THE USE OF SATELLITE REMOTE SENSING FOR LAND COVER MAPPING IN EUROPE

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ABSTRACT:

The use of Earth observation satellites for producing a large scale general land cover map in Europe is described. An overview of the recent stage of the CORINE Land Cover programme, some examples of its application and a short description of the experimental, extended refined version for national and regional level information is given. High resolution mapping by making maximum use of automatic procedures and low resolution mapping on the base of AVHRR data at continental level are shortly presented.

1. CORINE Land Cover and associated projects

The use of satellite Earth observation data for producing large scale general land cover maps in Europe can be viewed from three main points of view: the type of data (visible-IR data or radar SAR data), the spatial ground resolution (high resolution from 10 to 30 m or low resolution around 1 km) in turn connected to the scale envisaged, and the type of processing utilized (mainly visual interpretation or automatic classification and mapping).

General land cover mapping on large areas by using high resolution SAR data and for a relevant number of land cover classes (say, at least ten) is still a research topic and will not be considered here, although the European ERS-1 and ERS-2 satellite, the Canadian Radarsat and the Japanese JERS-1 all deliver high resolution data which will prove to be more and more useful for that purpose in coming years.

The CORINE (Coordination of Information on the Environment) programme of the Commission of the European Communities is "an experimental project for gathering, coordinating and ensuring the consistency of information on the state of environmental and natural resources in the Community" (CORINE Land Cover, EUR12585, 1993). The Land Cover project is part of the CORINE programme. Its aim is to provide up to date information on land cover at the scale of 1/100.000 for the whole Europe.

This prototype of large of land cover mapping applications in Europe using high resolution data was launched in 1985 (Cornaert, Maes,1992) by the General Directorate XI. (Environment and Civil Protection) of the European Commission and is now continued by the European Environment Agency within the frame of the "Topic Centre" on Land Cover.

The CORINE Land Cover project began on Portugal and extended progressively to the whole of the present European Union. It will be completed at the end of 1996, apart from Austria, Finland, Sweden and the United Kingdom, where completion is foreseen for the end of 1997 Norway is also being considered. An extension around the Mediterranean Basin in Turkey, Tunisia and Morocco will also soon be completed through the METAP (Mediterrenean Technical Assistance Programme) and MEDSPA (Mediterrenean Space) programme. In 1991 it was decided to extend the CORINE Land Cover inventories to the Central and Eastern European countries as part of the PHARE Regional Environmental Programme. The project started in 1993 in Bulgaria, Czech Republic, Hungary, Poland, Slovak Republic and Romania and will be completed at the end of 1996.

At first Landsat MSS (resolution around 80 m) data, then - thanks to high spectral and geometric resolution (7 bands and 30 m respectively) Landsat Thematic Mapper data were used as input data for photointerpretation. A standard methodology for data collection and presentation has been developed for Europe. The CORINE Land Cover includes 44 land cover classes embedded in a 3-level hierarchical system (11 classes for "artificial surfaces" and for "agricultural areas", 12 for "forest and semi-natural areas" and 5 for "wetland" and for "water bodies") at a nominal scale of 1/100.000. Such a detailed legend was only expected as being feasible by visual interpretation (although aided by computer procedures), with the simultaneous consultation of ancillary data (maps, aerial photographs, statistics). The minimum "interpretation unit" of 25ha was adopted and refined to 5ha in some cases. Field visits constitute an integral part of the project either for resolving ambiguities or for general checking of the photointerpretation. The land cover data is collected by different national teams, and integrated into a seamless European database according to the GISCO standards (Steenmans, C. 1996). The CORINE land cover data base has recently become available for a large part of the European territory. Although its exploitation is just starting, there exist many encouraging applications of the land cover database in countries which have already completed the project (Büttner et al., 1995).

