Urban Growth and Sprawl of Mersin City, Turkey: Change Analysis Based on Earth Observation and Socio-Economic Data

Mersin Şehrinin Kentsel Büyümesi ve Saçaklanması: Dünya Gözlem Verisine ve Toplumsal-İktisadi Verilere Dayalı Değişim Çözümlemesi

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The aim of this study is the contextualization of urban growth and sprawl experienced in the coastal conurbation of Mersin in southern Turkey. For this purpose, an interdisciplinary approach has been developed by using methods of remote sensing and social sciences. The sample areas, identified by using a series of satellite images available for the period 1987-2009, have been examined using a multi-temporal change detection approach in combination with available statistics and on-site excursions in order to understand the pattern of development. What is evident from this study is that an interdisciplinary perspective on the examination of urban growth and sprawl provides us with timely results that can be employed in urban and regional planning activities.

Key words: Urban sprawl; informal settlement; social housing; elite segregation; tertiarisation; remote sensing.

Bu çalışmanın amacı Türkiye'nin güneyinde yer alan Mersin kıyı bitişik-kentleşmesinde (konürbasyonunda) yaşanan kentsel büyüme ve saçaklanmanın bağlamlaştırılmasıdır. Bu amaç doğrultusunda, uzaktan algılama ve toplum bilimlerinin yöntemleri kullanılarak disiplinlerarası bir yaklaşım geliştirilmiştir. 1987 ve 2009 arası dönem için elde edilebilir olan bir seri uydu görüntüsü kullanılarak tespit edilen örnek alanlar, bir çoklu-zamansal değişim tespiti yaklaşımı eşliğinde elde edilebilen istatistiki veriler ve yerinde yapılan incelemeler ile gelişme örüntülerinin anlaşılabilmesi ve bağlamlaştırılması amacıyla incelikli biçimde araştırılmıştır. Bu çalışmadan ortaya çıkmıştır ki, kentsel büyüme ve saçaklanmanın disiplinlerarası bir bakışaçısı ile irdelenmesi, kent ve bölge planlama çalışmalarında kullanabileceğimiz sonuçları bizlere daha vakitlice sunmaktadır.

Anahtar sözcükler: *Kentsel saçaklanma; kaçak yapılaşma; sosyal konut; seçkin ayırımı; üçüncüleşme; uzaktan algılama.*

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Introduction

The former United Nation (UN) Secretary-General, Mr. Kofi Annan, called our time the "urban millennium" (UN Press Release SG/SM/7479). According to recent UN prognoses, almost 60% of the global population will live in urban areas by the year 2030 (United Nations, Department of Economic and Social Affairs, Population Division 2009). In Turkey, the urbanization rate has even increased to 76.2% in 2010.

Due to these developments, urban spaces have come into the focus of regional science. Closely related to the effects of polarization within globalization, academic examinations focus especially on the field of global cities in the Northern Hemisphere (Brenner and Keil 2010) and megacities, which are primarily located in the Southern Hemisphere (Borsdorf and Coy 2009). The latter ones are seen as "new socio-economic and political 'laboratories of the future' as they seem to reflect global development trends compactly" (Kraas 2007, 80).

Following Kraas (2007), there are five dimensions of change, which structure the main research questions in this field:

- Geo-ecological change (vulnerability; land consumption; sustainability),
- Geo-economic change (globalization; transnational markets; informal sector),
- Geo-social change (migration; transnational social spaces; social justice; human security, urban life styles),
- Geo-cultural change (urban ethnicity; global urban scapes; global media; social movements; urban cultural diversity and hybridity),
- Geo-political change (resource security; global urban regulation; geo-political competitiveness; social stability; participation; social justice; welfare; transnational Non-Governmental Organizations (NGOs)).

One fundamental issue for researchers and city planners in this context is uncontrolled urban growth due to the urban sprawl. Owing to their dynamics and dimensions, it is difficult to monitor the urban sprawl by employing the existing conservative methods, like on-site interviews and mapping. In this paper, we show the first steps towards tackling this problem with the interdisciplinary cooperation of remote sensing and social science.

Urban sprawl is an inevitable consequence of the spontaneous development of cities. Although the cause of sprawl can be considered to be market mechanism at work (the tendency of consumers and business to "prefer outlying locations where land is inexpensive and congestion moderate", decreasing need for face-to-face contact due to modern telecommunications, and diminishing travel costs allowing "people to live far from their places of work" and shopping), land markets with lack of good information and similar kinds of market imperfections can also be considered the main causes inducing sprawl (uncertainties in the rate of land appreciation cause land speculations and subsequently urban sprawl) (Ewing, 1997:110-111). Overall, Ewing (1997) considers two main categories for the causes of urban sprawl: market-related causes (consumer preferences and technological innovation) and causes stemming from market failures (subsidies and existence of public and quasi-public goods).

There is no doubt that from the point of view of urban and regional planning, the desirability of urban sprawl is questionable, particularly if it is conducive to problems in the proper functioning of cities. Thus, planners should be equipped with the analytical tools both to understand the nature of the sprawl and also to intervene into the process. Within this context, it is important to note that the employment of the concept of urban sprawl in the literature leads to some ambiguities. As Galster et al. (2001: 681) remarks, "[i]t explains everything and nothing". Definition of sprawl can be grouped into six general categories (Galster et al., 2001: 683-685): (1) as a direct example from a particular city, (2) as an aesthetic judgment (usually ugly development), (3) as a cause of an unwanted externality, (4) as a consequence of some independent variable (such as fragmentation of control over land use), (5) as an existing pattern of development (such as continuous development, ribbon development along corridors and leapfrog development), and (6) as a process of development (as a stage in the development of a city).

Departing from the fact that "a thing cannot simultaneously be what it is and what causes it or what it causes", in their study Galster et al. (2001: 685) propose that urban sprawl can be empirically defined as "a pattern of land use in [an Urban Area] that exhibits low levels of some combination of eight distinct dimensions: density, continuity, concentration, clustering, centrality, nuclearity, mixed uses, and proximity". Testing their definition on 13 urban areas in the US, Galster et al. (2001) show that each dimension proposed for the measure of urban sprawl is not only free

of judgment about their intrinsic value, but also measurable on a continuum and comparable across urban areas. Parallel to these considerations, in this study, urban sprawl is conceptualized as a pattern of land use characterized by low levels of integration within an urban area, in terms of different dimensions of spatial configurations such as the ones proposed by Galster et al. (2001).

Urban sprawl can manifest itself in different forms such as leapfrog or scattered development, strip development, and low-density or single-use development (Ewing, 1997:108). Nevertheless, as Ewing (1997:109) remarks, any attempt to associate sprawl with related forms of development can be easily defied "unless the choice is (1) quantifiable and (2) related to impacts". If urban sprawl is not considered to be desirable, it is important to notice that "it is the impacts of development that render development patterns undesirable, not the patterns themselves" (Ewing, 1997:109). Based on this distinction, parallel to the different dimensions of urban sprawl defined by Galster et al. (2001:685), Ewing (1997:109) also defines some sprawl indicators, such as poor accessibility and lack of functional open space that can be easily operationalized and measured owing to their recognition of the real-world development patterns, as a matter of degree rather than simple archetypes.

By using these indicators and dimensions, one can distinguish sprawl from other development patterns. Nevertheless, such an effort is out of orbit of this study. In this study, the main intention is to present and discuss the merits of interdisciplinary cooperation between remote sensing and social science for the observation and explanation of the urban growth and sprawl in cities subject to rapid change. Although this can be a problem for big cities, many of the issues shown above are also applicable to smaller urban agglomerations, which are subject to many of the same underlying processes in the context of rapid urban growth. Due to their spatial manageability, these urban spaces can be seen as laboratories, offering rich avenues of research to test new techniques in order to sophisticatedly monitor the actual urban growth in a revisable and proper way.

The employment of remote sensing to monitor the growth of cities is quite common today. Remote sensing techniques have already proven useful for mapping urban areas at various scales and obtaining data for the analysis of urban land cover change (Batty and Howes, 2001). The literature on digital image classification algorithms presents a wide variety of methodologies. Basically, one can distinguish between supervised classification, unsupervised classification and classification approaches involving artificial intelligence (Jensen 2005). Classification algorithms based on statistical approaches such as maximum-likelihood, box classifier (Landgrebe 2003; Mather 2004) and neural networks have been used frequently at the pixel level (Shackelford and Davis 2003; Benediktson et al. 2003). Recently object-based classification methods have received increasing attention (Blaschke, 2010), especially in the urban domain. Multi-temporal change detection approaches have been presented in recent literature as well. For example, Mas (1999) compared different change detection techniques such as image differencing, selective principal component analysis or post-classification change detection. Zhou, Troy and Grove (2008) presented and compared object-based vs. pixel based post classification change detection methods. Nemmour and Chibani (2006) applied support vector machines to map urban expansion over time.

Many studies have been conducted to map, measure and characterize urban sprawl using multi-temporal remotely sensed data. Research studies on long-term monitoring of the spatial effects of urbanization are mostly based on MR data from sensors such as Landsat or SPOT, with geometric resolutions of 10-30 meters due to the long-time availability of data. These studies range from individual case studies (Griffiths, Hostert, Gruebner and van der Linden, 2010; Ji et al., 2006) to cross city comparisons (Schneider and Woodchock, 2008; Taubenböck et al., 2009b). Angel, Sheppard, and Civco (2005) even classified 90 cities at two time steps (1990 and 2000) and applied spatial metrics to compare the dynamics and patterns of spatial urban growth. Angel (2011) extended this study to 120 cities across the world, applying various methods to analyze urban land cover, its density, fragmentation, compactness and centrality.

