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○ **Applications à l'agriculture, aux forêts et à l'usage du sol**
Applications to agriculture, forests and land use

MONITORING LAND USE CHANGE BY REMOTE SENSING

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Abstract

Man's use of land is not a static process but an extremely dynamic one. Changes in land use take place in all categories and are necessary both for developing land use and for monitoring their effectiveness.

A systematic analysis of remote sensing procedures for detection of land use change was performed, taking for a test site the Filder Area near Stuttgart, FRG. The Filder Aera suffers strongly from environmental stress, due to the Metropolitan Area of Stuttgart, the International Airport, fast growing urban areas, etc.

Remote sensing data using LANDSAT/MSS and TM as well as SPOT-HRV taken in different years were combined with ancillary data from plainning agencies. The results obtained by Maximum Likelihood classification show similar tendencies like public statistics.

◆ Introduction

For large areas with uniform aspect mapping of the actual land use is very expensive. Most applications take maps or aerial photographs as primary data. Therefore, there is a great amount of work to collect and to integrate these data for the different applications. Satellite remotely sensed imagery provide actual and useful information in digital format.

The majority of satellite remote sensing data is transmitted to earth as digital values of the response of each pixel in the wavelength employed by the sensor. The data have to be handled in digital from before an image can be produced. Manipulation of the data can be performed by computer to extract useful information out of the data.

The described work was performed on the Institute's Digital Data Analysis System, called DIDAK (Wiesel, 1985). The implemented **digital image processing** subroutines for remote sensing can be divided into:

- vector-to-raster conversion
- geometric transformations
- multispectral classification
- GIS-data analysis
- digital cartography

◆ The Filder Test Site

Detection of land use change was carried out in a 200 sqkm test area near Stuttgart, FRG. The Filder Area has the following characteristics:

- close to Stuttgart, the capital of Baden-Württemberg
- increasing building rate
- high traffic load by highways and the Stuttgart Airpot
- intensive agriculture activity
- less natural areas
- environmental stress

For the renovation of the airport many studies were performed considering environment, agriculture, hydrolgy, climate, ecology and others [Meluf 85], all done manually in a traditional manner. However, the combination of such data sets is a complex procedure, and today we may use digital techniques – the Geographical Information System (GIS).

Remote Sensing Data

Four remote sensing data sets were used for monitoring the land use change:

- LANDSAT-MSS 08/1975
- LANDSAT-TM 07/1984
- LANDSAT-TM 08/1987
- SPOT-HRV 09/1987

The satellite data sets show different sensors, different spectral bands and especially different spatial resolutions (table 1). Consenquently, one LANDSAT-MSS-pixel includes nearly 7 LANDSAT-TM- or 16 respectively 64 SPOT-pixels.

Table 1 : Used satellite sensors (see : Bähr 85)

Satellite	Spectral bands	Spatial resolution	Picture size	Orbit data	Repetition
LANDSAT MSS USA	0.5-0.6 μm 0.6-0.7 μm 0.7-0.8 μm 0.8-1.1 μm	79 m×79 m	3200 × 2300 elements 185 km×185 km	h=920 km i=99°	fixed 18 days (since 1972)
LANDSAT TM USA	0.45-0.52 μm 0.52-0.60 μm 0.63-0.69 μm 0.76-0.90 μm 1.55-1.75 μm 10.40-12.50 μm 2.08-2.35 μm	30 m×30 m (120 m×120 m)	7020 × 5760 elements 185 km×185 km	h=705 km i=98°	fixed 16 days (since 1982)
SPOT F	0.50-0.59 μm 0.61-0.68 μm 0.79-0.89 μm 0.51-0.73 μm	20 m×20 m 10 m×10 m	3000 × 3000 elements 60 km×60 km 6000 × 6000	h=832 km i=99°	flexible 26 days (since 1986)

For the reference data set (LANDSAT-TM 07/1984) all data sets were geometrically transformed by a correlation method yielding an accuracy of 0.3-0.5 pixel. Il order to integrate the remote sensing into the ancillary data on a GIS base, an absolute geometric transformation was made by polynoms using ground control point of a 25 m raster (Gauss-Krüger-Grid). The mean coordinate error computed from check points was 0.5 to 0.7 pixel.

