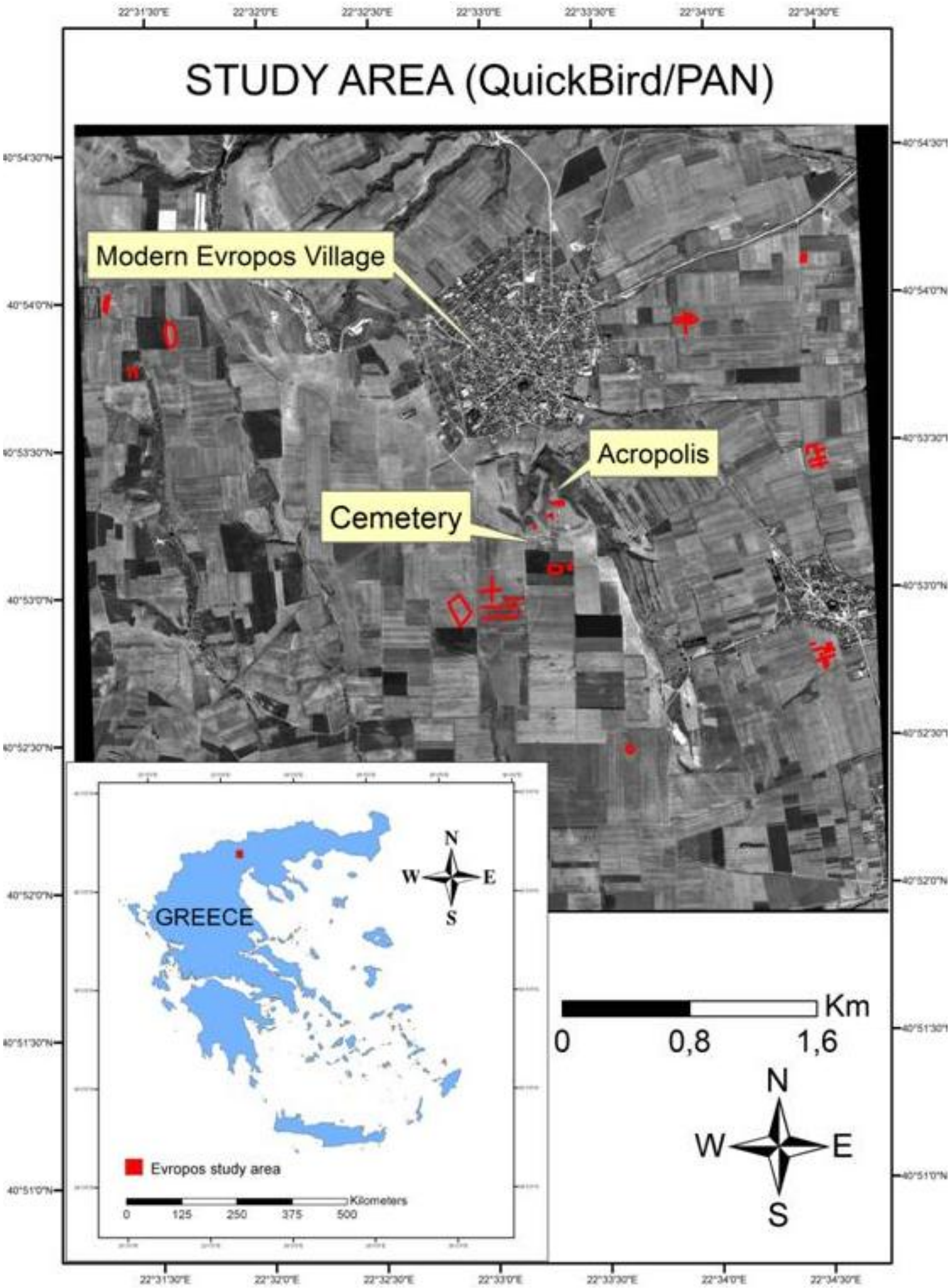

Figure 1a: Study area. Red lines on the satellite image show the potential archaeological areas.

