A Comprehensive 1 : 100,000 Landuse Map Series for the Federal State of Saxony (Germany) from Satellite Imagery

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0 Abstract

Under contract of the Federal Agency of Environment and Geology of Saxony the Institute of Cartography of Dresden University of Technology digitally classified a monotemporal set of actual Landsat-TM data to generate a digital landuse data bank for the whole territory of Saxony and adjacent areas (approx. 27,000 km^2) based on a 16 categories classification key. Parallel to the digital classification the Institute was put in charge to produce an analogue 1:100,000 landuse map series in cooperation with the Federal Geodetic Survey of Saxony. For this product the digital results were visualized and combined with a specifically designed base map derived from the official Topographic Map series of the same scale. The whole project has a pilot character for Germany since it made hybrid analogue and digital landuse data sets for the whole territory of a federal state available to everybody with geometric accuracy standards matching those of the official 1:100,000 Topographic Maps and the misclassified pixels being limited to a total of less than 5%.

Geometric accuracy could be guaranteed by using a large set of ground control points (340) and a independent, statistically distributed set of control points not used for the calculation of the transformation polynomials. A multi-step classification method has been applied which combined spectral and textural image features. Finally, generalization methods can briefly be presented to allow the generation of secondary cartographic products from the existing data.

1 Introduction

A detailed knoledge of the actual landuse patterns can be regarded as a key parameter for ecological and economical spatial planning. For any level of environmental assessment the basic task is a comparison between the natural potential of a given section of the geosphere and its existing and/or planned human utilization. A couple of reasons can be set forth why remote sensing often is the most appropriate source of information for a landuse inventory, of which the following might be the most obvious ones:

- high actuality,
- an unequivocal temporal datum of the data,
- accessability of a-priory digital image data or quick conversion of image data into a digital format enabling a digital processing chain from raw data to classified GIS-data,
- a concise interpretation key and system which is unaffected by administrative or statistical borderlines,
- high efficiency compared to field surveying.

A number of digital landuse data bases has already been prepared in most parts of Europe, of which the CORINE land cover programme might be the best known. It can be seen as a contribution to standardize European statistics. Landuse data are intensively used in the private sector, too, for example for signal propagation calculations in the rapidly growing field of telecommunication [1]. Further examples are hydrologic, meteorologic modelling or ecological impact analysis for transport lines [2]. Depending on the information requirements of the orderer and the remote sensing data used, the classification scheme, the spatial resolution of the results, and the accuracy standards are varying in a broad range. There are, however, scale-independend minimum resolution requirements for remotely sensed data related to the properties of the landscape since radiance measurements as from satellites cannot produce landuse-specific signals if the percentage of mixels (spatial integration of a measurements over more than one type of object) exceeds a certain frequency.

2 The Outline of the Project

The Federal Agency of Environment and Geology (Freiberg, Saxony) commissioned a digital landuse classification for the whole of Saxony with the Institute of Cartography of Dresden University of Technology in autumn '93. The project working time was at first envisaged to be 9 month but had to be extended until December '94 because of unforseeable problems due to the change in the geodetic reference system of the official Topographic Maps. The key specifications of the classification can be summarized as follows:

- Full coverage of the state of Saxony plus some adjoining territory in Czech Republic, Poland and four other federal states of Germany (approx. 27,000 km^2);
- Digital classification of monotemporal Landsat-TM data according to a 16-class landuse scheme (comp. table 1);
- Precise geometric rectification of the data to match the standards of the official 1:100,000 Topographic Map;
- Accuracy requirements for the classification allowing only 5% of misclassified pixels.

Forest, deciduous	Agriculture, Meadows	Settlement, Allotment Gardens	Transport (Roads, Airfields, Railway Tracks)
Forest, mixed stands	Agriculture, ploughed land	Settlement, low density built-up	Quarries, Waste Deposits, Stone Pits
Forest, coniferous	Agriculture, Orchards	Settlement, medium density built-up	Lignite Open Pit Mining
Forest, heavily damaged stands (or young afforestation)	Agriculture, Vineyards	Settlement, high density built-up	Waterbodies

Table 1: Landuse/Landcover Classification Scheme.

The classified data were made available in digital and analogue form. Digitally, they are stored in ERDAS-Imagine or ArcInfo raster format and can also be handed over as ArcInfo coverages. For the compilation of the analogue landuse maps a contract was signed between the Saxonian Geodetic Survey and the Institute of Cartography. The institute was put in charge for map design and all processes *up to the colour-separated fair draughts on film* while printing and distribution of the maps was laid in the hands of the Geodetic Survey.

3 Geocoding and Classification of Satellite Image Data

Our first step was selecting of appropriate satellite data. Three Landsat TM scenes from two orbits (192_24 from Aug. '92 and 193_24/25 from July '93) were chosen, all of them cloud-free and not older than 15 month at the time of project kick-off.