Nevertheless, the majority of the respective studies are usually conducted on big metropolitan areas while other areas receive little attention in comparison. This seems to be also true for Turkey where most of the studies in the field of remote sensing are conducted on İstanbul (Maktav and Erbek 2005; Coşkun et al. 2005; Kaya and Curran 2006; Taubenböck 2008; Geymen and Baz 2008). Yet, it is important to note that the remote sensing analysis of the growth of cities in Turkey can also be observed for urban spaces other than İstanbul (see for instance Alphan (2003) for Adana, the biggest city in the Çukurova (Cilicia) Region where Mersin is located; Doygun and Alphan (2006) for İskenderun

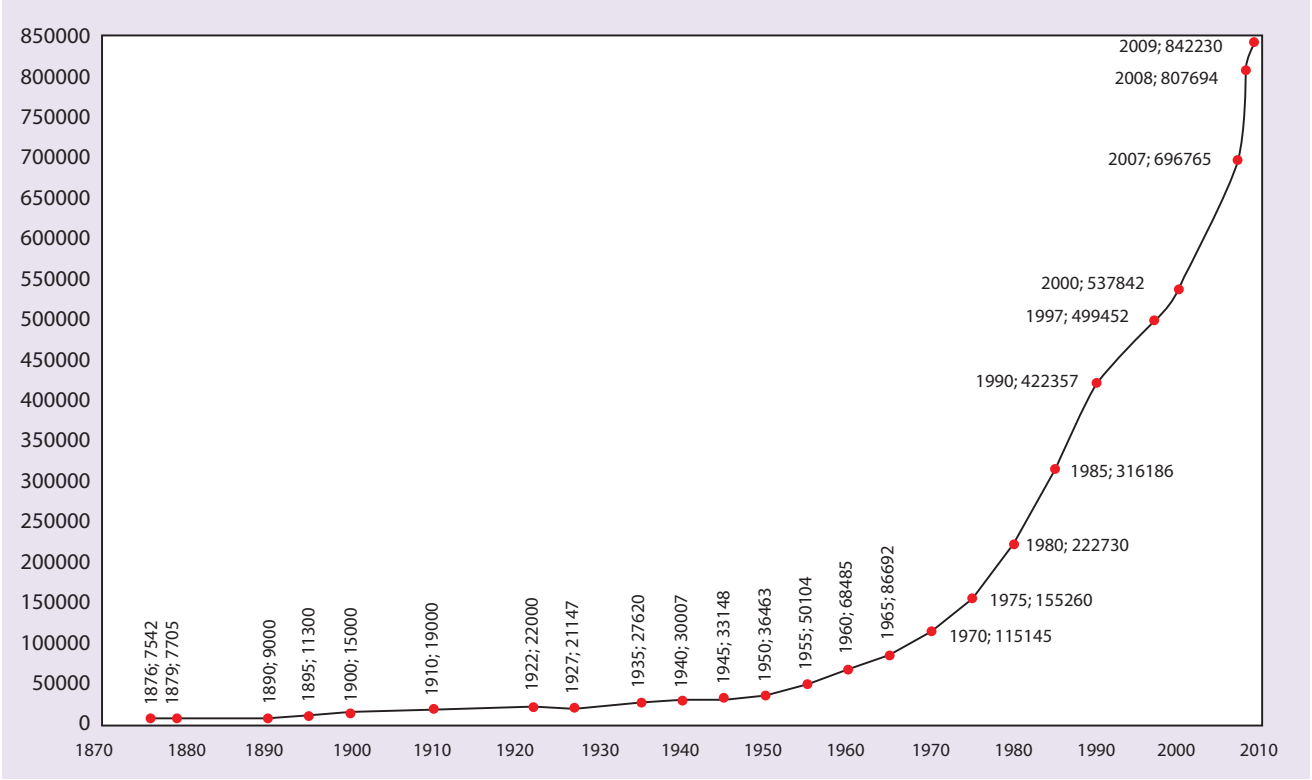


Fig. 1. Population of Mersin City according to years for which information is available (Sources: Beyhan (2009) updated using the information available from TUIK for 2009).

(Alexandratte), another considerable port town located along the Mediterranean coast of Turkey in close proximity to Mersin; Sancar et al. (2009) for Trabzon, an important port city located along the Black Sea coast of Turkey; and lastly Özen Turan et al. (2010) for Kastamonu, one of the most preserved cities in terms of its historical and traditional buildings in the Black Sea Region of Turkey). As can be seen, there has been an increasing number of studies on both inland cities and port cities in Turkey. Although some of the important urban spaces located in southern Turkey have received attention in terms of employment of remote sensing techniques in the analysis of city growth, there has been no study conducted for Mersin, even though it is the second largest metropolitan city in the Çukurova region after Adana and it has been rapidly growing for decades (Figure 1).

For the examination of the causal and contingent relationships that are operative behind the growth of cities, we employ a method that equates analytical priorities of not only space and society, but also space and time. The respective socio-spatial dialectic (Soja 1980; Soja 1985; Soja 1989) can also be observed implicitly in other studies trying to enrich the results of remote sensing analysis with available statistics for the growth and the demographic properties of the cities. Martinuzzi et al. (2007) conducted an analysis of urban sprawl in Puerto Rico; Long et al. (2007) studied the analysis of socio-economic driving forces of land-use change in Kunshan, China. Taubenböck et al. (2009a) clearly showed correlations between urban spread, the resulting morphological structure types and two socio-economic parameters ('income per month' and 'value of property') for the city of Padang, Indonesia. Although these studies tried to reveal the causative processes behind land-use change in cities, most of them did not employ a detailed database at the spatial level of city neighborhoods. In this respect, it is important to note that a very detailed database is used in this study in order to divulge the causative and contingent processes behind the spread and the increase of building density in Mersin Metropolitan Area by focusing on neighborhoods of the city. There is no doubt that the phenomenon of urban sprawl and growth can be studied at multiple levels (from the metropolitan level down to the building-unit level) by combining remote sensing technology and socio-economic databases (Hasse, 2008).

Building on the introductory framework given above, in the following chapters we will present the results of an interdisciplinary analysis that has explored the actual growth of the City of Mersin by dealing with the following research questions: (1) How much has the City of Mersin physically grown during the last decades both overall and on a small-scale level in terms of its covered area and its building density? (2) Which economic, social and demographic processes have driven this growth? In relation to the questions given above, it should be particularly emphasized that the basic contribution of this study is the analysis and contextualization of the nature of the urban sprawl and growth of Mersin City by combining the geospatial technology of remote sensing with the socio-economic data available for the city at the neighborhood level.

Data

Earth Observation Data

This study uses multi-temporal and multi-sensoral remote sensing data sets from the optical Landsat sensors as well as the German Radar Satellite TerraSAR-X. From the Landsat program of NASA, data of the Thematic Mapper (TM) (for August 10th 1987) as well as of the Enhanced Thematic Mapper (ETM) (for July 13th 2000) were available. To extend the time series of remote sensing data sets, an orthorectified Enhanced Ellipsoid Corrected (EEC) TerraSAR-X radar-scene from August 28th 2009 was also applied. All three scenes were georeferenced, showing a good accordance after semiautomated coregistration of optical and radar data. Two additional Free and Open Source Software applications for GIS (gvSIG and Mapwindow GIS) were also employed for georeferencing purposes. The results of the settlement change detection were revised on site. Figure 2 displays the Landsat data from 2000 of the seaport of Mersin and its longish pattern along the Mediterranean coastline.

Statistical Census and Survey Data

To revise the results of the remote sensing analyses and to explain the causative processes which led to the detected changes in the urban morphology, we employed secondary data of the Institute of Statistics of Turkey (TUIK), which is from the currently available population census of Turkey (census year 2000)

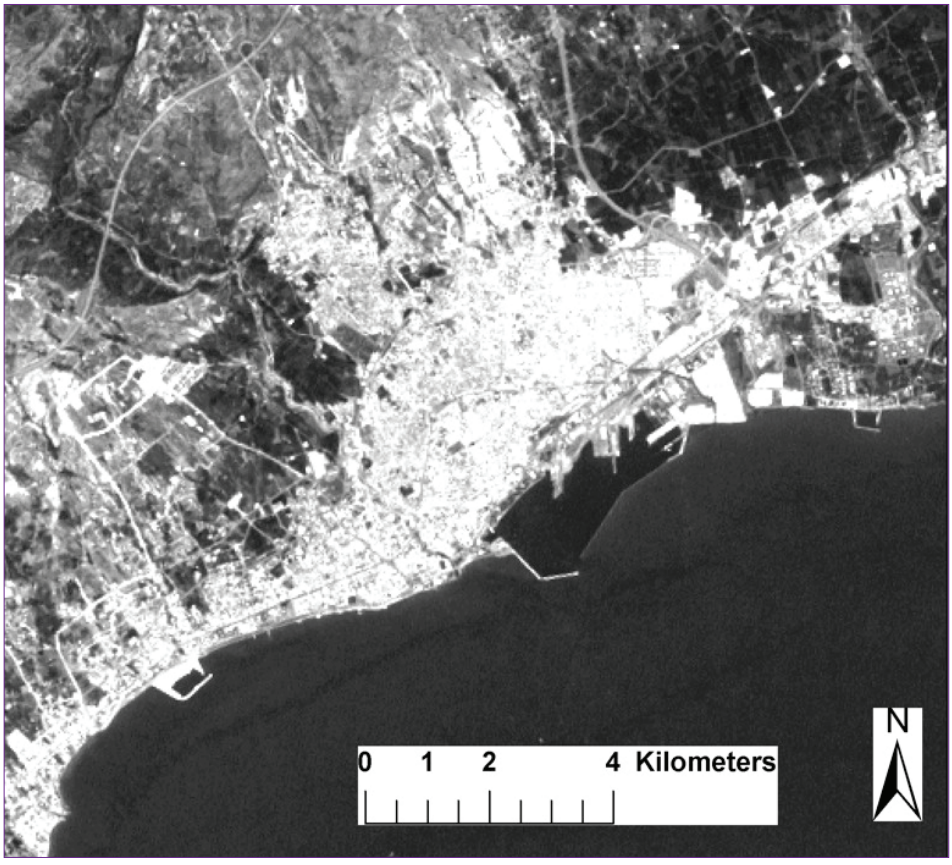


Fig. 2. Landsat imagery of Mersin in 2000 (Source: NASA Landsat ETM: 2000).