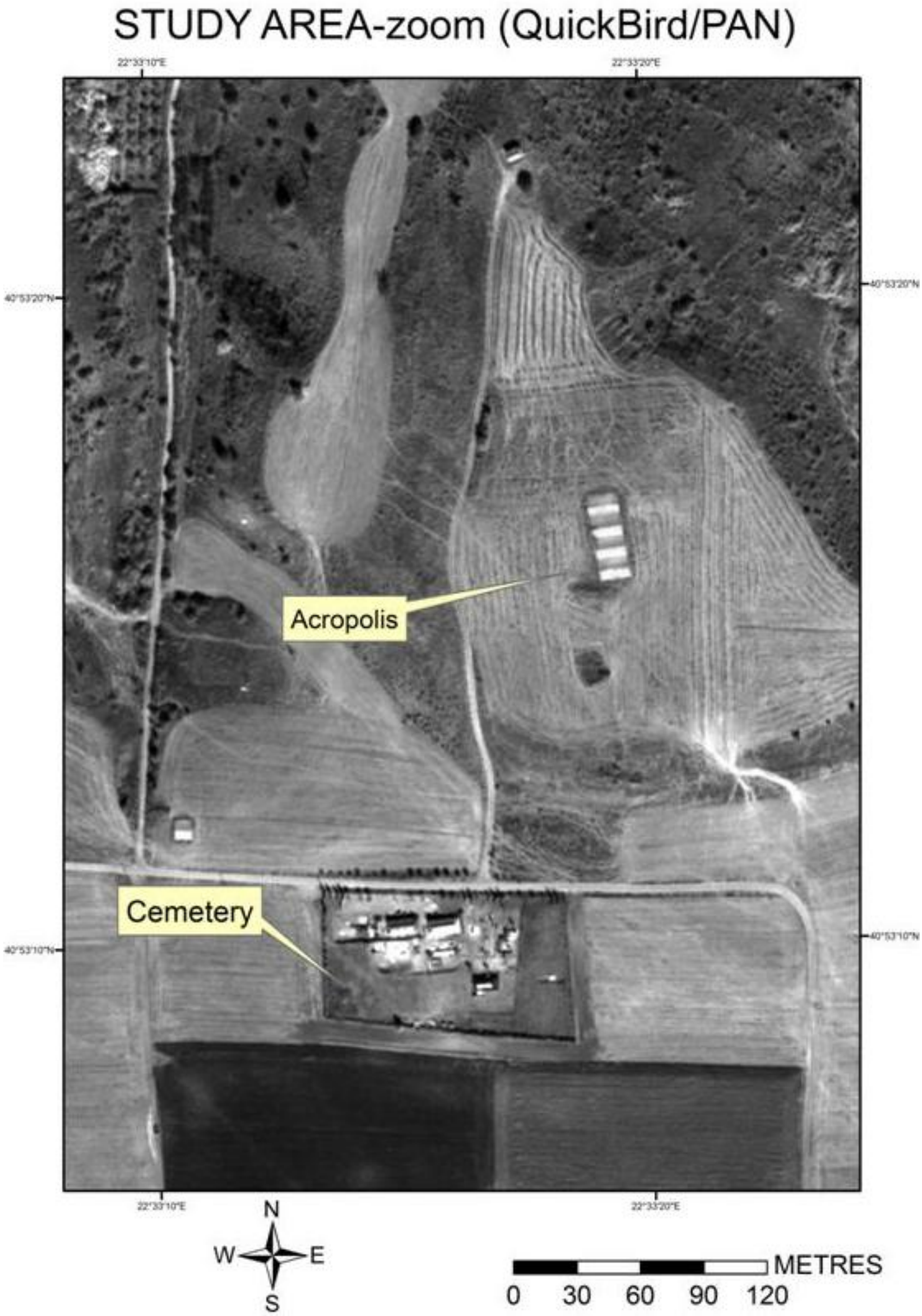

Figure 1b: A close-up of the excavated areas

Figure 2: Ancient Macedonian tomb in the Cemetery of Europos

3. Methodology

3.1 Satellite images

The ALOS, SPOT-4, IKONOS, QuickBird satellite images and air/photo have been digitally processed and visually interpreted, they have been inserted in a GIS environment, and having used them as a background, a number of target areas have been detected and delineated in a line shapefile. More specifically:

The two ALOS Radar images were digitally processed using the NEST-4A software. They were ordered at first place, because of their penetrating capability. Calibration, Speckle filtering, Coregistration and RGB/FCC synthesis took place. Some linear features were extracted, especially on the image of 22/08/06, but the spatial resolution of 10m is not very helpful.

The digital image processing of the SPOT-4 satellite images, was performed using the ENVI software. The spectral bands from this satellite were processed both individually, by applying radiometric corrections, enhancements and filters and as Red-Green-Blue/RGB False Colour Composites/FCC. The results of these images are not satisfactory for our research, mainly due to the inadequate spatial resolution of the images (20 m pixel size/). Therefore, pan-sharpening techniques were applied, with high-resolution images (IKONOS-QuickBird). Unfortunately, the big difference in pixel size, (20m and approximately 1 m respectively), didn't produce the desired results.

The IKONOS satellite imagery has satisfactory spatial resolution for archaeological purposes (4m in XS and 1m in PAN), but still didn't show very good results.

Finally, the best results were derived from the QuickBird image. The 4 XS bands (2.5m) were pan-sharpened with the PAN band (0.61m), using the Principal Component Analysis/PCA technique and Nearest Neighbor resampling. Then, many processing techniques took place, including image ratioing, FCC, IHS transformation, etc. However the best results were shown using the band 4 (Near Infrared/NIR), after applying a linear 2% enhancement. From this image, certain points of interest were delineated.

3.2 Geophysical data

Exploration/Applied geophysics is the applied branch of geophysics which uses surface methods to measure the physical properties of the subsurface Earth, in order to detect or infer the presence and position of ore minerals, hydrocarbons, geothermal reservoirs, groundwater reservoirs, and other geological structures. There have been many applications to archaeological research as well.

Geophysical measurements took place in the archaeological area of Europos in order to detect and map the archaeological structures. The project was performed by the Aristotle University of Thessaloniki by professor Gregory Tsokas, during the years 1989-1991 (Tsokas et. al, 1994). The gradient of total magnetic field and electrical resistivity were measured (figure 3). The goal of the magnetic methods is to detect the sub-surface´s magnetic changes because of the presence of buried structures. On the other hand, the purpose of the electrical method, which is also known as "Direct Current method", is the determination of the subsurface resistivity, by conducting measurements on the surface of the Earth.

