REMOTE SENSING FOR MEGACITIES RESEARCH

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ABSTRACT

Urbanization, as a social phenomenon and physical transformation of landscapes, is one of the dramatic current global changes. For the first time, more people will live in urban centres than in rural areas by 2007. The UN estimates that about 90% of the future growth will take place in cities. Particularly in mega-urban regions and metropolises, urbanization anticipates trends with regional and global consequences that are yet difficult to predict. The urban environment influences the daily quality of life for residents and ecological processes, climate, flows of materials, and land transformations. These influences—both internal and external to the city—are not uniform among or within cities, but depend on bio-geographic regions, urban structures, urban functions, and rationales of growth. Using remote sensing and GIS methods scenarios of historical urban development trajectories and future change in urban ecosystem structure and function must be developed with these variations in mind, so that all levels of political organization can make rational decisions.

Earth Observation Data and GIS resources have become truly accessible tools for cities in general and megacities in particular. Specifically, visual and multi-spectral image classification, texture analysis and object oriented image analysis will be used to identify urban land cover and land types, such as different densities of vegetation patchiness, soils, man-made materials and water bodies. The change in urban form (for instance city growth) and structure (spatial composition of the urban land use/land cover) can be linked to all kinds of social changes and the relationships can be visualized by GIS methods.

1. INTRODUCTION

Reflecting global socio-economic and political changes, megacities present a recent phenomenon of highly complex urbanisation processes. On the one hand, they promise significant potentials for economic progress by creating 'innovative environments' through connecting human capital, globally interlinked actors, and financial and information resources. On the other hand, megacities pose significant risks on global, regional and local scales by aggravating social disorganisation, economic disparity, loss of governability, and ecological stress creating an unhealthy local environment(i). These factors turn the urban habitat into both, a *space of risk and a space of opportunity*. Large cities are the world's most important consumers of resources, generators of waste, and in consequence, sources of environmental problems. At the same time, they are the engines of national and regional economic growth. While urban areas present fundamental and pressing challenges to ecological, social, and economic development, they carry the promise and the potential to overcome them.

This study is part of a joint research initiative 'Risk Habitat Megacities - Strategies for sustainable development of megacities and urban agglomerations' (http://www.ufz.de/index.php?en=6143) of the German Helmholtz Association of National Research Centres (HGF). Its focus will be initially on Santiago de Chile. Santiago shows all typical phenomena of megacity development, such as rapid social and spatial segregation,

urban growth and suburbanisation as well as high environmental and health loads. Stretching across roughly 2400 km^2, the city is located in an Andes valley, surrounded by high cordilleras. Due to this topography, the levels of air pollution in Santiago de Chile are comparable to those in Mexico City, although the composition of pollutants is quite different. High winter rainfalls in a semiarid Mediterranean climate expose the urban region to erosion processes and flood risk. Furthermore, earthquakes (ii) endanger Santiago.

In Germany, this ***HGF*** initiative "Risk Habitat Megacity" is one of three clearly distinguished current initiatives. As the "Integrated Earth Observation System" (EOS) is focused on the impacts of natural hazards on megacities, it develops strategies and means to tackle these hazards. Therefore the two other complementary activities derive from the recommendations expressed by the National Committee for Global Change Research (NKGCF). One is the "Research on Sustainable Development in Mega-cities of Tomorrow" programme ("Forschung für die nachhaltige Entwicklung der Megastädte von morgen") launched by the Federal Ministry of Education and Research (***BMBF***). It aims to generate practical solutions for the management of urban growth in large agglomerations. The other one is a research project of a group of scientists to the German Research Foundation (***DFG*** – Deutsche Forschungsgemeinschaft). It focuses on informal dynamics in megacities in relation to global change.

2. LANDUSE MANAGEMENT - MAIN RESEARCH THEME FOR MEGACITIES

Rapid informal and uncontrolled urban expansion and sprawl drives settlement and related infrastructure out towards fragile locations. These locations are prone to earthquakes or volcanoes, landslides or floods. Conversion of open green spaces to built-up areas leads to a dramatic loss of other functions, such as agricultural production, supply and disposal infrastructure, ecological compensation and recreation for the local population. All this leads not only to environmental and health risks, as in Latin America, urban development and environmental and health protection are characterised by governance deficiencies. There is often no coherent administration for the metropolitan regions and horizontal and vertical communication between the administrative units is deficient. Informal stakeholders have a large influence on all aspects of public and private life (iii).