and from the building census of Turkey (census year 2000), provided on the level of neighborhoods (mahalleler[1]). Additionally, we conducted qualitative interviews (semi-structured) with inhabitants of the neighborhoods on site, as well as with the experts and city planners in Mersin, who have been watching certain processes in the urban structure of the city during the last decade.

Methodology

Analysis of Remote Sensing Data

Enormous population growth often goes along with spatial urban sprawl. One aim of this study was both to identify the urban built-up areas of Mersin City and to monitor and measure the changes in urban expansion from 1987 until 2009. Earth observation data allow for a time series of spatial data sets. The data sets needed require a large swath covering at least 20 km x 25 km of today's approximate urban extent in Mersin City, and a geometric resolution that allows delineating urbanized from non-urbanized areas.

With these data requirements, the Landsat programme is an obvious and cost-effective choice. Data sets from the sensors Landsat TM from 1987 and ETM+ from the year 2000 were available. The data sets have a 28.5 m geometric resolution and seven spectral bands. Furthermore TerraSAR-X data were available for the latest time step 2009. The standard mode for classification of the urban footprint is the 'stripmap' single polarized mode with approximately 3 m spatial resolution. The swath width is 30 km. With the combination of optical data sets of the series Landsat TM and ETM+ as well as radar data sets from the TerraSAR-X satellite, we intend to cover the extent of the large urbanized area of Mersin City at three time steps from 1987 until 2009. Due to the different data types, we focused only on the differentiation of urbanized and non-urbanized areas.

For the purpose of classification, an object-oriented hierarchical top-down methodology has been applied for the time series of Landsat data (Taubenböck 2008; Taubenböck et al. 2008). We applied a user interface with a fixed processing chain, with a pre-defined feature set, but with the possibility to interactively adapt classification thresholds to the specific spectral characteristics of the particular imagery (Abelen, Taubenböck and Stilla, 2011). The developed service chain is a semi-automatic, object-based classification procedure implemented as Definiens Architect solution. The approach utilizes spectral, shape and texture features as well as principal component analysis to extract urbanized areas from the Landsat data sets. The results are individual land-cover classifications for the available Landsat data sets differentiating urbanized and non-urbanized areas at the respective time step.

In addition, a classification of built-up structures based on stripmap data from TerraSAR-X enables us to continue the monitoring of urbanized areas until today. An object-oriented methodology to extract sealed areas has been presented in Breunig (2008), Esch et al. (2006), and Thiel et al. (2008a, 2008b). The algorithm takes advantage of specific characteristics of urban SAR data showing strong scattering due to double bounce effects in highly structured urban areas. Detection of settlement areas from TerraSAR-X stripmap data was done by the use of speckle divergence and intensity data (Esch et al., 2011). Using the optimized segmentation algorithm an object-oriented methodology is utilized to infer built-up areas, which are characterized as highly textured surfaces due to a comparatively high directional non-Gaussian backscatter. In combination with high values in backscatter intensity an automated threshold-based image analysis procedure allows delineating urbanized from non-urbanized areas. The complete processing chain has been presented in detail in Esch et al. (2010) and Taubenböck et al. (2012).

The terms 'urbanized area' or 'urban footprint' are widely used in literature and basically refer to the spatial extent of urbanized areas on a regional scale; however, it is a fuzzy and inconsistent definition. We refer to the definition used in Taubenböck et al. (2012) where urbanized areas are defined as 'settlement mask' consisting of buildings, streets and impervious surfaces. The accuracy assessment (quantified in the next section) is based on this definition. The multi-temporal change detection is shown in Figure 3. To match the classification results of Landsat data and TerraSAR-X data, a downsampling to Landsats' pixel spacing of 28.5 meters and a georeferencing of the SAR data were performed. Subsequently, post-classification change detection is applied to identify spatial urban growth over time. Most studies on multi-temporal change detection using image fusion techniques use input data from the same sensor at various times (e.g. Ridd and Liu, 1998). Although algorithms for multi-source change detection exist (e.g. Zeng et al., 2010), the most natural and straight-forward procedure for indicating changes from multi-source and multi-temporal remotely sensed data with differing geometric resolutions, varying spectral

[1] 'mahalleler' means neighborhoods in Turkish.

behavior due to different atmospheric situations and times of recording as well as the combined usage of radar and optical data sets is post-classification change detection. This has also been put forward by Mas (1999) who compared different change detection techniques suggesting post-classification change analysis to be the most accurate procedure and having the advantage of indicating the nature of the changes. Therefore, independently, we implemented a pixel-based comparative analysis of land cover classifications for the available times t1, t2 and t3 to monitor and analyze the land cover changes in Mersin.

Accuracy Assessment

Accuracy assessment has been performed on the multi-temporal change detection derived from multi-sensoral remotely sensed data. We assessed the accuracy of every individual classification result with 250 randomly distributed pixels. Due to missing ground truth data, the accuracy assessment was done visually by comparing classification results to the Landsat as well as the TerraSAR-X data. Thus, this assessment of accuracy already includes uncertainties. Even so, the accuracy assessment reveals high overall accuracies ranging from 85% of the 1987 Landsat TM to 91% for the 2000 Landsat ETM+ and finally to 93% correctly classified pixels for the 2009 TerraSAR-X data set.

This high reliability of the results of our remote sensing analysis provided us with the possibility to precisely detect the quantitative change of the urban expansion in different time periods on a small-scale spatial level, below the level of neighborhoods. We have been able to reveal zoned hot spots of urban spread and densification, which we examined on site regarding their genesis. As discussed in the next sub-section, parallel to employment of remote sensing data, we also focused on the explanation of the driving demographic, social and economic processes leading to the urban density increases, using conservative methods of social science. The coincidence of the results, which were collaterally elaborated by quantitative and qualitative methods, underlines their high reliability for the time period 1987 - 2000. For the period 2000 – 2009, we used only qualitative methods of social science as there is no secondary statistical data available yet. But as the ascertained geneses of the neighborhoods are highly replicable and as there is a high compliance of the various statements in the conducted interviews, we assume a high quality of the results also for the second period.

In-situ Analyses

The results of the remote sensing analyses were revised on site, and the causative and contingent processes that led to the detected changes in the urban morphology were analyzed. As aforementioned, we employed secondary data from the Institute of Statistics of Turkey (TUIK). Hence, we obtained information from the population census 2000 about the number of households per neighborhood (mahalle) and about

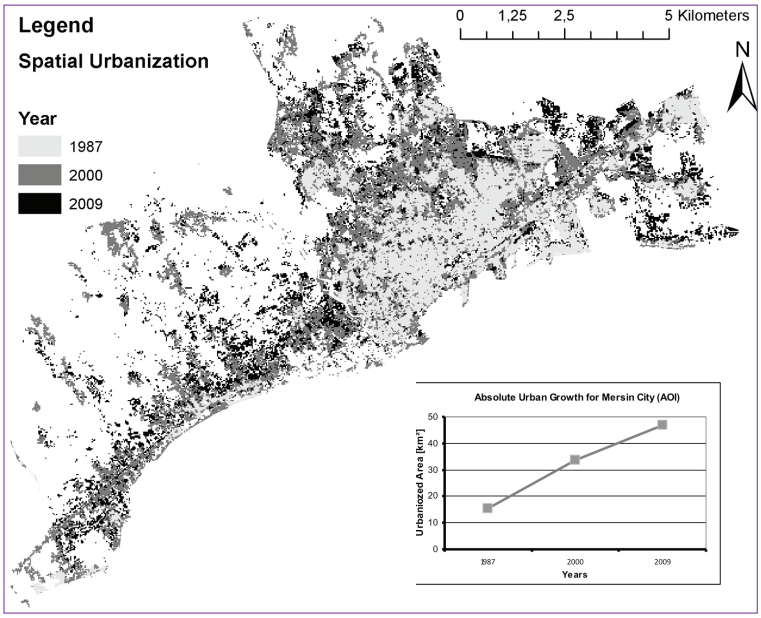
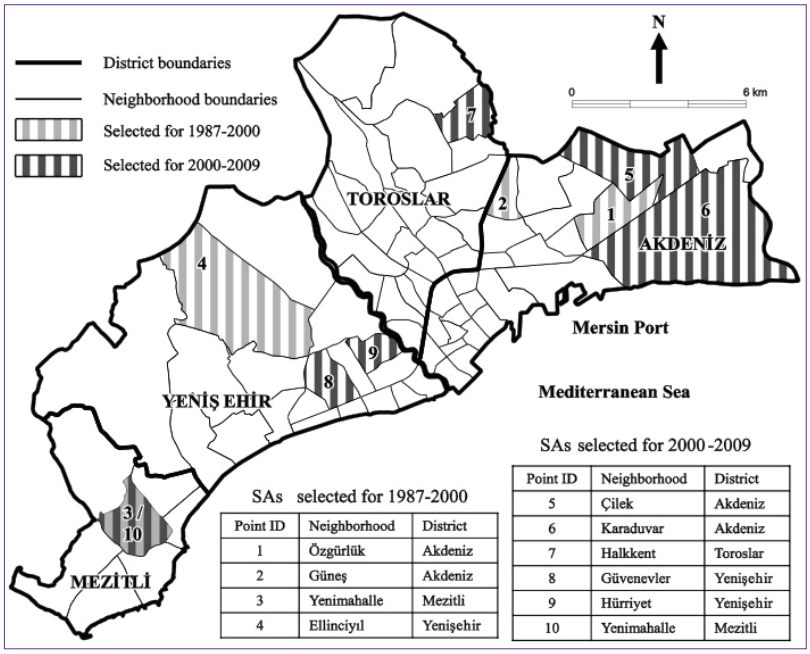


