THE FUSION OF GIS INFORMATION AND REMOTELY SENSED DATA FOR MAPPING EUROPEAN SCALE LAND COVER

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ABSTRACT:

The paper illustrates the complementary usage of low and high spatial resolution remote sensing data and GIS information in the production of a digital European land cover map at an approximate scale of 1:2million. Regionalization, pixel class labelling, and classification accuracy assessment procedures are performed at a variety of spatial scales using ancillary remotely sensed preclassified data and spatial and aspatial information held in a GIS. The study indicates that high spatial resolution remote sensing images can be used to assign and validate AVHRR clustering results. The processing procedures described in the study could not be implemented in an efficient, reliable or timely manner without the use of GIS techniques.

INTRODUCTION

The Environmental Mapping and Modelling Unit (EMAP) of the Space Applications Institute (SAI) has initialised a project to demonstrate the feasibility of producing a European land cover map using Local Area Coverage (LAC) NOAA-AVHRR data. Land cover mapping procedures usually require extensive user interaction, particularly in the assignment of meaningful land cover labels and in the assessment of classification accuracies. The cost of user interaction rapidly becomes prohibitive as the amount of remotely sensed data increases (Hoffmann and Belward, 1996). The study indicates that summary and agglomerated statistics of high spatial resolution remote sensing images can be used to assign and validate AVHRR clustering results.

There is a rich history of using NOAA-AVHRR data for land cover classification at regional and continental scales. This is because of the moderate spatial resolution of the AVHRR sensor and its daily world-wide coverage. Most studies have used vegetation indices extracted from AVHRR time series to discriminate between land cover types. Recently it has been empirically demonstrated over Europe (Roy, 1996) and Africa (Lambin and Ehrlich, 1995) that the inclusion of surface temperature can discriminate regional land cover classes more effectively than vegetation indices alone. In this study surface temperature (Ts) information and a vegetation indices (NDVI) are derived from multitemporal AVHRR data. This is for two reasons, firstly, in an attempt to increase classification accuracy and secondly because there is evidence to suggest that NDVI and Ts may be interpreted in a biophysically meaningful manner at regional or continental scales.

METHODOLOGY

NDVI and Ts data, extracted from a time series of European AVHRR images are used as the primary data source. These data are processed independently on a regional basis in an attempt to reduce regional variations in NDVI and Ts and in an attempt to automate the process as shown in Figure 1. Principle component analyses is performed in each region to reduce inherent data redundancies (e.g. temporal correlation) and to remove residual noise.) The methodology used for land cover class separation is unsupervised classification, followed by cluster labelling. The cluster labelling is performed by examination of NDVI and Ts values and by the examination of pre-classified high spatial resolution (20m) SPOT/LANDSAT TM test images selected from the data archives of the Monitoring Agriculture by Remote Sensing (MARS) project. In addition, urban classes are located across the entire image using the Digital Chart of the World database.

The AVHRR clusters in each different region, resulting from unsupervised classification, are labelled into land cover types by resampling, using the nearest neighbour resampling scheme to the same pixel resolution as the pre-classified high spatial resolution test imagery. This permits a one to one pixel relationship between the two scales of data. The MARS classes are then agglomerated and compared with the unassigned resampled AVHRR clusters. This is achieved by histogramming the agglomerated MARS classes that fall under each unique AVHRR cluster. Several test images within the same region are treated independently in this manner and then compared to ensure consistency within region cluster labelling. Cluster labels are then applied to the rest of the AVHRR data lying in the region. In many regions this procedure is performed iteratively using progressively more agglomerated classes defined by the higher spatial resolution image classifications. Validation of the classified regions is finally performed by comparison of the classification results with regional surface area land cover summary statistics.

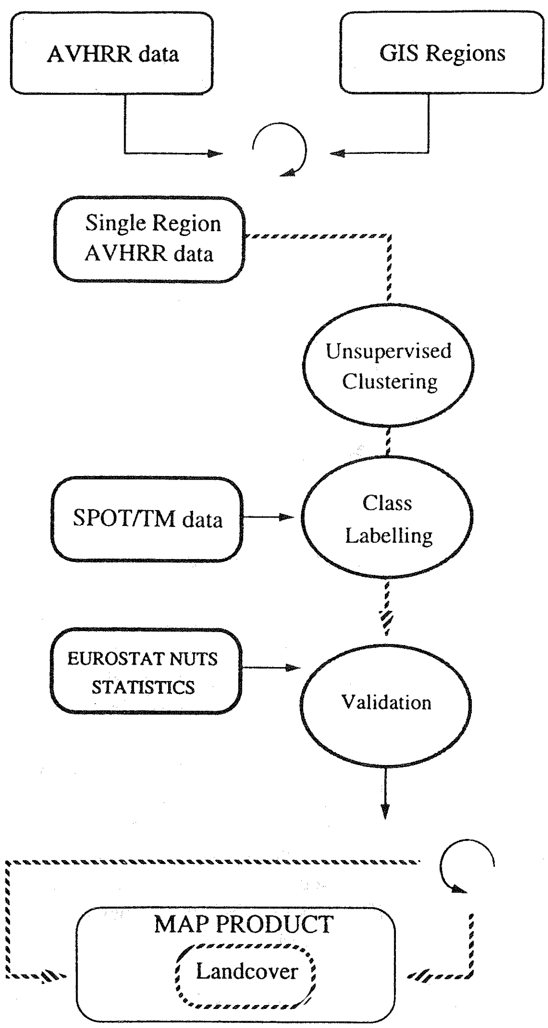

Figure 1: Flowchart describing the regional approach with class labelling and validation procedures.