The research focuses on evolving strategies for risk provisioning (i.e. for avoiding and minimizing risks) in the field of land use management. Quantitative and qualitative risk analyses, as well as discriminating areas affected by different risk types and intensities, are important to develop strategies for risk provisioning (iv). In this regard, satellite remote sensing provides an important tool for continuous and objective monitoring of land use change and enables global and regular observations of key parameters to characterise the state of urban areas.

3. REMOTE SENSING ANALYSIS IN THE PREPARATION PHASE

For the ***HGF*** initiative a preparation phase it is planned to conduct the following basic activities in close cooperation with the Chilenian cooperating partners where geoinformation is intended to play a crucial role:

- Analysis of existing Chilean spatial and risk management and environmental assessment procedures,
- Analysis of governance structures and approach to stakeholders and cooperation partners relevant to land use management as well as environmental and health risk provisioning,
- Identification of research areas with serious land use conflicts,
- Analysis of availability and possible access to remote sensing data in order to generate an archive of remote sensing data covering the selected Latin American megacities and their surroundings,
- Performing first land cover / land use classifications based on an agreed land cover classification system including indicators for socio-spatial polarisation.

In an initial step the available Landsat data (1975, 1985 & 1999 – details see Table 1) have been visually analysed to identify new settlement growth kernels - both adjacent to the compact urban fabric as well as isolated development beyond the former actual settlement borders ('leapfrog developments'). As it can be demonstrated below (figures 1 and 2) these newly built-up areas can be clearly and accurately mapped using Landsat data from different instruments and decades and thus contain crucial information for urban land-use legacy.

Table 1: Available Landsat data for urban expansion analysis

Sensor	MSS	TM	ETM
Acquisition Date	1975	1985	1999
Geometric resolution	80 m	30 m	30 m