Fig. 3. Change detection for Mersin 1987, 2000, 2009 and quantification of urban growth (Source: own calculation).



Point ID	Neighborhood	District
1	Özgürlük	Akdeniz
2	Güneş	Akdeniz
3	Yenimahalle	Mezitli
4	Ellinciyıl	Yenişehir

Point ID	Neighborhood	District
5	Çilek	Akdeniz
6	Karaduvar	Akdeniz
7	Halkkent	Toroslar
8	Güvenevler	Yenişehir
9	Hürriyet	Yenişehir
10	Yenimahalle	Mezitli

Fig. 4. Sample Areas (SAs) of the in-situ revision (Source: Our own drawing based on the information compiled from the Greater Municipality of Mersin).

the profession and the place of birth of the residents. From the building census 2000, we acquired data regarding the number of buildings constructed from 1960 to 2000 per neighborhood, the corporation type of the awarding authorities, the heights of construction by numbers of stories, the land tenure of the buildings, the number of rooms in dwelling units and the building material used in the construction of the buildings (Figure 7-14). This data was used for conducting descriptive statistics, in particular frequency analysis for the time period 1987-2000.

On the other hand, we conducted qualitative interviews (semi-structured) with inhabitants of the neighborhoods and service staff, such as private watchmen on site, as well as with experts and city planners in Mersin, who have been watching certain processes in the urban structure of the city during the last decade. These interviews were transcribed and interpreted using qualitative content analysis (Mayring, 2008) in order to understand the geneses of the respective neighborhoods and the driving forces behind their development. For each sample area (SA) at least two residents, muhtar[2] of the neighborhood unit covering the respective SA and a real estate agent operating in the area were interviewed in order to reveal the origin of the neighborhood unit (early comers and historical development) and general socio-economic characteristics of the respective neighborhood by conducting semi-structured and in-depth interviews.

Results and Discussion

Spatial Urban Sprawl of Mersin City

Mersin City is rapidly sprawling. Figure 3 displays the urban footprint of Mersin in 1987 and its spatial expansion over 22 years until 2009. From 1987 until 2000, the urbanized areas more than doubled within the Area of Interest (AOI). Until 2009, we measure a slight decrease in spatial urban growth, resulting in an urban footprint 1.4 times as big as in the year 2000. The urban footprint of the coastal city is orientated in a south-west to north-west direction, following the main transport axis connecting Tarsus and Adana City located in north-east direction to Erdemli and Silifke located in south-west direction.

In general, we notice a re-densification in the inner city districts. Furthermore, the change detection reveals two main development directions: a dominant sprawl in north-east to south-west directions, corresponding to the main transport axis along Silifke -Erdemli-Mersin-Tarsus-Adana, and a second development direction is orientated from the sea to the hinterland, following roughly south-east to north-west direction as an urban concentration around the center. In fact, the decreasing urban sprawl in the last decade

[2] Muhtar is the local government official elected by the residents of a village or neighborhood unit as the head of the respective village or neighborhood.

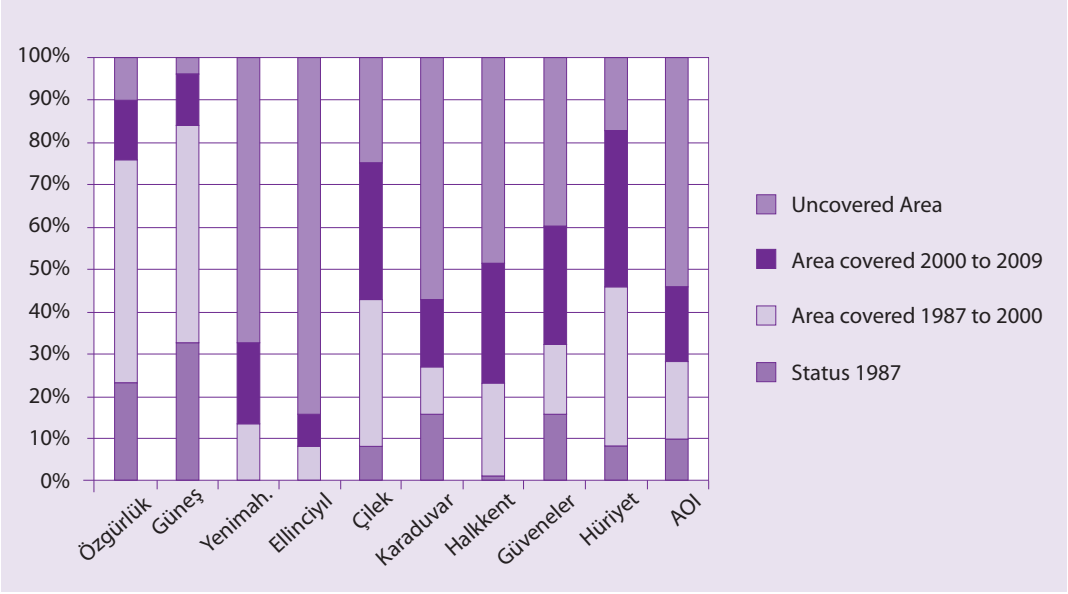


Fig. 5. Bar chart (100%) of urbanized area 1987 and spatial growth until 2000 and 2009 per neighborhood (Source: own calculation).

within the AOI is partly misleading due to the sprawl along this axis outside the AOI. Regarding the individual neighborhoods (Selected Areas (SA) 1-10 in Figure 4), the process of physical urbanization has been analyzed in a more detailed context. It becomes obvious that the peripheral neighborhoods of the urban center (especially Yenimahalle, Ellinciyıl and Halkkent) have developed after 1987 and experienced high growth rates since 2000 (Figure 5).

In addition to this, the analysis of the built-up density reveals enormous re-densification processes in the central districts of Özgürlük and Güneş resulting in the high-density areas of today. While for these districts closer to the center built-up densities of up to 90% and more can be identified, the peripheral neighborhoods still show low density rates of 15-30% (related to the administrative area) (Figure 6).

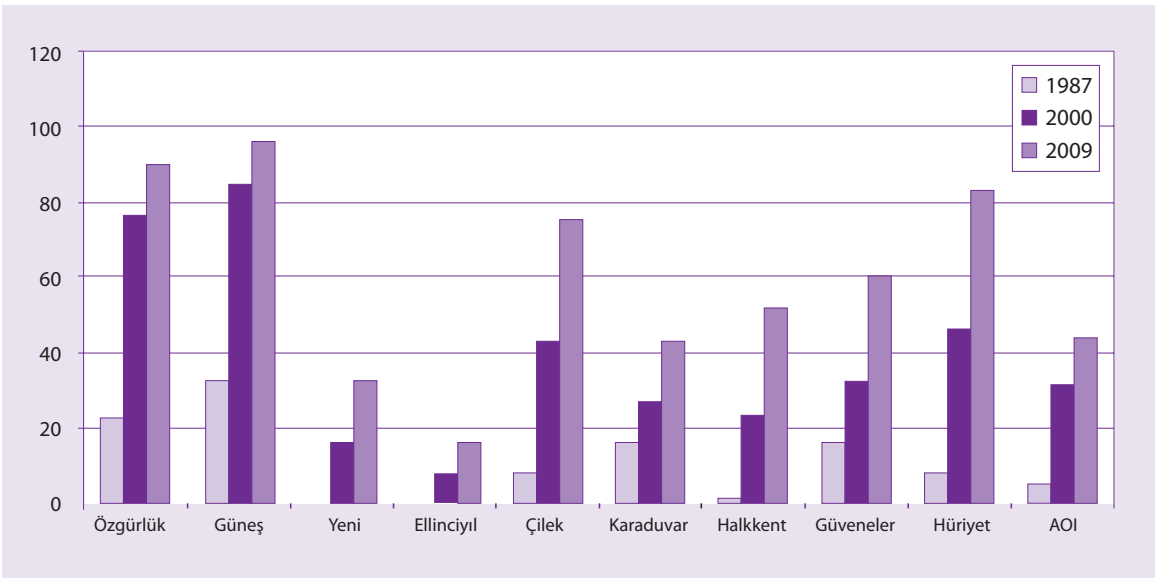


Fig. 6. Built-up density per neighborhood (%) (Source: own calculation).