After having finished the interpretation phase of the CORINE Land Cover in the scale 1/100 000, in four of the PHARE countries (Czech Republic, Hungary, Poland, Slovak Republic) an experimental project was

launched to extend this type of information for national level needs. As a first step to satisfy these needs the scale 1/50 000 and a minimum interpretation unit of 4ha was adopted. The merged SPOT P (resolution 10 m) and Landsat TM data integrated in false. A colour images represent the input data for photointerpretation. New 4th level of interpretation was introduced: 25 classes of 3rd level (scale 1/100 000) were divided into 63 classes of the 4th level (scale 1/50 000), while 19 classes of 3rd level could not be divided further in the sense of delimitation criteria (or they do not occur on the territory of the four proposing countries), their names of the 4th level as well as definitions agree with the 3rd level (Feranec et all., 1995). In the frame of the PHARE programme an experimental CORINE Land Cover interpretation in the scale 1/50 000 started in selected areas of Czech Republic, Hungary, Poland and Slovak Republic at the end of 1995 and will be finished by the end of 1996.

In the frame of the 1992 PHARE Regional Programme, a Remote Sensing Programme was requested in order to finalise the CORINE Land Cover Programme, but also to focus on specific applications of remote sensing for environmental management and assessment. This project deals with GIS (Geographic Information System) and the use of remote sensing as one of the basic data sources, which permits to obtain a tool for decision makers each within a specific area (Steenmans, C. Willemsen,H. 1996). Such programmes in Central and Eastern Europe are:

The Black Triangle GIS (Czech Republic, Poland with the technical support of the Phare Land Cover Unit). This project started in the Summer of 1995 and will demonstrate by means of practical examples the advantage of using GIS and integrated remote sensing techniques. Cross-boundary comparable environmental data are now available from the CORINE Programme. Detailed land cover information at scale 1/50 000 have been collected by means of integrated SPOT P and Landsat TM data using the refined CORINE nomenclature (level 4).

Danube Delta Project (Romania) is also carried out on the base of refined CORINE nomenclature (level 4), in the frame of the PHARE programme. These data will be used mainly to identify and delineate mapping units upon the nature and degree of intensity anthropic induced changes in landscape and ecosystems i.e. changes in vegetation and soil cover, in hydrological regime, in silting intensity, soils salinization, wind erosion on sand dunes etc. Finally a map with restoration problems will be compiled as a base for assessing the priorities to ecological rehabilitation (Vajdea, Munteanu 1994).
As concering the definition, as a general frame, the Corine Land Cover categories will be used for level 4 categories. But for improving thematic details new definitions will be added whenever they appear necessary. To have comparable results with other case studies a coordination of the Central Land Cover Team to necessary.

Danube Basin Remote Sensing Demo project (Hungary). The aim of the project which started at the end of 1995 is to demonstrate the possibility of the use of CORINE Land Cover data for a practical application, like hydrology/water management. The purpose is to estimate, model and analyze the run-off of non-point pollutants in the catchment of the Zagyva river. This can be achieved using land cover, provided by the CORINE project based on satellite imagery, other geographical data (topography, soils), meteorological data and an appropriate simulation model. Measured data (river flow, pollution concentration) will be used for calibration purposes (National Report of HSO, 1996).

Although the CORINE Land Cover programme succesfulhas been and has created European standard for land cover mapping and applications, the type of methodology chosen (visual interpretation involving an inevitably of subjectivity) brings serious difficulties for the necessary updating of the land cover data base at regular intervals. On the other hand, adopting automatic or semi-automatic procedures updating, would probably lead to redefining the original map/data base with a different, reduced legend. The trade off is in fact difficult to arbitrate at the present stage.

2. High resolution mapping by making maximum use of automatic procedures

A number of mapping exercises using high resolution satellite and automatic procedures were undertaken in the last few years at national level in various countries, including Finland, Germany, Great Britain, The Netherlands (Thunnissen et al.,1993) and Sweden (Rosengren et al.,1992). Landsat TM data were generally preferred due to the increased discrimination potential on soil and vegetation brought by the two middle infrared bands of TM. SPOT data were also associated in the case of Finland and Sweden, where the emphasis was put on forest mapping. The advantage of using automatic computer classification for mapping is, of course, the reproducibility of the processing which minimizes the amount of subjectivity involved and allows easier regular updating of the data base. The drawback of this solution lies in the more limited number of classes included in the nomenclature produced. They range within a minimum of 12 or 13 for Finland or Sweden and a maximum of 25 for Great Britain in the works mentioned above, although it must be noted that six typical Mediterranean CORINE classes are not present within those countries.