For the rectification of the imagery (method comp. [3]) the German Gauss-Kruger-System (Transversal Mercator) with a 3-degree width of the meridian stripes served as reference system. Therefore, half of the data are georeferenced to the 12°-East meridian and the other to 15°-East meridian, but can easily be transformed to the other with most GIS- or image processing software. Alltogether, 340 ground control points measured in 1:50,000 Topographic Maps were used for calculating a second-order transformation polynomial. At first, however, a substantial part of these data had to be transformed into the target geodetic system since they had to be measured in old GDR maps with a different geometry. Despite of this dubbling of transformation for some data the quality check based upon independent control points showed good results with RMS-errors of approx. 20 meters in NS- and EW-direction.

Care should be taken in the scaling of data subsets which have to be classified in one set:

- Not too large to allow a better interactive control of the classification process and to reduce the number of different landscapes incorporated,
- not too small to keep the number of interactive steps and the length of borderlines between data sets (where often some trimmming is necessary afterwards) in a tolerable range.

From our experience we can state that a 2000 km^2 area in the partition of the 1:100,000 Topographic Map sheets was a good compromise.

A sophisticated processing chain [extensively described in 4] had to be created to minimize the time consuming interactive editing of the classification results. Our basic strategies were the following:

- Hierarchical structure of the classification process allowing an optimization of the classifiers at each step;
- Combination of seperately started spectral- and texture-based classifications by logical operators;
- Controls and interactive corrections of the results at early stages of the classification process;
- Class assignment of 'problem pixels' at a late stage of the classification considering the patterns formed by the surrounding, already classified pixels.

Common pixel-by-pixel classifiers (hyperbox, maximum-likelihood) were combined at many of the various stages of the classification process. Texture classification especially assisted the classification where surface materials (and the measured spectral remission) are highly variable, what is typically found in built-up areas. Our texture measure is the development of minimum differences of gray values (for one band) or spectral distances (for multispectral data) in small windows sized between 2 and 9 pixels, which are moved into different orientations around the central pixel.

Primary sources for the evaluation of the classification results and also for the corrections were the 1:50,000 maps with full coverage and 1:10,000 CIR aerial photographs. The aerial photographs were selected in contiguous blocks of approx. 100 km^2 to form one reference unit per 1:100,000 map sheet (approx. 2000 km^2) and to represent the variety of different landscapes in Saxony. An effective method to check the results visually proofed to be the digital combination of the classified colour-coded raster data with high-resolution panchromatic Russian space photos of the KWR-1000 system (2.5 m linear geometric resolution). For that an overlay effect was produced by IHS-transformation. The structures of the KWR-1000 data appear as the intensity part of the composite image and the hue and saturation origined from the colour-coded classification. Because of limited availability of these data and the costs the test was limited to an area of approx 100 km^2 centered to the town of Dresden.

4 Updating of Landuse Data Bank

Parallel to the statewide landuse classification research work has also been directed to the detection of landuse change in the agglomeration of Dresden using multitemporal Landsat-TM data in cooperation with the Institute of Ecological Spatial Development, Dresden [5]. From the results for a 3000 km^2 study area conclusions can be drawn concerning the speed of landuse change and the periods when updating of the landuse data bank will become necessary. In a 6-year span covered by the TM-data 25% of the area showed changes of landcover. However, a major part could be attributed to internal changes in different classes of agricultural land or forests, 9% were relevant in the sense that changes occured between vegetation-dominated open space and classes with a substantial part of man-made surfaces (like built-up land, roads, airstrips, construction sites, ...). After rigorous filtering of the 'change image' with a specifically designed kernel uncertain and dispersed pixels were removed and an accuracy of approx. 96% could be achieved in the secondary results. For Dresden and surroundings approx. 3.5% of the total area was lost for agricultural utilization, whereas 1.2% were converted into settlement area and 1.6% reforrested. Even larger areas of change can be found in the open-pit mining areas in Saxony when landscaping and afforestation is taking place after mining has stopped. We can conclude that with such rapid change rates a 5-year updating interval by remote sensing data would be a desirable target.

5 Map Design and Production

Digital and conventional methods were combined for the compilation of the 1:100,000 landuse map series (fig. 1). Subsets of the colour-coded thematic data were printed using a precision laser film writer and combined with reduced information of the corresponding official 1:100,000 Topographic. Map size, front and backside, as well as typographic style were adapted to the Topographic Map as far as possible. A fully digital map compilation was inhibited by the following deficiencies:

- Until now there is no comprehensive, fully structured digital topographic data base available in Saxony;
- The scanned flaps of the 1:100,000 Topographic Maps had the disadvantage, that their feature separation was not sufficient for our purpose;
- Resampling of landuse image to the resolution of the topographic raster data (to allow the print of fine linear structures) means expanding the original data size by 10 times.