◆ Multispectral Classification

The multispectral classification of the satellite data was done by Maximum Likelihood Classification. The Maximum Likelihood model determines the probability of all points in the feature space belonging to a particular class. Consequently each point has a probability of belonging to each of the classes identified. Unknown points may be assigned to a class taking the class of highest probability, i.e. the class to which it will belong most likely. The main problem of that so called supervised procedure is the selection of representative sample areas for the classes. Here, the ground truth was a common data set of training samples for the following land use/land cover classes:

- **Forest land**
  - deciduous forest
  - coniferous forest
  - mixed forest

- **Agricultural land**
  - vine/bushes
  - meadows/orchards
  - cropland
  - root crops

- **Urban or built-up areas**
  - residential
  - commercial
  - industrial

- **Water**
  - river/lakes

The term "land cover" is commonly used in association with term "land use". But the two are not synonymous. For example, urban or built-up areas are divided into the land use classes residential, commercial and industrial. Really classified are the vegetational parts covering the land surface: high vegetation, moderate vegetation and low vegetation.

The classification accuracy was determined by a common data set of test samples yielding 80 to 95 percentage true for several classes. Low accuracy was obtained only for mixed classes like vine/bushes and residential urban areas, showing nearly the same spectral signature.

◆ GIS-data Analysis

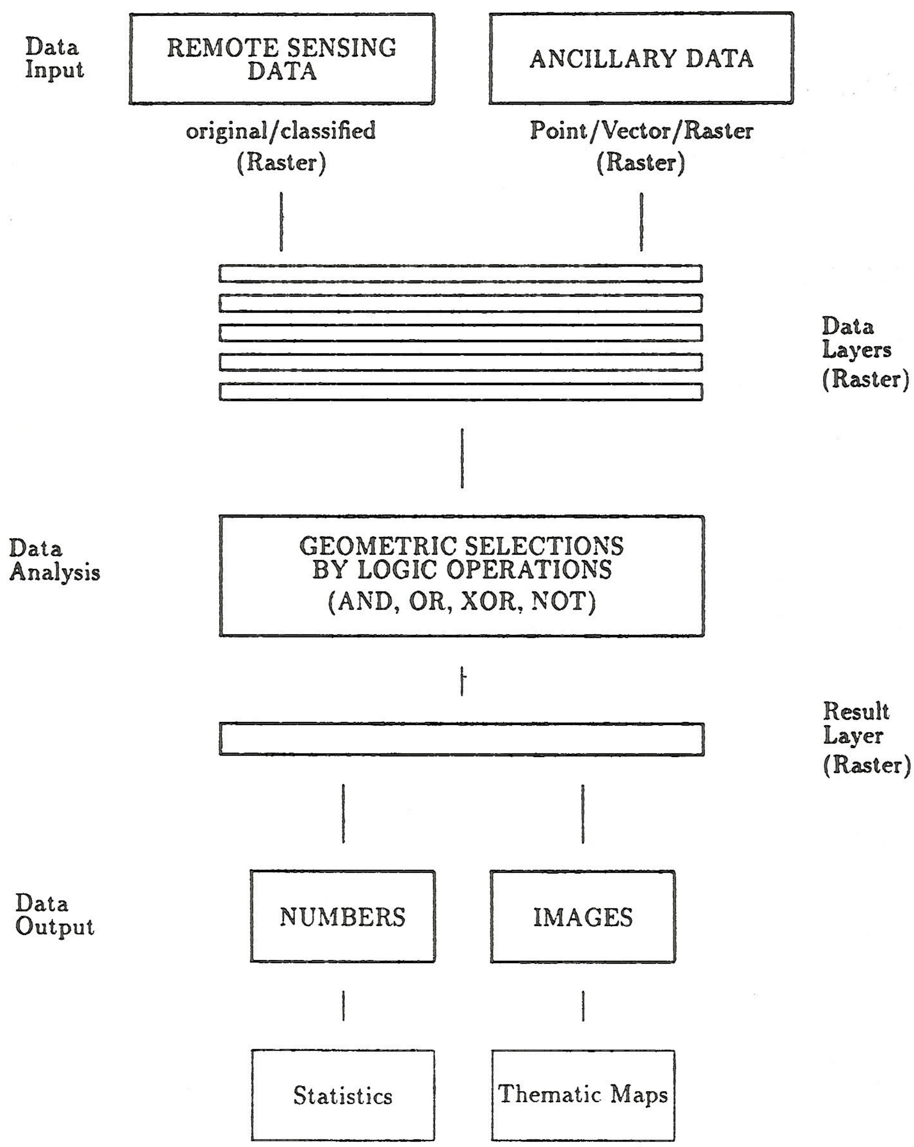

Fig. 1 : Combinaison scheme of remote sensing and ancillary data

In most geographical information systems it is assumed that the information in the data-base is present as points, lines, and areas and their associated attributes. Figure 1 shows the combination scheme of remote sensing and ancillary data. In this case the spatial extent of the data is given in a raster (pixel) form. Point or vector data must be converted. The original or classified remote sensing data is already in a raster form. Each data set has an own data layer. Then geometric selections mays be done by logic operations. Boolean algebra uses the operators AND, OR, XOR, NOT to see whether a particular condition is true or false [Burrough 86]. From the result layer there are two possibilities for the data output: numbers and images. For example numbers are to create statistics and images are taken for thematic maps.

For the studies remote sensing data were combined with **ancillary data.** Maps from planing agencies (scale 1: 25 000) were manually digitized and then converted into a 25 m raster. Such were:

- boundary of the region
- existent urban area
- planned urban area
- different land uses
- roads, highways
- ecological studies
- geological map
- and others

◆ Change Detection

If urban areas can be identified on satellite imagery, time change may be estimated analysing sequential images. For change detection analysis two methods of classification comparison are used: comparison by numbers (statistics) and by images.

Table 2 : Statistics of land use in the Filder Area for each satellite data set, in per cent

	Filder Area			