In-situ Revision

The results of the urban sprawl and density change detection were revised on site in selected sample areas (SA), where according to our results, the building density has increased up to 100% and more during at least one of the time periods analyzed (Figure 5). For the period 1987–2000, the causative processes have been additionally analyzed using secondary data of the 2000 census, which was obtained from TUIK (see the section entitled in-situ analyses). These SAs were studied in order to revise the results and to contextualize the pattern of the development in different parts of the city. At this point, a special effort is made to represent the totality of the metropolitan area (Figure 4). For each SA, the results of the settlement change detection are proven by qualitative interviews held with the inhabitants on site and supported by the statistics of TUIK (Figure 7-12).

Migration and Segregation: The first SA in the east of the city is located in the Özgürlük neighborhood unit, which is north of the port area (Figure 4). According to our remote sensing analyses, it covered a total built-up area of 0.36 square kilometers in 1987 and underwent a dynamic growth till 2000, as the built-up area sprawled 234% (Figure 5), reaching 1.21 square kilometers. In the same time, it was compacted by an increase in building density of 53% (Figure 6). Qualitative interviews conducted with the residents during the field survey revealed that this growth was caused by massive immigration in the 1990s, which slowed down in the following decade. Accordingly, we monitored a moderate increase of the built-up area of 18% spread and 14% additional densification for the period 2000-2009, reaching a covered total area of 1.43 square kilometers at a total building density of 90%. The inhabitants of the SA generally immigrated from the provinces of Gaziantep and Adıyaman, which is also confirmed by the data of the 2000 census compiled from TUIK. Following the population structure in these provinces, Özgürlük's households are relatively large, as 42% consist of 5 to 7 people and almost 9% count 8 or more family members (Figure 7).

The inhabitants mainly earn their livelihood in local agricultural companies (Figure 8). Due to their migration background, their employment structure and the neighborhood's typical building morphology, the SA can be described as part of a typical 'gececondu' (squatter housing area). The mainly one or two story buildings (Figure 9) have been raised by the inhabitants on their own (Figure 10). Concrete armored pillars on the top roofs point to the possibility of increasing the number of stories in the future if, feasible and necessary. The roofs are usually lapped by a mason balustrade, which gives them the function of a terrace. Pieces of furniture and self-made awnings show that the families owning the buildings use these roofs as additional living space in the summer, e.g. as a sleeping area during hot nights. Vast numbers of plant pots (usually former food cans) with agricultural plants green the top roofs. Vegetables, tomatoes, herbs and sunflowers are grown here and in vegetable patches in the open areas around the houses for the self-supply

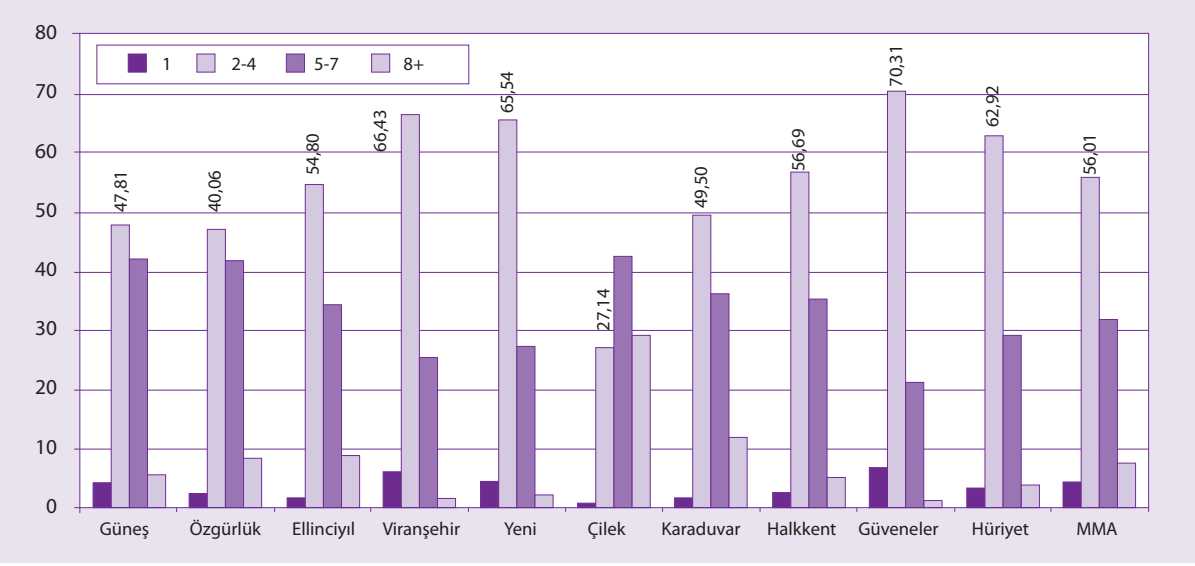


Fig. 7. Share of households in the neighborhood units accommodating the selected SAs and MMA according to the size of the household (%) (Source: TUIK 2009a). Mersin Metropolitan Area (MMA).

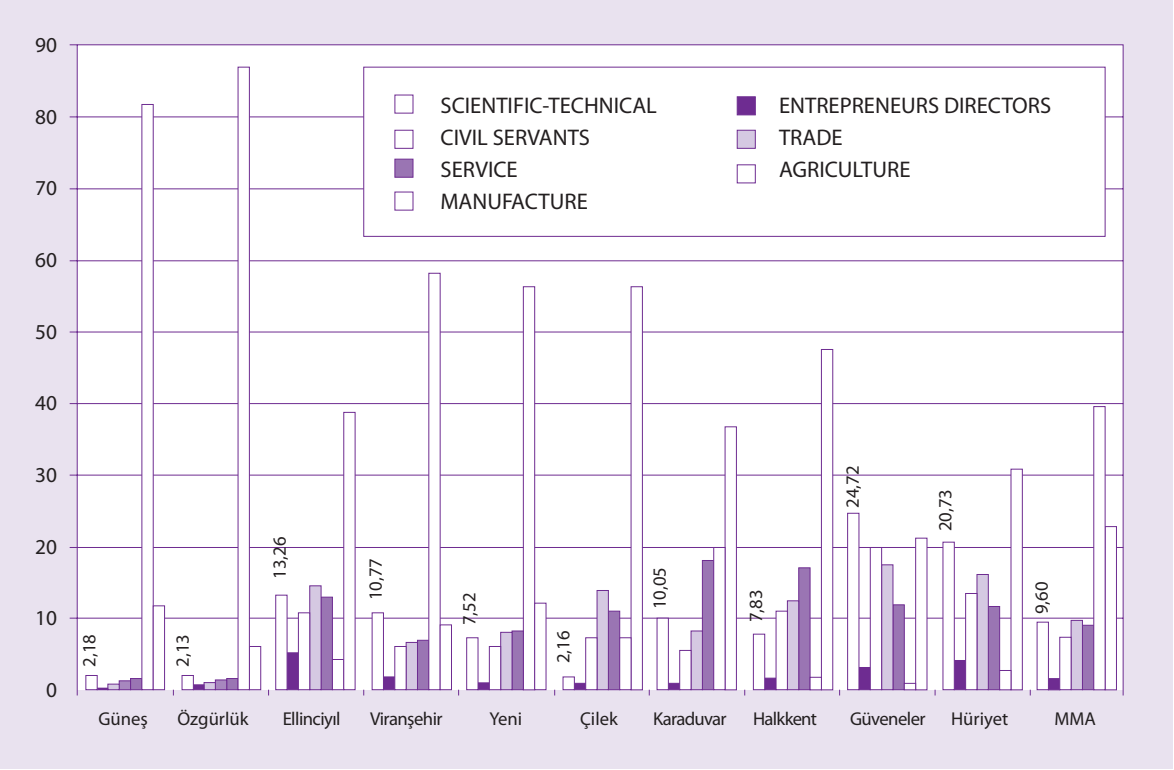


Fig. 8. Profession of the people living in the neighborhood units accommodating the selected SAs and MMA (%) (Source: TUIK 2009a).

of the owner families. This underlines the typical mixture of elements of rural and urban lifestyle in gecekondular (Wedel 2004).

Next to this first SA, we selected three further SAs in the eastern district of Akdeniz (Figure 4). Our results have shown extreme growth rates during the last two decades: In this respect, a second SA located towards the north-east of the city is in Güneş neighborhood unit. Covering a total built-up area of 0.25 square kilometers in 1987, it also underwent a rapid spread (of 158%) till the year 2000, accompanied by a compaction rate of 52%. Like in the case of Özgürlük, the reason for this development was a strong immigration, which faded in the 2000s, resulting in a retarded growth of the neighborhood (Figure 5, Figure 6). Nevertheless, the building morphology of the two neighborhoods differs from each other, as the houses in Güneş are significantly higher.

Indeed, in Güneş one can find many buildings with up to 4 stories added (Figure 9), which generally have less planted surfaces and have a more urban appearance than those in Özgürlük. This morphology supports the characterization of the neighborhood as a further developed squatter housing area. The average household size in Günes is also slightly smaller than in Özgürlük (Figure 7), indicating a further progressed urbanization and economic rise of the population. Still, the employment-structure of the neighborhood shows a vast majority of 82% being employed in the first sector but only 12% working in manufacturing (Figure 8). It is known that the inhabitants of Güneş mostly immigrated from the provinces of Diyarbakır, Batman and Bitlis.