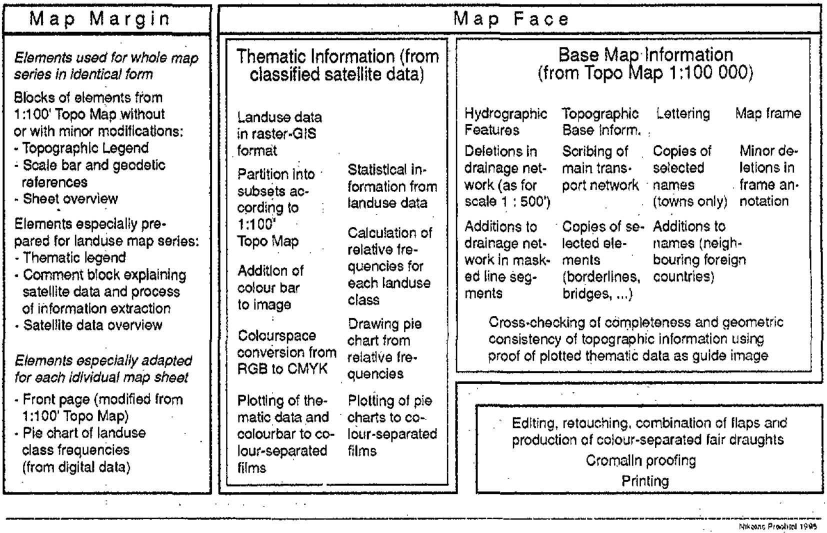

Fig. 1: Compilation of the 1:100,000 Landuse Map of the Federal State of Saxony.

The visual organisation of all map elements (fig. 2) was arranged in a way that blocks could easily be inserted or exchanged with every new sheet being compiled while other elements could be used in every sheet without alterations. All thematic information including a pie chart of landuse class percentages and the colour bar of the thematic legend were digitally processed and sent to a raster film writer. All other elements were conventionally prepared using positive and negative artwork techniques. For the base map the original contents of the Topographic Map sheets were reduced to the following elements to keep the map well readable:

- Drainage network using a 1:500,000 work sheet of the National Atlas of the GDR as guide image;
- Transport comprizing major country roads, motorways and railway lines;
- Lettering confined to town names and hydrographic names.

A time consuming task was the reconstruction of numerous line segments on the drainage flap which had been taken off for the placing of symbols or lettering but were needed for the landuse map.

6 Landuse Data in Overview Scales

With a given cell resolution of 25 meters a scale of 1:100,000 or 0.25 mm for one printed landuse element seems to be appropriate for visual representation. Furthermore, tests have been carried out how the data could be used for overview scales showing the whole territory of Saxony in one sheet (1:200,000 to 1:300,000).

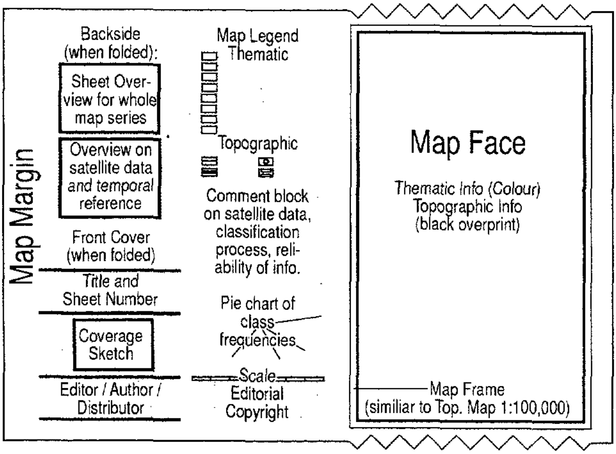

Fig. 2: Visual Organisation of the 1:100,000 Landuse Map of the Federal State of Saxony (not to scale !).

Some generalization seems to be unevitable if one regards the spatial organisation of the classes which can be fairly disperse in some cases. Majority-filtering of the raster data - an easy solution to simplify a classified raster image - leads to biased changes in the class frequencies. Landuse classes forming large clusters are obviously favoured compared to classes which typically show no or small clustering. Therefore, a raster generalization procedure has been developed which allows an individual treatment of classes or groups of classes. The following steps are implied:

- Recombination of the 16 classes to 5 super classes (water, forest, agriculture, settlement, mining);
- Simplification and smoothing of the contourlines of the super classes;
- Majority-filtering among the original classes confined to the area of the corresponding super classes as created in the step before;
- Recombination of the 5 majority-filtered data sets.

7 Conclusions

Despite of numerous landuse studies founded on satellite image interpretation the project has pilot character for Germany because of the following facts:

- Full coverage of the state by analogue and digital actual landuse information derived from an uniform data source and with a standardized method of classification;
- Precise geometric rectification of the data to match geometric accuracy standards of the 1:100,000 Topographic Map;
- Classification accuracy of 95%;
- Central storage and marketing of digital data and maps.

We hope that this product will find a wide acceptance and usage. Based upon the existing data a regular updating is strongly recommended. It will certainly cost less effort than the production of the original data set since the training process needed for classification can be speeded up by using the existing data set.

8 References

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