The scales range from 1/25.000 to 1/100.000 and the objective of the projects was generally to produce and regularly update a national land cover data base, with particular emphasis on the updating requirement. For Germany (Ellrott, Wendt,1993), the work was commissioned by a telecommunications company, for optimizing the cellular mobile telephone network.

In the case of Finland (Jaakkola,1994) and Great Britain (Wyatt,Fuller,1992), the mapped results will serve as a basis to produce the national CORINE land cover map by applying suitable map generalisation procedures. The maps should be completed in 1997 and will constitute the challenging task of combining a maximum amount of automatic processing with the CORINE legend requirements. In the framework of Cooperation in Science and Technology with Central and Eastern European Countries a cooperative project: the "Application of integrated methods for the monitoring and evaluation of natural and cultivated landscape vegetation for status, stress and drought, using remote sensing (with participation of Telespazio/Italy, EU JRC, FÖMI RSC/Hungary, OPOLIS/Poland, Czech Technical University/Czech Republic) is being implemented. The first results are connected with crop monitoring while the next phase will focus more on the natural vegetation monitoring.

Our own experience at the Joint Research Centre - on land cover inventory and mapping at a scale of 1/50.000 and for complex and variable physiographic conditions (Megier et al., 1991; Hill,1993) suggests that at the present stage and especially for demanding conditions which are often encountered in Europe, a compromise has to be found between reproducibility and large scale spatial consistency obtained with automatized computer processing and a more detailed legend affordable by visual interpretation. The necessity for consistent radiometric preprocessing and calibration of multitemporal imagery (Hill et al.,1995) - to accumulate information throughout the vegetation growing season - has also to be counted in. Future developments in sensor technology and computer-based image understanding might of course alter the present situation.

3. Low resolution mapping at continental level

Mapping by remote sensing over the whole of Europe, from Portugal to the Urals, was first performed in 1992 (Pseiner et al.,1992) for producing a digital forest map of Europe with only two classes ("forest", "non-forest") at a maximum scale of 1/1.000.000 by using NOAA-AVHRR data (1,1 km ground resolution).

A number of exercises have started meanwhile, aimed at producing similar scale, large extension land cover maps over Europe using AVHRR data (Veldkamp et al.,1995), but the results are not yet available. The anticipated objectives range from global land cover monitoring to agro-meteorological modelling and global climatological assessments.

The use of these data bases must naturally be compatible with the reduced number of broad land cover classes technically affordable in this context (four to six maximum, excluding inland surface water). However, even such a modest legend requires the implementation of a systematic use of multitemporal satellite data over the whole growing season (typically, one coverage per month from March to September or October) in order to reach the required potential of class discrimination. Preliminary geometric and radiometric calibration of the data are thus mandatory although not at all a trivial problem, especially for the latter.

The European AVHRR land cover map at scale 1/1.000.000 undertaken at the JRC Ispra well illustrates the above mentioned requirements and problems. The first rather extended results on Belgium, France, Germany and The Netherlands are presented in more detail in this congress (Hoffmann,C.: The fusion of GIS information and remotely sensed data for mapping European scale land cover, Com.IV. W.G.1.) They are obtained with 4 land cover classes (built-up, sparse vegetation, vegetation, cropland) but forest will be separated from vegetation in a second step.

The AVHRR data have been previously stratified into 13 ecosystem regions and are then processed independently on a regional basis (European Commission, 1995). 68 relatively cloud-free AVHRR mosaics have been used and reduced to eight monthly maximum value composites from March to November 1995. Each month NDVI and surface temperature values (Ts) are used together in an attempt to more effectively discriminate the regional land cover classes (Hoffmann C., Roy D., Stein A., 1995; Roy D., Kennedy P., Folving S., 1996). The first accuracy assessments indicate a high degree of consistency with the high resolution mapped results on eight test areas of 40x40 km extension and a reasonable correlation with EUROSTAT regional statistics of soil occupation together with a constant spatial consistency of the class labels across the boundaries between the various ecosystem regions considered.

The trade-off on using this type of low resolution data obviously lies between the limitation of the broad class legend achievable and the possibility of easily mapping and updating extensive areas up to continental level, although the near availability of the "Vegetation" instrument on SPOT 4 (1998) will improve the class discrimination potential, due to the presence of the middle IR band around 1,7 mm.

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Appendix: Authors and Co-authors Index
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