DATA

68 relatively cloud-free AVHRR mosaics have been selected from the data archive of the SAI-MARS project (Roy, 1996). These images cover a geographical area from the Portuguese coast to central Crete and from northern Algeria to southern Sweden, and were acquired over the main growing season from March to October 1993. Each mosaic is made from between 3-6 AVHRR-LAC (1.1km pixel) afternoon pass images. Missing data, water and clouds are thresholded out. The 68 AVHRR mosaics are reduced to eight monthly maximum value composites to lessen the amount of data to be processed and to reduce undesirable atmospheric effects (Holben, 1986). NDVI values are extracted from the AVHRR composites using the red and near infrared pixel values (Curran, 1983) and Ts values are extracted using the thermal infrared pixel values (Price, 1984). In total six images, each composed of 2779 by 2343 pixels with NDVI and Ts counts defined over a 10 bit range are derived.

The AVHRR data are stratified into 13 ecosystem regions and classified independently on a regional basis. The ecosystem were defined by a recent European Commission study at a scale of 1:2.5million using topographic, soil and climate variables (Kennedy et. al., 1995). Large inland water bodies are also defined and are used to assign water class labels. While the ecosystem regions serve as a basis for stratification, a further sub-division of some geographically large areas was found to be necessary after visual inspection of the clustering results.

Class labelling is performed using MARS pre-classified high spatial resolution test images selected from the SAI data archives. In addition, urban classes are sited across the entire image using the Digital Chart of the World database (DCW) (ESRI, 1993). The DCW database consists of spatial and aspatial data that can be accessed, queried and displayed with a GIS. The populated place layer of the DCW depicts the urbanised areas that can be represented as polygons at 1:1Million scale.

Validation of the classified regions is performed by comparison of the classification results with landcover summary statistics defined by the Statistical Office of the European Union (EUROSTAT). The Nomenclature of Territorial Units for Statistics (NUTS) has been established to provide a uniform breakdown of territorial units for the production of regional statistics. The NUTS regions use a common landuse nomenclature and are hierarchically defined at different scales based on the institutional divisions in force in the Member States.

RESULTS

A strong spatial correspondence between the cluster patterns and the urban area as defined in the DCW was generally observed across Europe, and led to some confidence in the assignment of the urban class labels. Furthermore 10 MARS high resolution test images across four independent regions were examined and showed a high degree of surface area correlation between the labelled AVHRR land cover classes and the MARS test images (e.g. cropland $0.61 \leq r \leq 0.99$). However, the results must be regarded with some caution as area estimates made by pixel counting over large regions are biased when there are mixed pixels and when the classification accuracy is not high (Czaplewski, 1992). A further indicator of the consistency of the results is the fact that spatially continuous AVHRR class labels occur across ecosystem region boundaries even though the AVHRR data have been classified independently in each region. Figure 2 and 3 illustrates a strong relationship between the AVHRR cropland and forest classes and the validation statistics derived from EUROSTAT for NUTS 2. While not all validation data for Belgium, France, Germany and Holland were available and in addition only NUTS 2 regions with less than 10% cloud coverage were selected, it was possible to examine the surface area coverage correlation of cropland in 27 regions (R2=0.71) and of forest in 20 regions (R2=0.75).

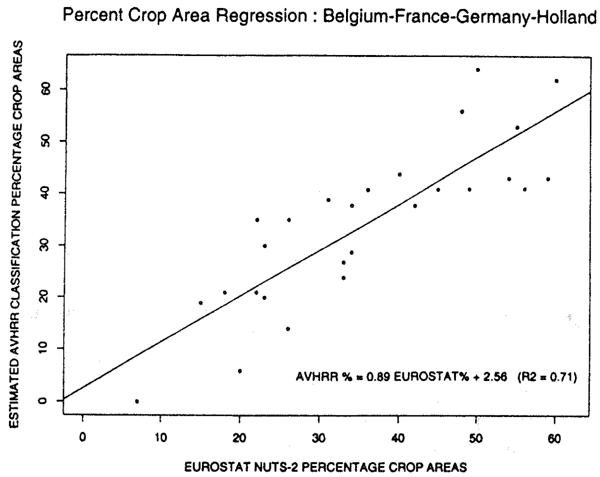

Figure 2: Regression showing the surface percent crop area coverage in 27 NUTS 2 regions.

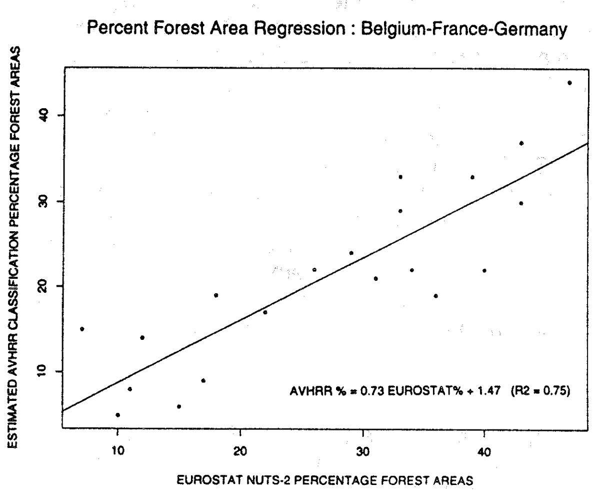

Figure 3: Regression showing the surface percent forest area coverage in 20 NUTS 2 regions.

CONCLUSION

This paper has illustrated the complementary usage of remote sensing data and GIS information in the production of a digital European land cover map at an approximate scale of 1:2million. The high repetitive rate on which each process has to be carried out and the large amount of data requires the efficient integration of diverse data sets and a reduction in user interaction. The proposed methodology indicates that a high degree of automatization can be implemented but that some user interaction particularly in the assignment of land cover classes is and should still be required. The processing procedures described in this study could not be implemented in an efficient, reliable or timely manner without the use of GIS techniques.

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