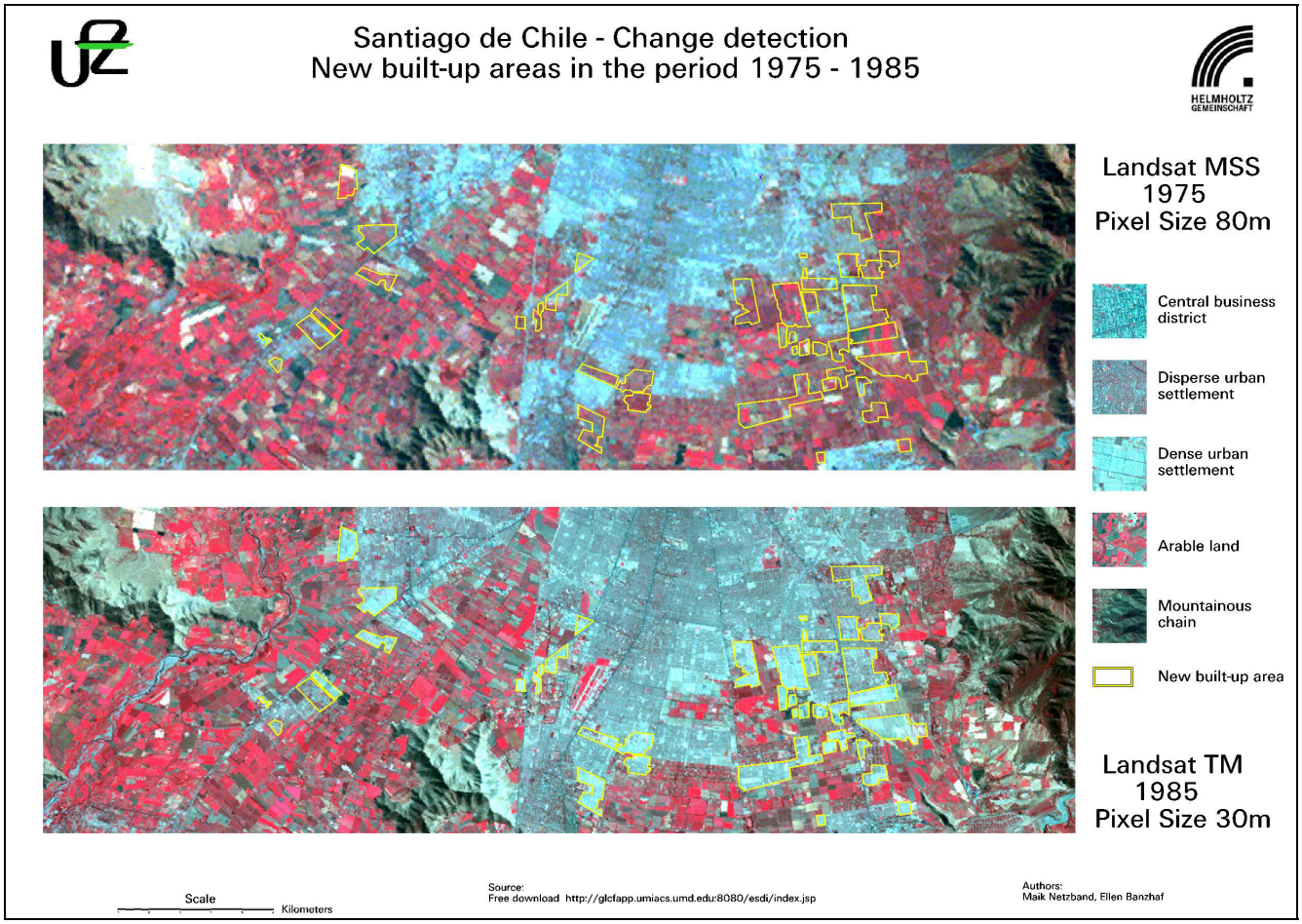


Figure 1: Santiago de Chile - Change detection Landsat MSS 1975 – Landsat TM 1985

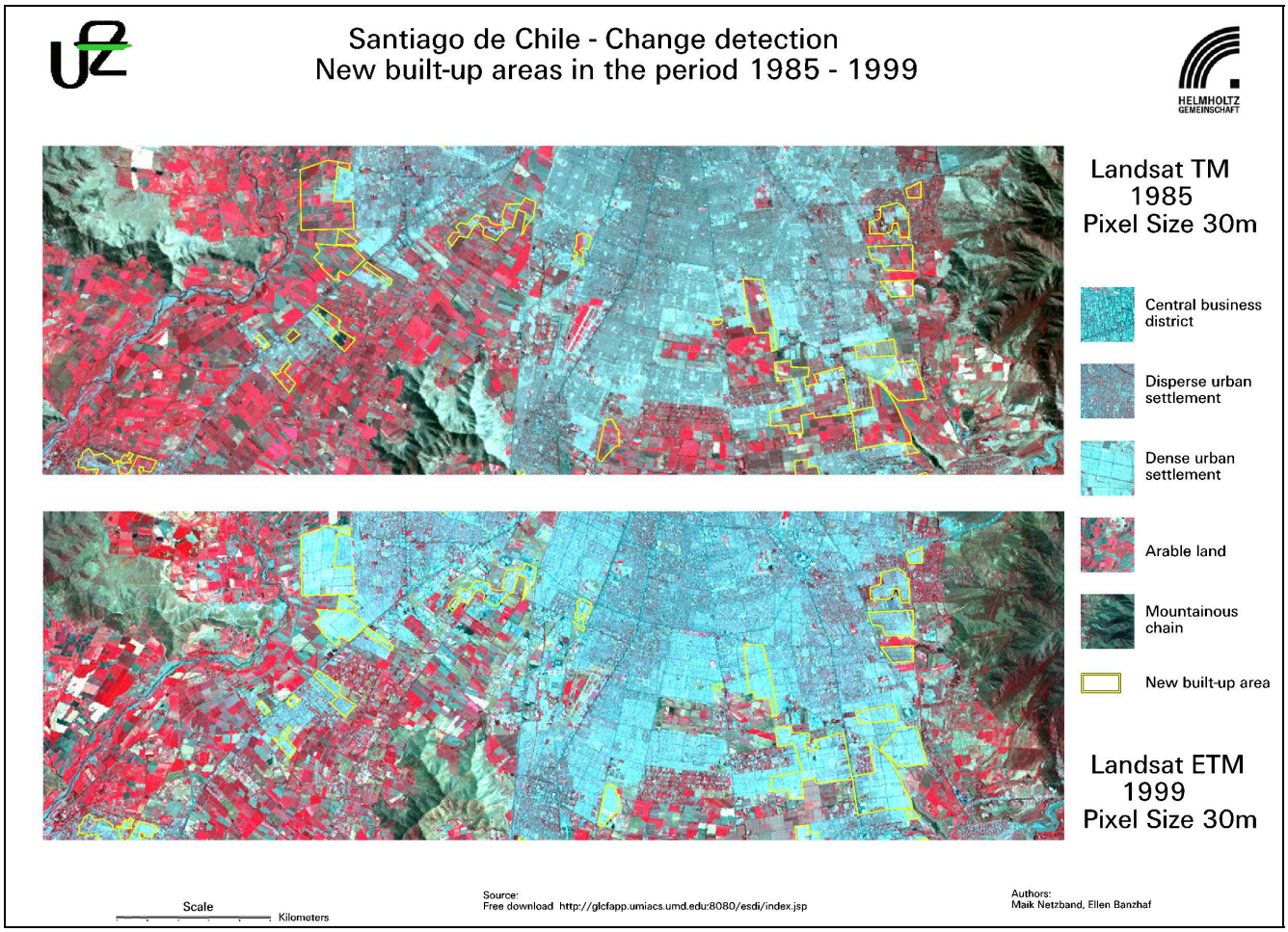
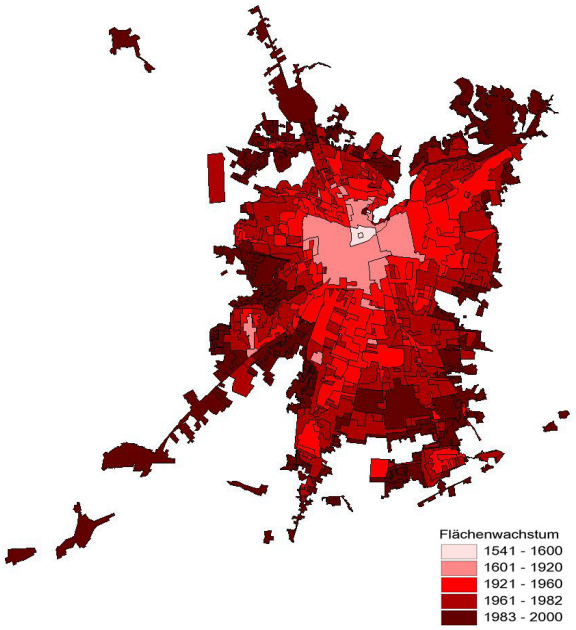