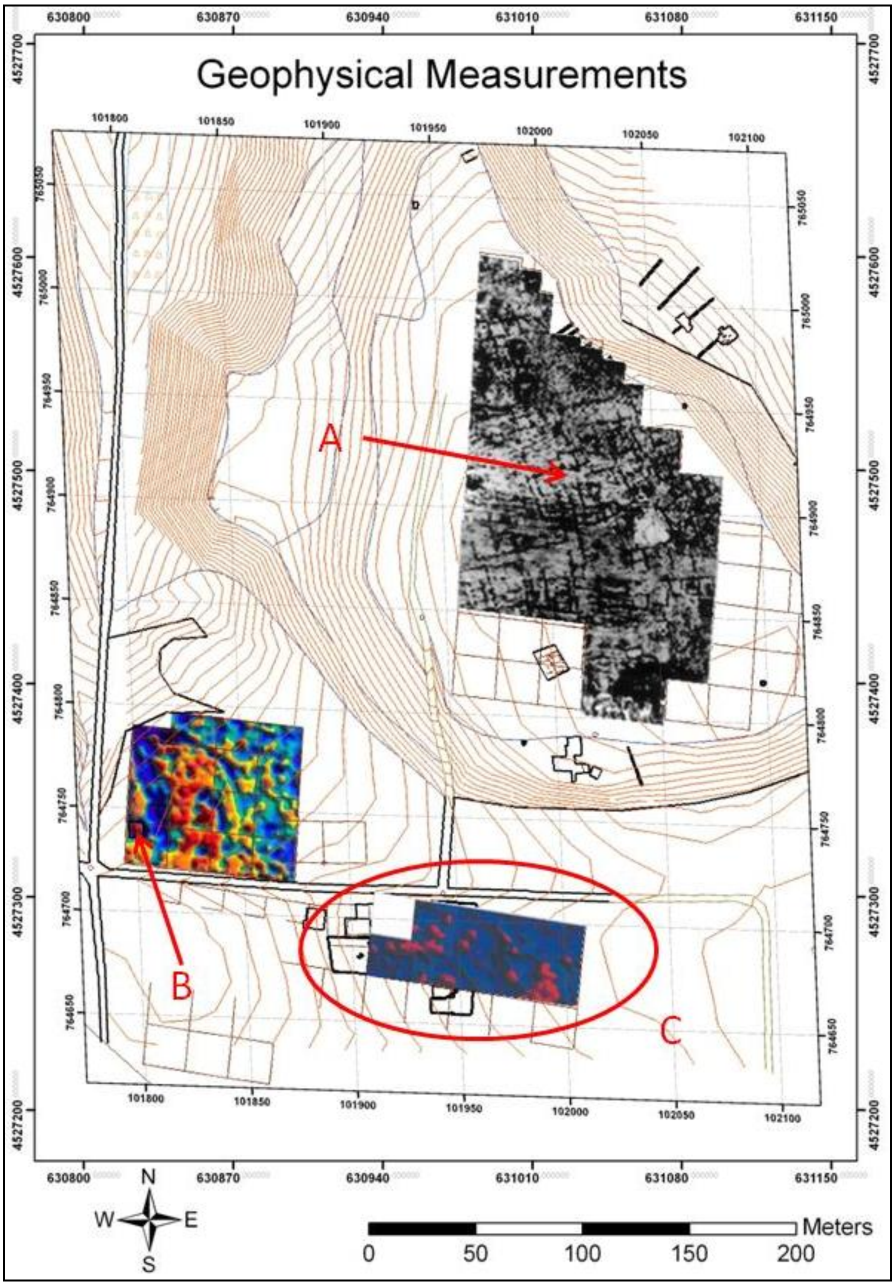

Figure 3: Ground resistivity measurements/top and bottom and magnetic measurements/left (see text for details/Tsokas et al, 1994).

More precisely, the gradient of total magnetic field was measured in areas left of the image (figure 3/B) and the variation of ground electrical resistivity was measured in areas top and bottom of the image (figure 3/A and C). The area was divided into 1m x 1m cells for the magnetic measurements carried out on top of the hill and at the foothills, in the area where craftsmen workshops existed once upon a time. Also, on top of the hill, resistance readings were recorded along 1m spaced traverses stepwise at 1m intervals. The area of the cemetery of the roman era (south part of figure 3), was explored employing the resistivity method. At this particular spot, readings were taken at 1m intervals, along traverses being 2m apart each from the other. The "twin-probe" array was employed for all electrical measurements. (Aspinall and Lynam, 1970), having the roving electrodes at 0.5m spacing for the uphill area (acropolis) and 1m for the cemetery. In figure 3, black or red colours show high values whereas white or blue, low.

The geophysical measurements proved to be very successful, considering the fact that based on the geophysical results the excavations in Europos took place during the years 1993-1995, revealing exactly the position of the monumental tombs in the Cemetery (figure 3c), part of the Acropolis (figure 3/A) and a pottery kiln (figure 3/B).

4. Results

Nine (9) points-areas of potential archaeological interest were delineated on the QB pan-sharpened Near-Infrared image. These are areas with straight/rectangular lines or circular structures (figures 4-9). In figure 4, the circular (point 1) and linear (points 2-3) structures extracted from the QB image match the structures depicted on the geophysical measurements. In figure 5, a rectangular structure and a set of straight structures (point 4) were delineated on the QB image. Also, some ellipsoid-circular structures were identified on the same image (point 5). Similar findings are detected in the figures 6-9.

In this point we must note that since many times the last decades in Greece, a re-allotment of land took place, it is necessary to check if the detected photo-lineaments/crop-marks represent old borders of fields/properties or not. This took place with the comparison of the results with the air-photo of 1979 and in the vast majority of the detected photo-lineaments, this was not the case.

5. Conclusions

SPOT images, although capable from the spectral point of view, proved insufficient, due to the low spatial resolution.

ALOS images, though promising due to the penetrating RADAR capability, showed weaknesses for the same reason (medium spatial resolution).

