The Role of GIS, Remote Sensing and Official Census Data in Monitoring Urban Growth

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Abstract
The use of GIS and remote sensing technology has relatively long history as a tool of monitoring urban dynamics and land use changes, but a little studies has been used in remote sensing and GIS techniques as complementary tools to verify and consolidate official census data. Remote sensing offers practical benefit in the field of urban dynamics. The analysis of urban dynamics in the region of Rostock over the period of 1973-2006 was carried out based on the interpretation of satellite imagery from Landsat MSS (1973), Landsat TM (1989), and Landsat ETM+ (1999) and assisted by detailed CORINE 1990/2000 and ATKIS 1999 information on land use. The satellite imagery has been analysed based on an object-oriented image classification approach as an alternative to pixel based classification.. The analysis of growth in the region of Rostock over the period of 1973-1999 was carried out based on interpretation of remotely sensed satellite imagery from Landsat MSS (1973), Landsat TM (1989), and Landsat ETM (1999) and assisted by detailed Corine 1990 and ATKIS 1999 information on land use. The remotely sensed satellite imagery has been analysed based on an object-oriented image classification approach as an alternative to the pixel based classification.
Census data are acquired and published in many countries on a more or less regular base, for instance annually. Data collected are for instance the number of inhabitants, the birth, mortality, and migration rates, in some cases more detailed information might be available considering settlement activities and others. These data registers are part of the administration processes in municipalities, counties and states. At all administrative levels development strategies and decisions are often based on these files. Rarely these data are analysed with spatial information systems nor are they visualized with spatial mapping technologies.
In our research project we try to link official statistical data with the results of remote sensing data. The hypotheses are as follows:

- Remote sensing data and official statistical data are simply different measures to quantify land use/land cover and land use/cover changes, especially related to settlement activities.
- Official statistical data are very often at a more course level, remote sensing data may consolidate the official statistics and may show the real spatial distribution of area sealing caused by settlement activities. Thus a combination will strongly improve decision making and strategic planning at administrative levels.

The study area is the region of Rostock, located in the federal state Mecklenburg-Vorpommern in the north of Germany. The study area covers 1553 km². The following data are used:

- Satellite data: Landsat MSS 1973, Landsat TM 1989, Landsat ETM+ 1999.

- Geoinformation: ATKIS 1999, the Authoritative Topographic Cartographic Information System in Germany, CORINE 1990, a land use data set for all EU member states, DEM (Digital Elevation Model) data at 25 m resolution.
- Census data from the years 1973, 1990, 2006

The following methods were investigated and a workflow was designed. The remotely sensed data generally requires radiometric calibration, atmospheric correction and geometric correction of undesirable sensor characteristics and other disturbing effects before carrying out data analysis reliably. When using Landsat satellite imagery to map land use and land cover or monitor land cover changes, it is desirable to remove these effects by implementing a method which can produce a radiometrically consistent time series of images. In this study, image based COST algorithms for radiometric calibration and atmospheric correction were applied. This method is very important for multi-temporal analysis, a method using theoretical spectral radiance and image acquisition date was used to convert TM DN values to at-satellite radiance. The COST-based model was then employed to convert at-satellite radiance to surface reflectance in the study area.

The spectral enhancement in this study was performed by selection of colour-composites based on the calculation of the optimum index factor (OIF). The OIF is based on total variance within bands and a correlation coefficient between bands, a statistical approach to rank all possible three band combinations. Three band combinations with high total variance within bands and low correlation coefficient between bands will have High OIF-values indicate bands that contain more spectral information of the object (e.g. high standard deviation) with little "duplication" (e.g. low correlation between the bands). By using the OIF method, three band colour-composites can be evaluated on their effectiveness for display.

Image fusion is a concept of combining lower resolution multispectral image with higher resolution panchromatic data to increase the spatial resolution of multispectral imagery. Here, the high-resolution Landsat ETM+ panchromatic channel (14.25m res.) was used to enhance the three multispectral channels (1,4,7) (28.5m res.).

The data analysis was carried out with the software eCognition from Definiens AG. The three images were classified based on the standard nearest-neighbour method in five classes (urban, agricultural, coast, forest, and water). For accuracy assessment of the classification results, a TTA mask with independent samples was built in ArcGIS. An accuracy assessment was performed on the classification results. A confusion matrix of the TTA sites with the classification was produced. The overall classification accuracy is 95,9% for 1973, 98,95% for 1989, and 98,45% for 1999.

Multi-temporal analysis is a process to detect the changes which occurred on an area. Temporal analysis has been undertaken by considering differences to 1973, 1989 and 1999. Using GIS-intersection analysis, the changes can be detected and quantified.

During the investigation period, for the primary types of land cover, distinct changes have occurred: urban areas increased by 50 % between 1973 and 1999 (~ + 3.000 ha), agricultural land decreased over time (~ - 3.600 ha). Forested areas increased in the time frame 1973 – 1989, and have remained constant since then. Water bodies remained approximately the same during the whole time period. The strong increase of the urban land use / impervious area is due to two different processes. In the years between 1973 and 1989 the city of Rostock underwent a rapid growth in population and industrial areas. In the years 1989 to 1999, after German reunification, suburbanisation in the vicinity of the city of Rostock is the main driving force for construction of new houses and commercial areas.

In the last step, which is currently investigated, we are now combining the official statistical data (e.g. population density and others) with the area sealing numbers derived from remote land cover mapping by remote sensing. With statistical means we will compute correlation and regression measures and analyse the spatial patterns in the municipalities to proof our hypotheses.