Likewise located in Akdeniz municipality are SA five and six, which are in the neighborhoods of Çilek[3] (fifth SA) and of Karaduvar (sixth SA) respectively. According to our analysis, Çilek also underwent an extreme growth from 1987 to 2000 as we detected an increase of its built-up area of 424%, reaching 1.31 square kilometers at a building density of 43% (+ 35%). Thereafter it faced a further, though moderate spread of 76%, reaching an area of 2.3 square kilometers at a high densification rate of currently 75% (Figure 5, Figure 6). Covering already 1.42 square kilometers in 1987, Karaduvar's built-up area spread 70% until 2000. As in

[3] 'Çilek' means 'strawberry' in Turkish.

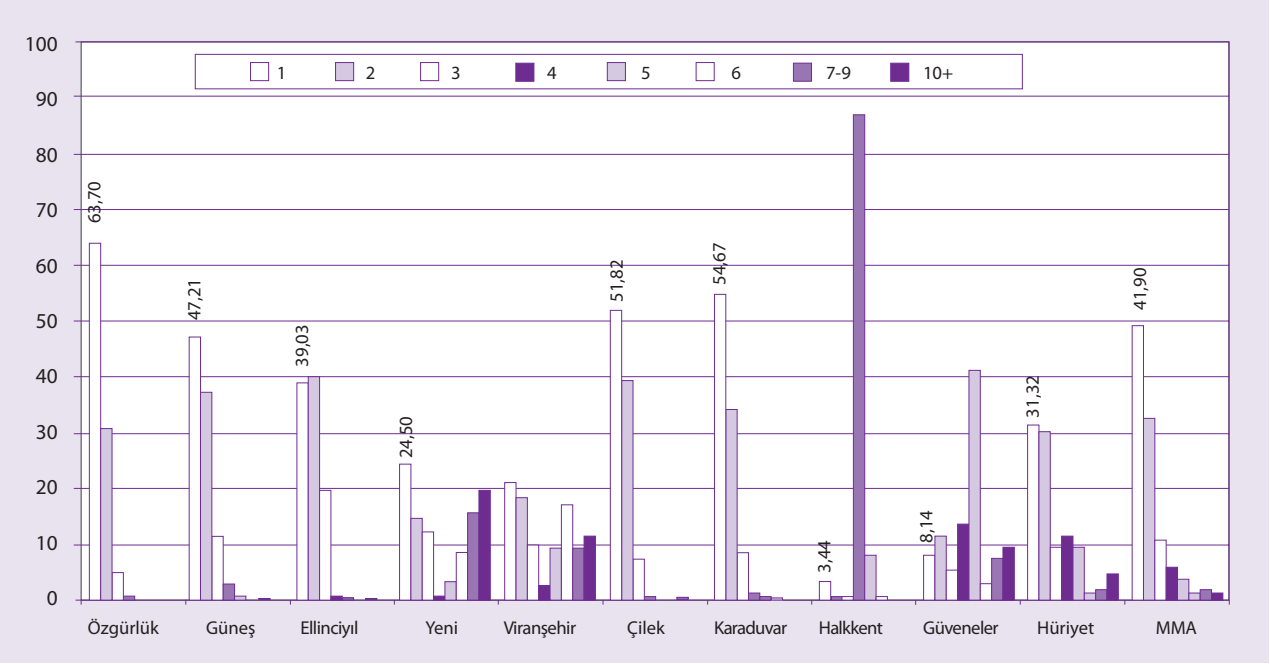


Fig. 9. Distribution of the existing housing stock in the neighborhood units accommodating the selected SAs and MMA according to number of stories (%) (Source: TUIK 2009b).

the case of the latter three SAs, Karaduvar grew more moderately in the 2000s, spreading 58% until 2009, when it covered 3.8 square kilometers at a relatively moderate building density of 42% (Figure 5, Figure 6). The relatively higher growth of the SAs five and six in relation to the SAs one and two in the period 2000-2009 is due to the simple fact that there is unspoiled agricultural land north and east of Çilek and Karaduvar, while Özgürlük and Güneş had already been locked by new emerging neighborhood units. Most of the people residing in Çilek neighborhood migrated to Mersin from the south-eastern Anatolian provinces of

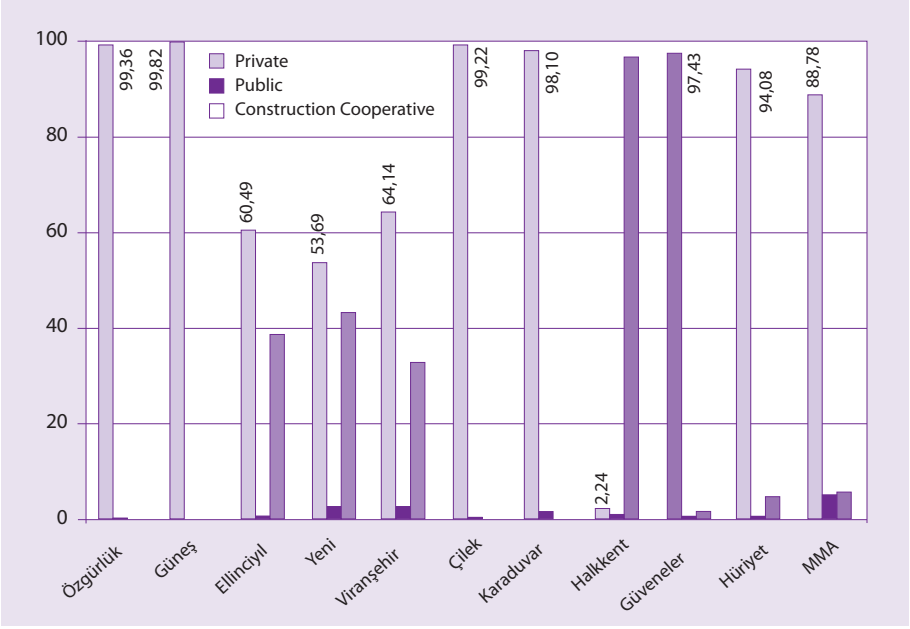


Fig. 10. Housing stock in the neighborhood units accommodating the selected SAs and MMA according to the share of major forms of provision (%) (Source: TUIK 2009b).

Adıyaman, Diyarbakır and Şanlıurfa. The inhabitants of Karaduvar mainly immigrated from the provinces of Hatay, Şanlıurfa and Mardin.

As expected, the two neighborhood units of Çilek and Karaduvar also show the typical social-demographic profile of gececondular, comprising big household sizes and an employment structure with high scores in unskilled jobs. The available statistics (census year 2000) for the respective districts show that 42% of the households in Çilek are composed of 5 to 7 persons and 29% are composed of 8 or more people. This is the biggest figure among all considered SAs (Figure 11). Although almost 50% of Karaduvar's households consist of 1–2 persons, 37% are larger than 5 and 13% larger than 8 persons. The majority of Çilek's population work as unskilled laborers (Figure 8) in near industrial enterprises at a low income. This is similar in Karaduvar, where a significant number of employees are also working in agriculture, another typical source of employment and income for inhabitants of gececondular. Nevertheless, almost 18% of Karaduvar's working population is self-employed, running little enterprises, predominantly in the fields of craftsmanship, services and retail. The building morphology of the two neighborhoods is dominated by simple one-storied houses. According to our studies on site, these have been built by their occupants (Figure 10), who usually own the buildings (Figure 11). As we assessed, the findings from TUIK data are basically also valid for the time span 2000 to 2009.

Thus, all four of the considered neighborhood units in the district of Akdeniz are predominantly inhabited by immigrants, who came to Mersin from eastern, south eastern and mid Anatolia from the late 1980s on. These people first worked in seasonal jobs that were mostly available in the agricultural and related sectors in the region. Today, most of the respective residents still work as unskilled workers in agriculture, in the nearby industrial companies, in the harbor or in agricultural wholesale (Figure 8) (Doğan 1999; Meçin 2004).

The areas where they settled down by constructing their own houses on illegally subdivided land in close proximity to their workplaces had previously been public land or had been used for agricultural production. Small lots in the respective land were sold to the immigrants by local farmers beginning from the 1970s onwards. In the case of Özgürlük, Güneş and Çilek, the settlers built their gececondular on agricultural land beginning from the 1960s onwards (Figure 12).