Figure 2: Santiago de Chile - Change detection Landsat TM 1985 – Landsat ETM 1999

In Figure 3 map based and satellite based urban growth analysis can be compared, left side showing the last period from 1983 to 2000 in dark red based on digitization of topographical maps which is almost identical with the shown period on the right side image (1985 to 1999, yellow polygon) and thus serves in both directions as an accuracy assessment.

Of particular interest is the interconnection of urban ecological parameters/indicators, their social implications and vice versa. Figure 4 shows the vegetation cover (shown left as Normalized Difference Vegetation Index NDVI) in cities which is not only a natural phenomenon but also strongly influenced by socio-economic distributions and potentials. In arid areas the availability of water as well as the populations resources to plant and maintain bigger trees, lawns, and gardens is clearly linked to the income situation of a certain city quarter and finds its expression in the distribution and intensity of vegetation, with its internal land-cover structure. As shown in figure 4 a strong spatial correlation between vegetation cover and, respectively the lack of it and the appearance of a predominantly low income situation is significant for the southern expansion areas of Santiago where mostly informal settlements have been established during the last decades.



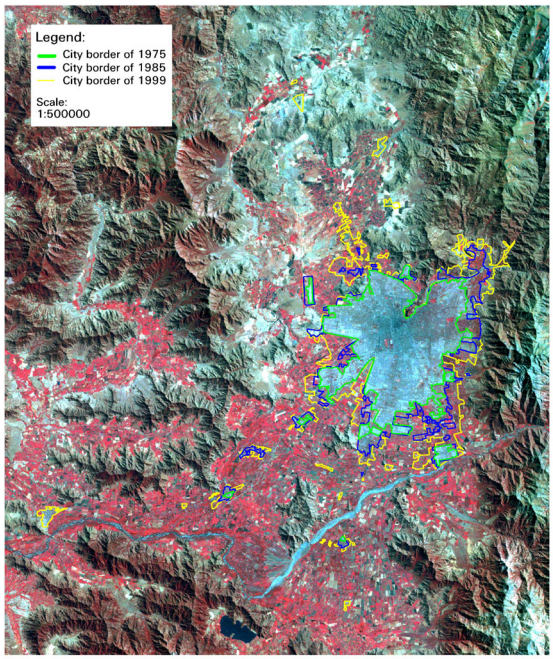
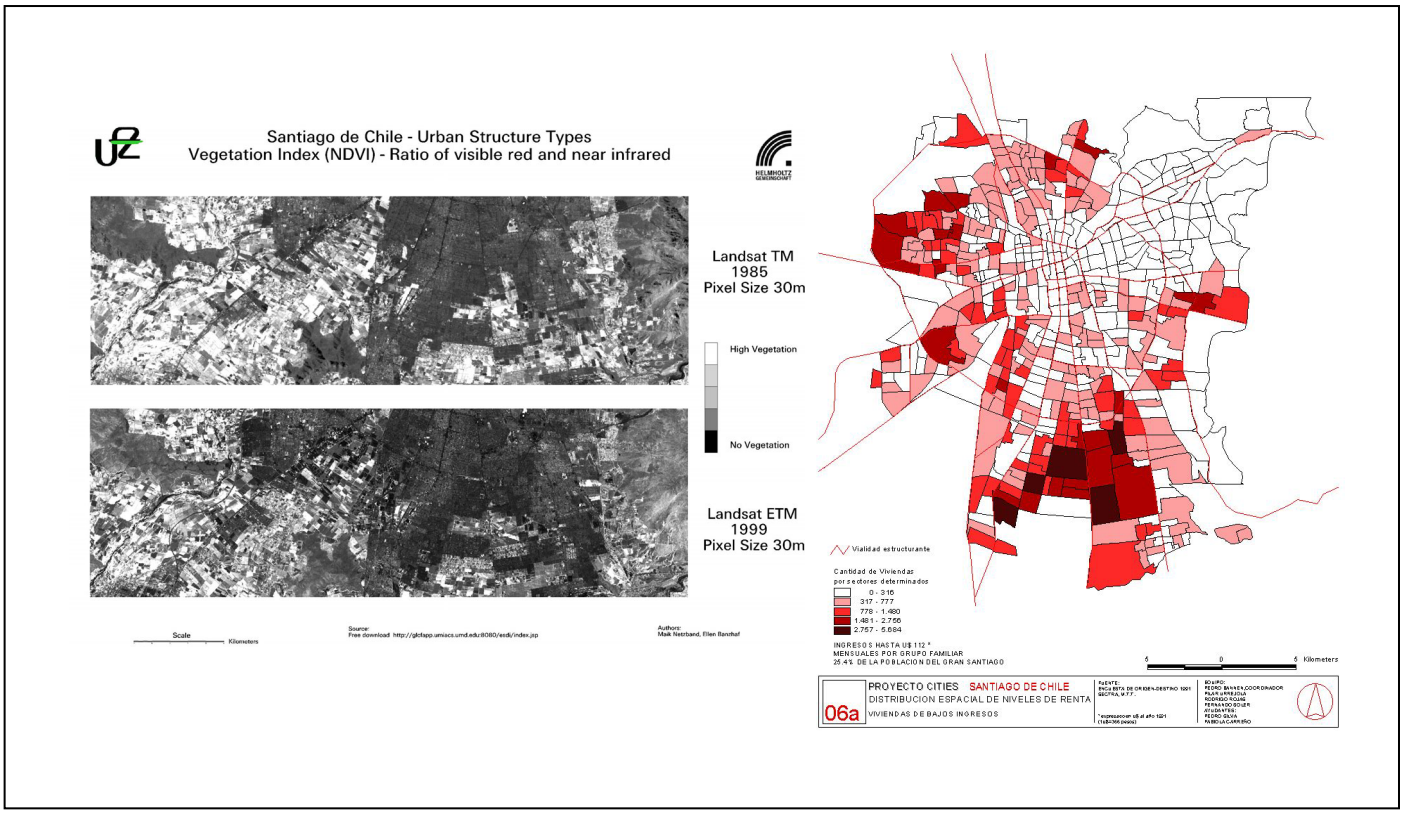


Figure 3: Santiago de Chile – Urban expansion based on landuse maps (left) and Landsat data (1975, 1985, 1998) (right)

Figure 4: Santiago de Chile – Vegetation Index (NDVI) Landsat TM 1985 – Landsat ETM 1999 (left) and the location of low income classes (right)



4. CONCLUSIONS AND FURTHER PLANS

Remote Sensing is used for mapping and documenting the growth of the urban area of Santiago de Chile interactively, both quantitatively and qualitatively (with ancillary data sets):

- Expansion or the illegal extension into restricted areas can be detected and monitored
- As interpretative syntheses, RS data are main sources for a general view of a city during its process of planning and legislation.

To direct the focus on the risk analysis for megacities we plan to use landcover / landuse information and digital elevation models (DEM) for landslide and flood potential mapping. Furthermore, the exploration of ecological parameters like the percentage of impervious surfaces, vegetation structure, temperature pattern, surface roughness, habitat modeling will be of particular importance. In this sense, the mapping of rapidly growing settlements and especially of informal settlements has accompanied and registered physical developments, but also became an important instrument for different fields of applications, for example for military, civil security, and commercial applications.

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