Class / Year	MS75	TM84	TM87	SP87
Deciduous F.	5	4	5	5
Coniferous F.	2	2	3	3
Mixed Forest	6	8	5	6
Vine/Bushes	5	7	8	12
Meadows/Orchards	35	35	28	20
Cropland	23	7	20	20
Root crops	2	11	6	8
Residential	16	17	16	18
Commercial	4	2	3	5
Industrial	2	7	6	3
Urban, total	22	26	25	26

Table 2 includes the **statistics** of each satellite data set within the Filder Area. The results for forest land do not differ very much for different years or different sensors, respectively. The classes of agricultural land differ strongly, however, Naturally there are differences in the acquired dates (july to september) and in crop planting. Totalizing the urban areas, the changes between 1975 and 1984/87 for the region ar nearly 4 per cent.

The data of the Statistical Reporting Service [Stala, 86] in Table 3 how the statistics for the categories "buildings" and "roads/places" in the yeards 1981 and 1985. The difference of 1 to 2 per cent in four years is in accordance to the classification result. But no direct comparison is allowed, because inventories of the Statistical Reporting Service are based on a land use catalogue of the cadastral survey, and the classification is based on the spatial, temporal, spectral and textural characteristics of the feature.

Table 3 : in per cent

	Filder Area	
Class / Year	1981	1985
Buildings	16.4	17.2
Roads/Places	8.6	9.4
Total	25.0	26.6

The **image comparison** demonstrated by the example "non urban area, 1975" (LANDSAT-MSS) and "urban area, 1987" (LANDSAT-TM) near the airport locates where the changes are. In the first step there are some groups of pixels, line structures (runway, roads), and some singular pixels. After digital filtering singular pixels disappeared, and only the groups are left. Such clusters are called "areas of interest". These areas combined with original data are well appropriated for checking the changes, if they are "true" or "false". "True" are new buildings in the periphery of the towns and villages. "False" are the pixels on the runway, of course.

The detection of land use/land cover change is a complex procedure. The main problems are the difficulty in the precisely registering or overlaying of multiple satellite data sets and the lack of sufficient separability between various categories of land use.

◆ Future aspects

Generally, existing digital change detection algorithms are based solely upon spectral analysis. However, accurate land change information cannot be produced only by spectral analysis. This is because spectral information cannot describe many of the important properties of a geographic area. In order to obtain correct results, a much wider range of spatial and contextual information is essential.

Therefore, information by ancillary data sources must be incorporated into the process of change detection. Strategies using knowledge about land cover, context, topographic information, planning stragegies etc. applied along with spectral information seem to be able to achieve correct results.

These strategies lead to knowledge based change detection systems, where – in addition to a data analysis rule base (knowledge base) – a geographical information system has to be integrated in order to store and to provide necessary ancillary data (Wang, 1987).

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