As the name of Çilek neighborhood suggests, the respective fields had previously been known for straw-

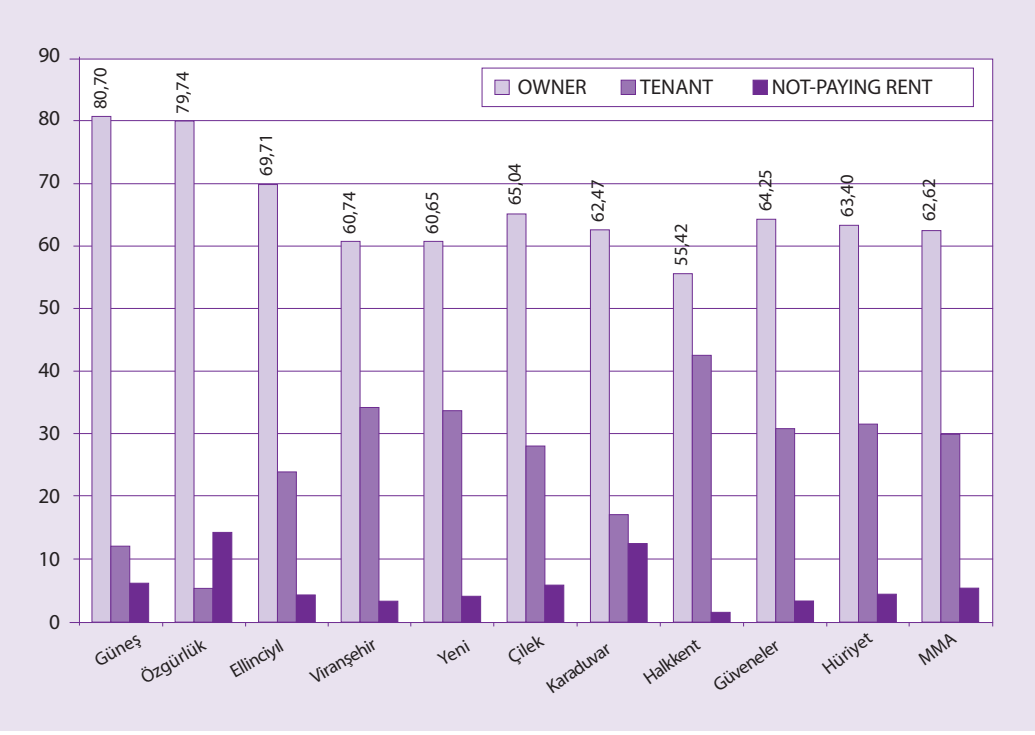


Fig. 11. Tenure distribution of the residents in the neighborhood units accommodating the selected SAs and MMA (%) (Source: TUIK 2009b).

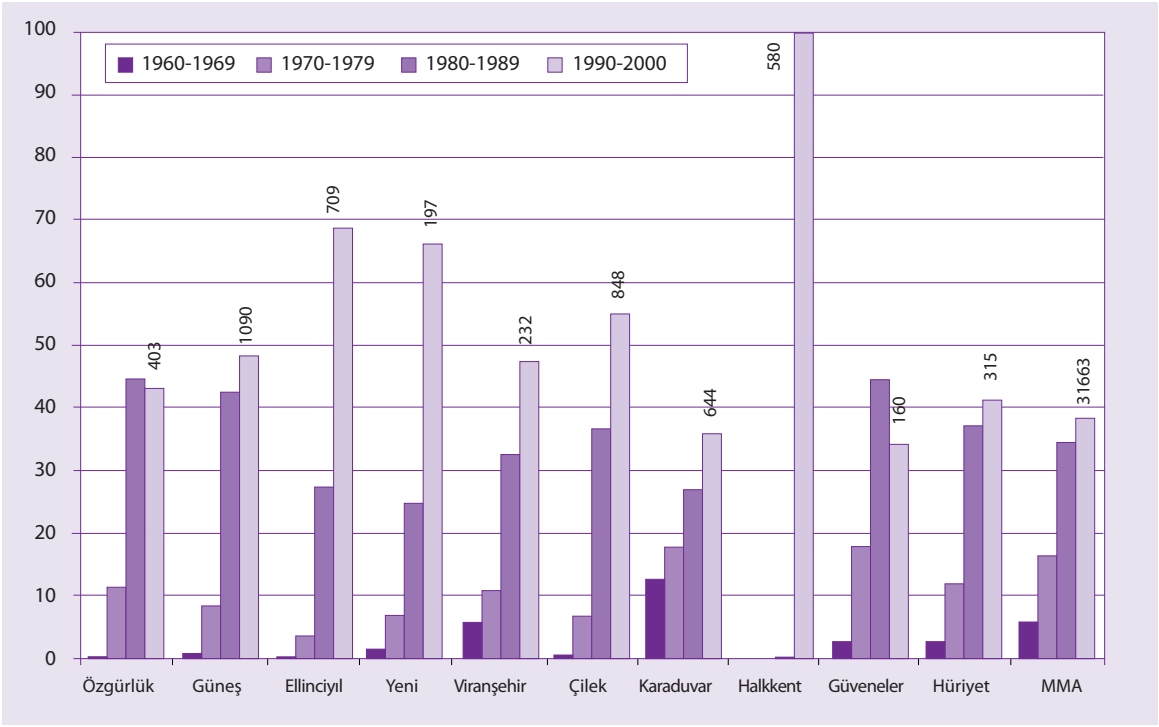


Fig. 12. Housing stock according to the share of the construction period by the neighborhood units accommodating the selected SAs and MMA (%) (Source: TUIK 2009b).

berry production. In contrast, Karaduvar is an ancient settlement site with proven Hellenistic / Roman origins (Seton-Williams 1954, 122). It used to be an independent village until the late 1960s when it was annexed into the emerging gececondular around. As everywhere in Turkey, "[the] loss of valuable fertile agricultural land to illegal subdivisions is the cause for great concern in [Mersin]" (Türel 2001, 3). The respective settlements that were built before 1986 were officially authorized by the National Amnesty Law (law no: 2981) enacted in 1984. Our on-site observations also reveal that the majority of dwellings within the SAs that were built between 1987 and 2000 have become institutionalized in terms of infrastructure in the meantime. Public and local services (such as electricity, drinking water, sewerage system, telephone and garbage collection) are provided in the neighborhoods by public and local bodies and all dwellers benefit from these services. Furthermore, all buildings are registered by the street address system (Address Information System) of the municipality and the inhabitants declared to pay the Environment Cleaning Tax.

Although the public and local services are provided, an important segment of the inhabitants is still not covered by the public social insurance system and has less opportunity to build savings. Only in Karaduvar the share of residents who have a social assurance seems to be slightly higher than in the other SAs located in Akdeniz municipality, which suits Karaduvar's relatively higher number of self-employed people.

In the early years of migration, family-networks and compatriotic relationships (so-called hemşehrilik) usually substituted for the lacking public social insurance and responded to the important problems of daily life, such as cushioning the costs of necessary medical treatment or providing care for elderly people. They further mediate jobs, build business networks, and help newcomers from their native regions to gain ground (Erengezgin 2009). As customary in gececondular, the density of the respective areas has "been gradually increased by the addition of new floors on top of the initial structures" (Türel 2001, 3). In compliance with our building density analysis (Figure 6), this can be observed especially in Güneş, where the inhabitants have obviously been economically slightly more successful, as a significant number of houses reaches a construction height of 2–3 stories, while in the other considered neighborhoods one usually finds 1–2 storied buildings (Figure 9). Generally, the unauthorized stock of housing is characterized by relatively low-rise buildings (Figure 9) as the owners of the respective houses cannot afford to build higher multi-storied edifices.

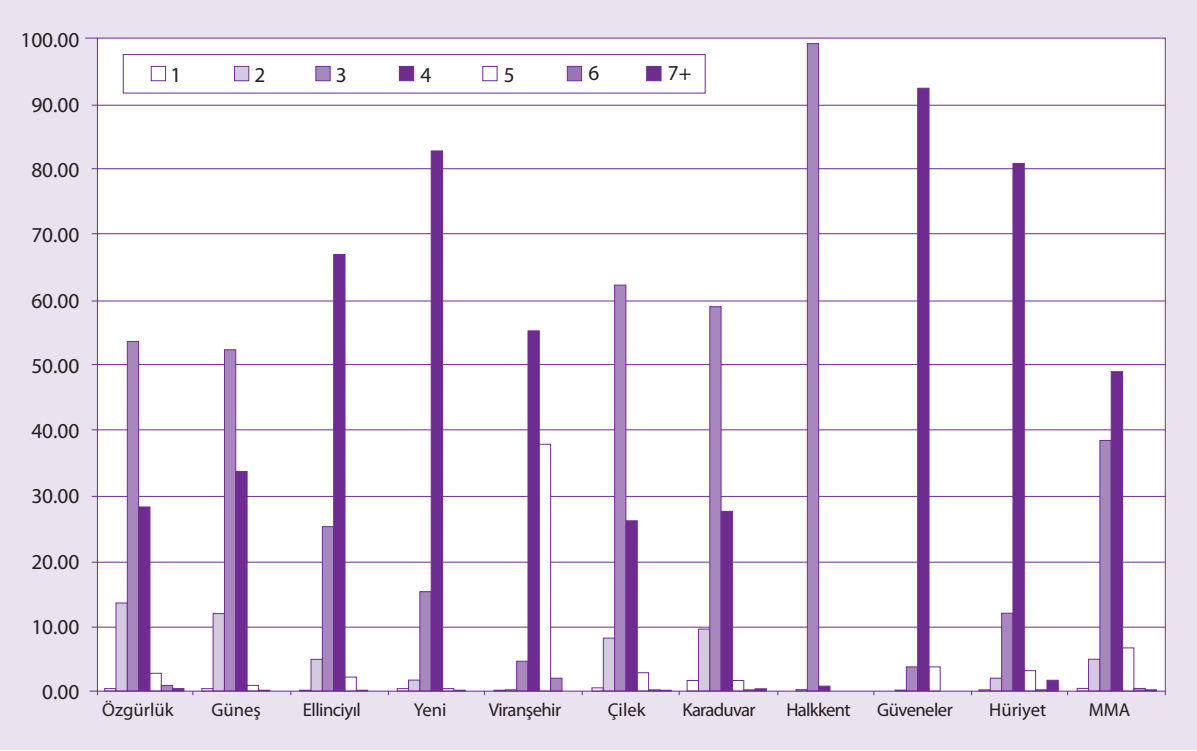


Fig. 13. Distribution of the existing housing stock in the neighborhood units accommodating the selected SAs and MMA according to the number of rooms in dwelling units (%) (Source: TUIK 2009b).