IKONOS image, though having a high spatial resolution (1m), didn't show the expected results, even though it is acquired in the same period of the year with the QB image (23/09/2007 and 07/09/2004 respectively). The answer probably is that there were different climatic conditions (rainfall), or the fact that the soil was cultivated a little before acquiring the IKONOS image.

QB image proved the most sufficient and effective means of remote sensing for exploring potential archaeological sites. In combination with geophysical measurements, in order to verify the results, it proved to be a very useful and time-saving tool.

The results of the present study will be passed to archaeologists, after the finish of the research project, in order to concentrate their efforts in the suggested areas, thus reducing a lot the time and effort needed for choosing new excavating sites.

Acknowledgements

The authors would like to thank the European Space Agency/ESA for the images given within the frame of Category-1 Project, ID: 7393.

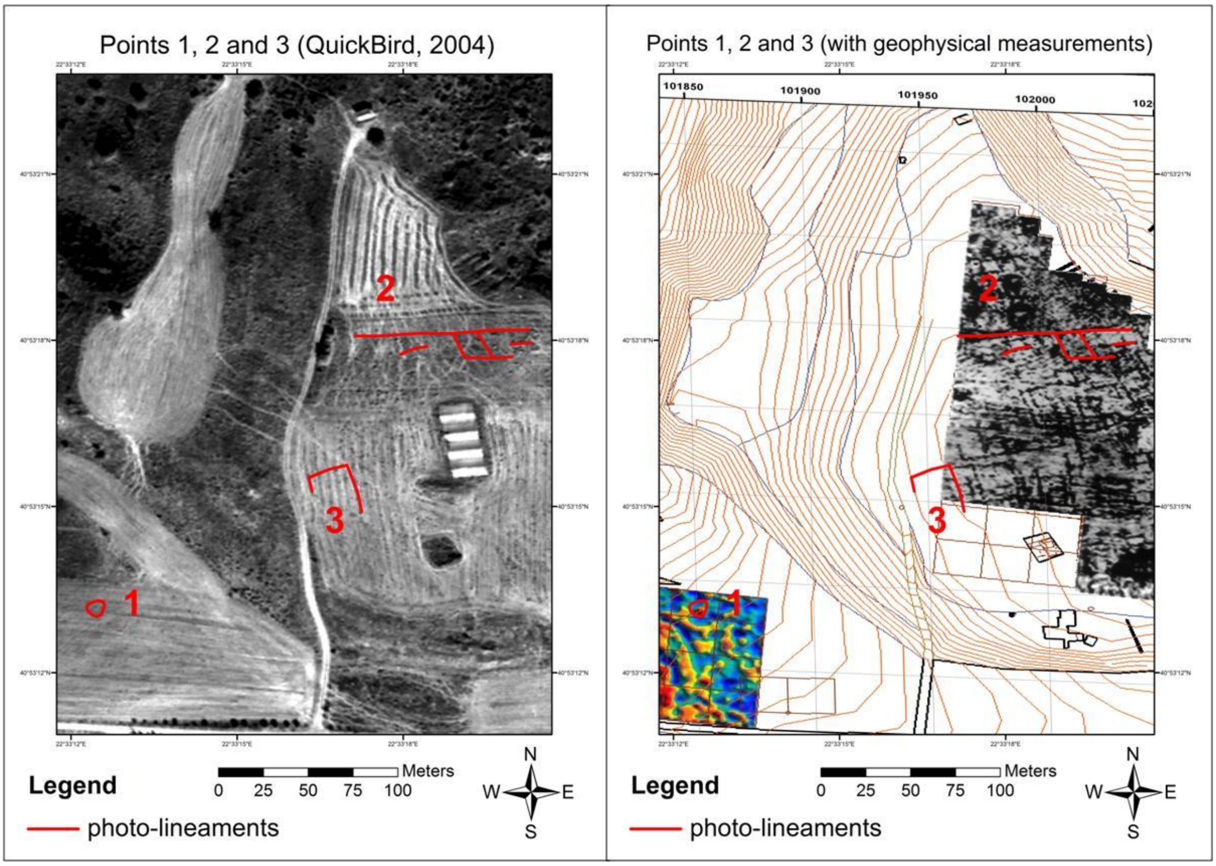

Figure 4. Points 1-3. Photo-lineaments (crop-marks) drawn from QB image (left) and super-imposed on the geophysical data (right).

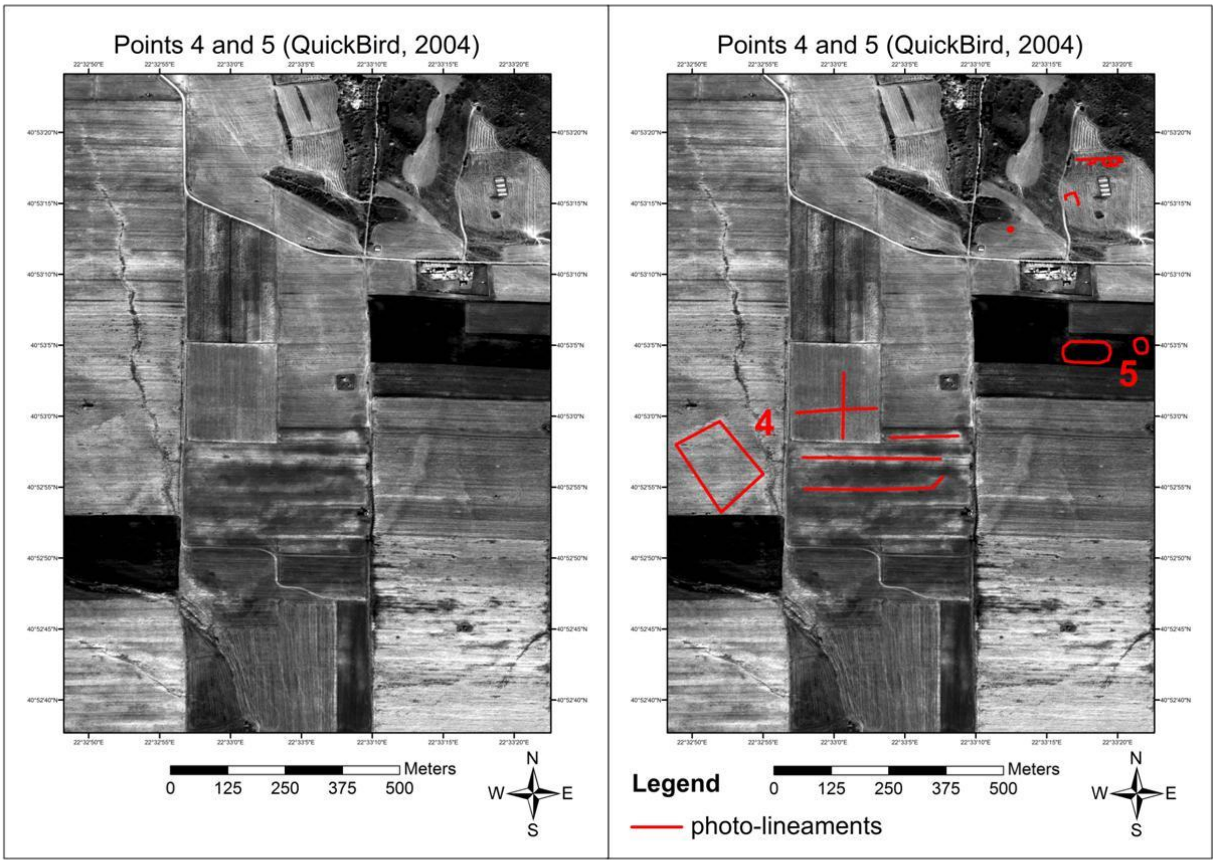

Figure 5. Example crop-marks detected from the QB image (points 4 and 5).

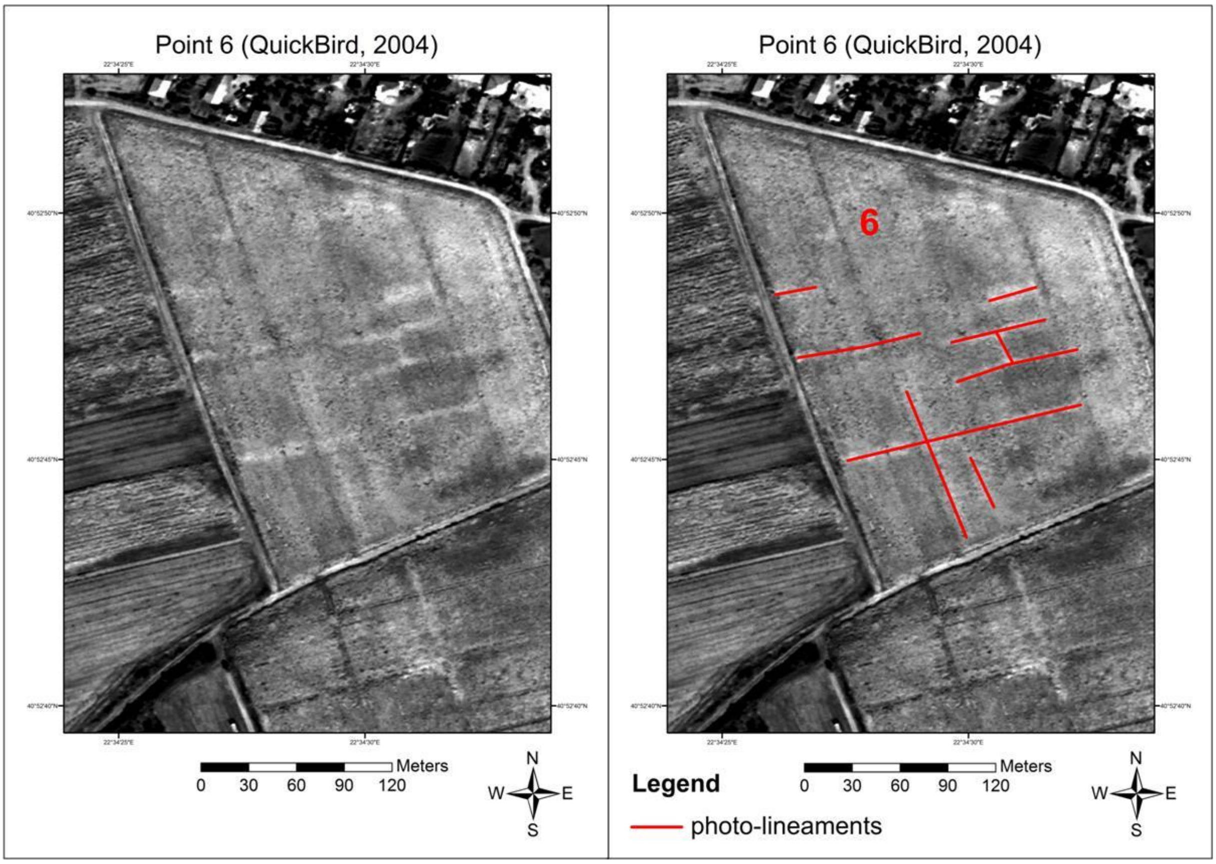

Figure 6. Example crop-marks detected from the QB image (point 6).

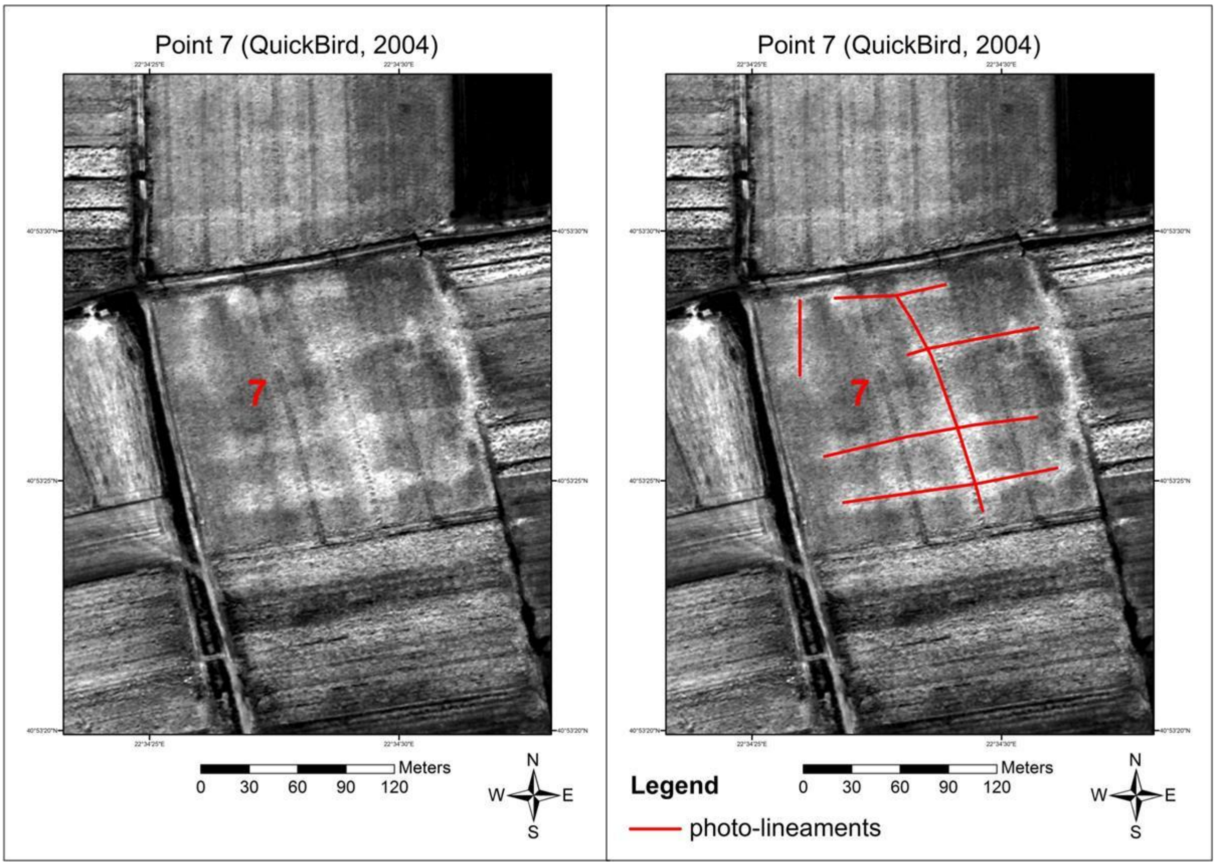

Figure 7. Example crop-marks detected from the QB image (point 7).

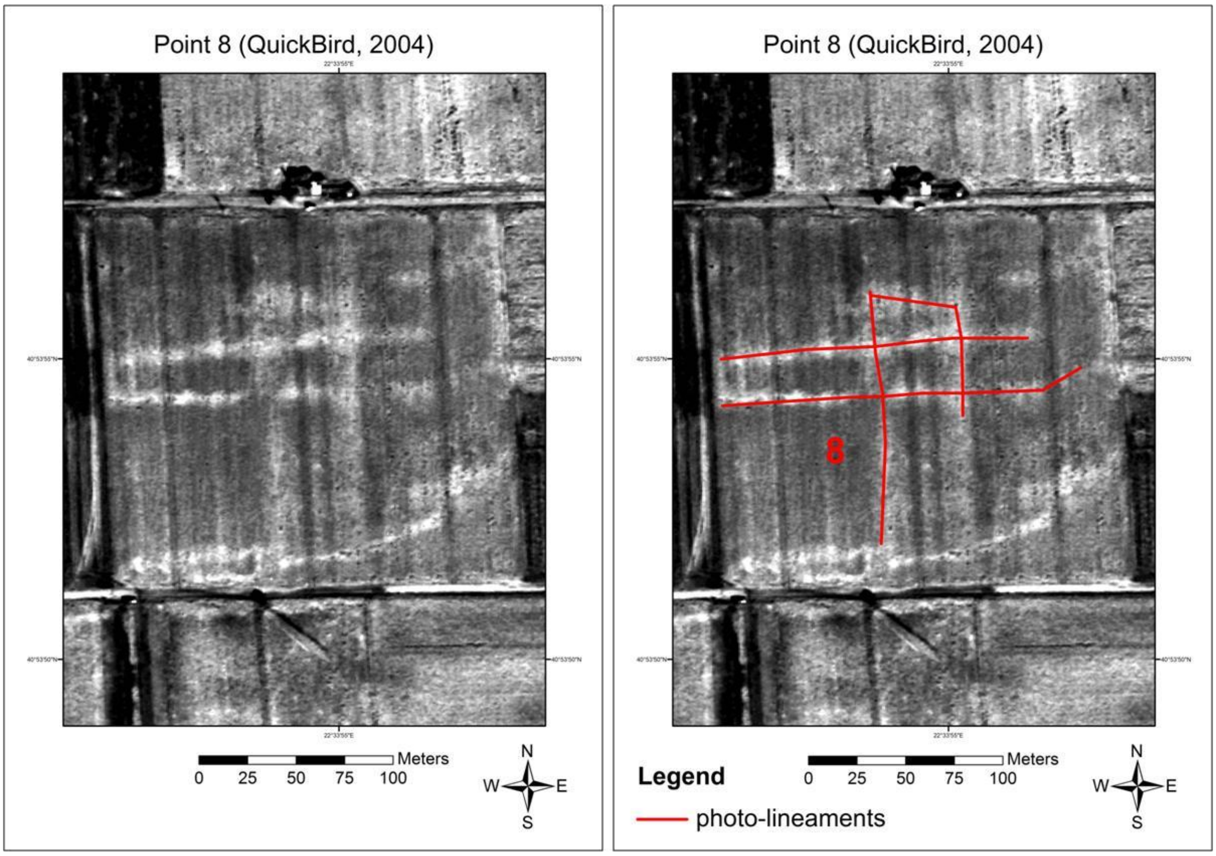

Figure 8. Example crop-marks detected from the QB image (point 8).

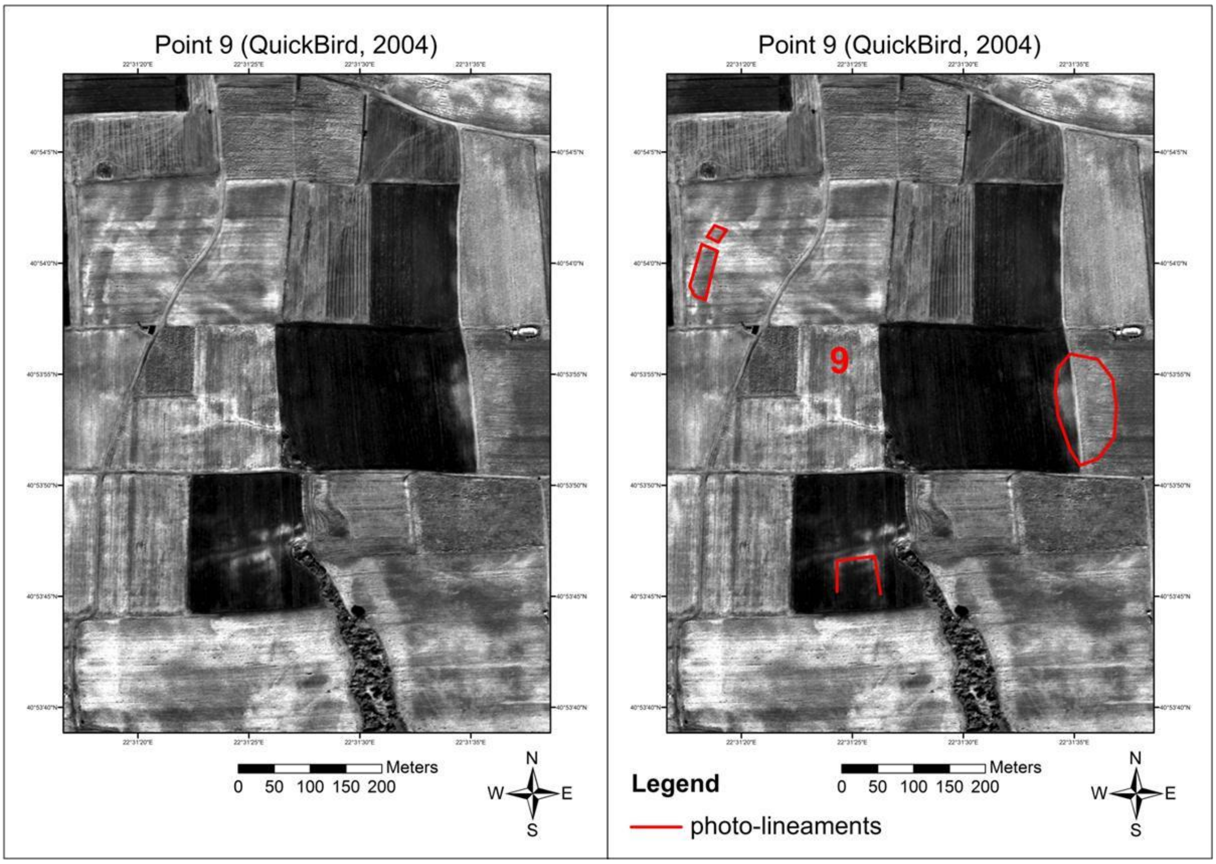

Figure 9. Example crop-marks detected from the QB image (point 9).

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EARSeL eProceedings

Publications in Vol. 10(2), 2011

ESA DUE Permafrost: An Earth observation (EO) permafrost monitoring system

Birgit Heim, Annett Bartsch, Kirsten Elger, Hugues Lantuit, Julia Boike, Sina Muster, Moritz Langer, Claude Duguay, Sonia Hachem, Aiman Soliman, Christoph Paulik, Tazzio Strozzi, and Frank-Martin Seifert

Abstract Read full paper online

The task of the ESA Data User Element (DUE) Permafrost project is to build up an Earth Observation service for permafrost applications with extensive involvement of the permafrost research community. The DUE Permafrost remote sensing products are 'Land Surface Temperature' (LST), 'Surface Soil Moisture' (SSM), 'Frozen/ Thawed Surface Status' (Freeze/Thaw), 'Terrain', 'Land Cover' (LC), and 'Surface Waters'.

A major component is the evaluation of the DUE Permafrost products to test their scientific validity for high-latitude permafrost landscapes. There are no standard evaluation methods for this range of remote sensing products, specifically not for these latitudes. Evaluation experiments and inter-comparison is done on a case-by-case basis, adding value and experience in validating products for these regions. A significant challenge in the evaluation of remote sensing products for high-latitude permafrost landscapes are the very sparse ground data. We rely on ground data provided by the Users and by international programmes. The primary international programme is the Global Terrestrial Network for Permafrost (GTN-P) initiated by the International Permafrost Association (IPA). Leading projects are the networks of the 'Circumpolar Active Layer Monitoring' (CALM) and the 'Thermal State of Permafrost' (TSP). Prime sites for testing methods and scaling are the long-term Russian-German Samoylov Station in the Lena River Delta (Arctic Siberia), and the tundra and taiga-tundra transition regions in Western Siberia (RU). The results of the first evaluations of LST, SSM and Freeze/ Thaw using GTN-P and User's data show the usability of the DUE Perma-frost products for high-latitude permafrost landscapes.

The DUE Permafrost remote sensing products will be adapted as drivers, validation data and as newly available external input data for permafrost and climate models.

AVHRR Archive and Processing Facility at the University of Bern: A comprehensive 1-km satellite data set for climate studies

Fabia Hüsler, Fabio Fontana, Christoph Neuhaus, Michael Riffler, Jan Musial, and Stefan Wunderle

Abstract Read full paper online

Over the last few years an increasing need for full resolution, multi-temporal AVHRR data for climate studies has been identified. To serve the purpose of climate change monitoring, certain requirements in terms of data consistency and continuity specified by GCOS need to be met. The University of Bern has received and archived daily full resolution AVHRR data over Europe for the period 1984 to date and aims at the establishment of a high-quality fundamental climate data record in accordance with these requirements. In this paper, details on the data availability and processing system are given. A selected application on snow cover retrieval from historical AVHRR data shows encouraging results regarding the generation of long-term climatologies from different essential climate variables. It is concluded that the archive presented and the existing preprocessing hold a great potential for becoming a valuable tool for the analysis of environmental changes in the European Alps and adjacent regions.

Retrieving forest biomass from the texture of SAR images

Isabelle Champion, Pascale Dubois-Fernandez, and Xavier Dupuis

Abstract Read full paper online

The objective of this paper was to study the use of texture features to retrieve forest biomass, which is of crucial importance to global carbon studies. Texture features are derived from: a) $\sigma°$ distribution statistics (variance and entropy), and b) the grey level co-occurrence matrix (energy, entropy). Radar images were acquired at P band cross and parallel polarisations using an airborne radar system built at the French aerospace laboratory and flying over an experimental forest at the north of the Landes region (France). This forest is documented by the French National Institute of Agricultural Research (INRA) as a controlled homogeneous test site: a single species, even-aged forest, subject to identical silvicultural treatment and the sampling of ten stands which cover all forest stages from sowing to harvest and provides sampled data on age, height, trunk dbh (diameter at breast height) and density measurements. Biomass was then calculated from ground data by means of allometric equations for these ten stands using stand age, dbh and density estimations.

Forest biomass was inferred from image texture using two methods. The first directly deduced forest biomass from image texture on the basis of biomass/texture regressions. As a second step we tried to avoid the use of structural measurements to calculate the biomass (stand dbh and density), so that dbh was inferred from texture and density was deduced from stand age. Total and stem biomass were then recalculated.

It was concluded that some of the texture indicators were significantly correlated to growth parameters (age, trunk dbh, biomass) displaying regularly linear variations. Moreover, the uncertainty related to these estimation methods was less than 20% of the biomass value, whichever way biomass is retrieved from texture (directly or through a dbh/texture regression). Texture could therefore be used as an alternative characterisation technique for plantation forests where intensity-based relationships are showing decreased sensitivity for mature stands.

The first seven years of the remote sensing based ragweed monitoring and control system

Gábor Csornai, Gábor Mikus, Gizella Nádor, Irén Hubik, István László, and Zsuzsanna Suba

Abstract Read full paper online

The Institute of Geodesy, Cartography and Remote Sensing (FÖMI) provides services to the Ministry of Agriculture and Rural Development. FÖMI has a 30 years' experience in the applications of remote sensing. The programmes carried out in this period served as a basis to ragweed control.

The allergy induced by ragweed pollen has become an important issue in Hungary: some 60-100 million Euros per year are spent for medication and medical visits and tests because of the allergenic effect of ragweed. In Hungary, some 500 000 – 700 000 hectares are estimated to be infected by ragweed. About 80% of this area can be pinpointed by remote sensing techniques concentrating on arable land. To ensure the efficiency of this priority programme, the government amended the plant protection law in 2005.

FÖMI has supported the nationwide Ragweed Control Programme by its proprietary remote sensing and GIS methodology to monitor and map significant ragweed infected areas. This development basically relied on the knowledge and experience gained in FÖMI's previous Crop Monitoring and Production Forecast programme (CROPMON, 1997-2003). The development of remote sensing (RS) and GIS methods plus the GPS technology makes the tasks of reconnaissance and field control more efficient. This system increases the success of preventing ragweed development. The system is a model for a range of integrated applications of remote sensing.

This article presents the main results of the programme until 2011. The seven years' operational experience in Hungary provides a realistic basis for adaptation in other areas.

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