Parallel to this, it is observed that the majority of the dwelling units in Özgürlük, Güneş, Çilek and Karaduvar neighborhood units characterized by squatter type of housing have at most 3 rooms (Figure 13). The share of dwelling units having only 1 or 2 rooms are also higher in the respective neighborhood units compared with both MMA and the neighborhood units covering other SAs, which is in line with our expectation for the respective areas. As the owners of the respective houses cannot afford to build larger dwelling units, they build dwelling units having generally at most 3 rooms despite the fact that their average household size is higher than the residents of the other SAs.

Furthermore, what is evident from the building census is that the main building material used in the construction of the dwelling units in the neighborhood units covering the SAs characterized by squatter type of housing is hollow concrete block, which is one of the cheapest building materials in Turkey (Figure 14).

Interestingly, Türel (2001, 11) shows that "although the supply of authorized housing has been much greater than the need (defined as new household formations) during the last 15 years ... more than a third of the housing stock constructed [in Mersin] has not been authorized". It can be assumed that, unless the purchasing power of the people increases by creating employment opportunities offering good salaries, most immigrants will continue to solve their housing problem by constructing their own houses as it was the case in the formation of the squatter type of housing in Akdeniz municipality.

Social Housing: In contrast to the gececondular, one can also find planned social housing in Mersin. An example for such housing areas is the seventh SA, which is located at the north of the city as part of the Halkkent[4] neighborhood unit within the district of Toroslar (Figure 4). The cheapest flats in Mersin (even in Turkey) are sold here at current prices (February 2010) of approximately 35,000-45,000 TLs[5] (470 TLs per square meter). The building process of this area had already begun in the 1990s. According to our analyses, starting from almost zero, 0.29 square kilometers of built-up area were constructed between 1987 and 2000 in the respective area. Until 2009, Halkkent grew further 121%, doubling its building density to 52% (Figure 5, Figure 6). These results match the data of the building

[4] 'Halkkent' means 'public-city' in Turkish.

[5] 1 TL= 0.4844 € (http://www.tcmb.gov.tr/yeni/eng/;18.02.2010; 15:30 GMT +2).

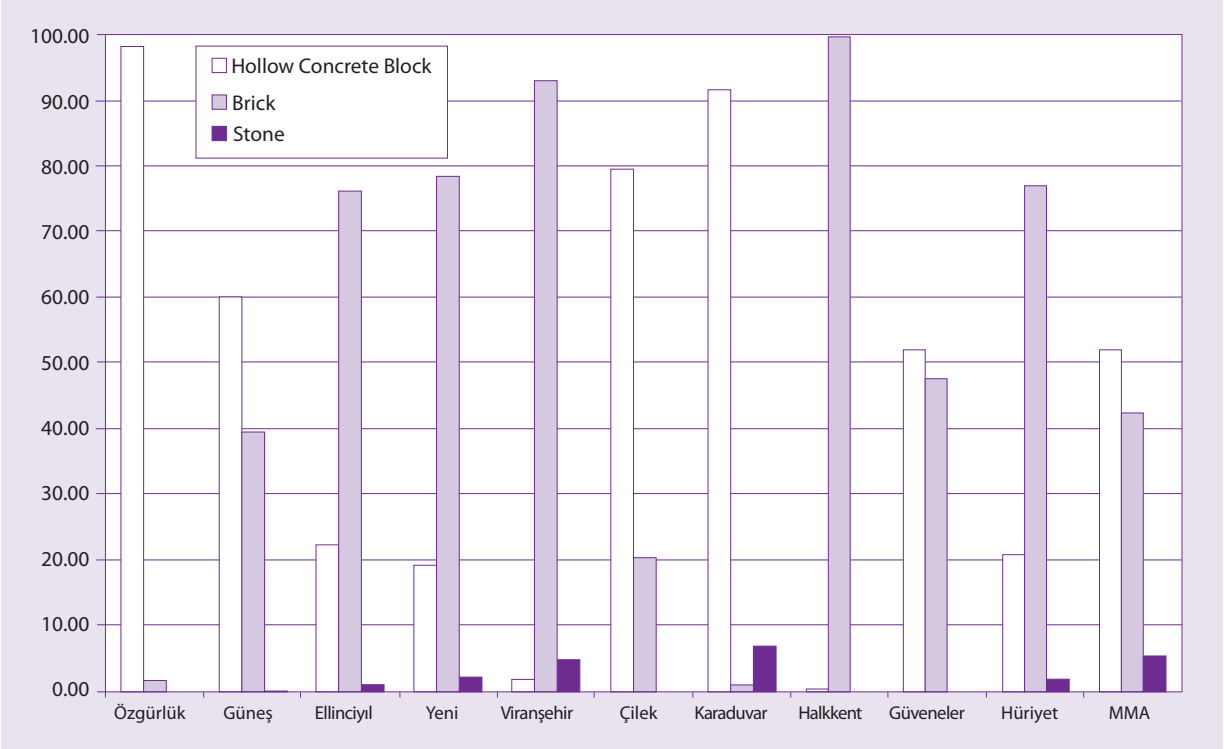


Fig. 14. Distribution of the existing housing stock in the neighborhood units accommodating the selected SAs and MMA according to the material of building (%) (Source: TUIK 2009b).

census 2000 (Figure 12), which clearly underlines the planned character of Halkkent neighborhood unit. Figure 10 illustrates that nearly all of the buildings in the area (97%) have been built by construction cooperatives, which reflects that the area is a planned district. Figure 9 and Figure 13 support this view by highlighting the fact that there is a rule for the maximum height of the buildings in the area (max. four stories) and also the number of rooms in dwelling units. The building morphology of the houses is almost homogenous. It is characterized by a flat roof and balconies that surround every floor. House blocks are not properly separated from each other by any regular concrete wall. Compared with the gecedondular or the planned developments observed along the western end of MMA (see below), one finds few greenings in Halkkent except small greened areas and some trees placed along the property lines.

The population of Halkkent clearly shows its own structure: The majority of the inhabitants were born in Mersin. 57% of the households consist of 2–4, 35% of 5–7 people. A vast majority of the working population is employed in manufacturing, 17% in services, 12.5% in trade and 11% in civil services. Yet almost 8% are employed in science and less than 2% work in agriculture (Figure 8). It is important to notice that almost 100% (99.18%) of the dwelling units in the area have 3 rooms, which is in line with the planned social housing characteristics of the area (Figure 13). Compared with the SAs characterized by squatter type of housing, in Halkkent covering the seventh SA it is observed that the main building material is brick which is a more durable and expensive building material than the hollow concrete block widely used in squatter areas (Figure 14). Our building density change analyses of the period 2000 to 2009, backed up by the qualitative interviews on site, revealed that the area is still under construction.

Conversion of Holiday Homes to Middle-Class Apartments: In addition to the growing gececondu areas of the city in close proximity to the city center and to a vast amount of social housing in the northern outskirts, much more "housing has been built in newly developing parts of the city, most notably in Mezitli and Yenişehir in the 1990s" (Türel 2001, 7)[6] especially for vacation purposes. The third SA, which is located in the west end of the city, in Yenimahalle neighborhood unit (close to Viranşehir), which is part of the district

[6] The share of unauthorized housing in Mersin in 2000 amounts to 39% (Türel, 2001).

of Mezitli, reflects this development properly (Figure 5). The SA and the area surrounding it are characterized by a dominance of multi-storied residential buildings (apartment houses up to 9 floors), often with roof terraces in relative proximity to the waterfront. Many of them are associated with a series of amenities, such as private swimming pools, sport facilities and little parks. The average floor area of the apartments reaches up to 250-300 m². The objects had been built in the 1990s by medium-sized construction firms and construction cooperatives as vacation domiciles and had been sold "mostly to upper-income buyers from central and eastern Anatolian cities" (Türel 2001, 3). During the 1980s and 1990s, a high amount of these multi-storied apartment buildings were built close to the coastline of Mezitli, whose origins can be traced back to the Iron Age. In the ancient world, the contemporary district of Mezitli had been the location of a city called Soli Pompeiopolis (today covered by Viranşehir neighborhood unit) (Seton-Williams 1954, 168). As the extension of this conurbation along the western coastline of Mersin continued in the 1990s, the village of Mezitli merged into Mersin Metropolitan Area (MMA).

As our spatial analyses show, the neighborhood of Yenimahalle mainly emerged after 1987 (Figure 5). By 2000 it had reached a built-up area of 0.24 square kilometers at a moderate building density of 13.5% (Figure 6). In the following 9 years, the covered area underwent a rapid spread of 140%, including a further agglomeration in building density of 19%. The district lost its function of a recreational zone as the beaches became unsightly, due to the construction of further apartment blocks and the increasing pollution of the sea. Over the last 10 years, the respective neighborhoods have been converted into suburban housing areas.

This development is reflected by the tenth SA, which is also located in Yenimahalle neighborhood unit (also Viranşehir), close to the remains of the ancient city of Soli Pompeiopolis. In terms of building morphology, it does not generally show major differences to SA three. On closer examination, one realizes that the new buildings within SA ten are of better building quality and show a slightly higher level of luxury with regards to the respective amenities than the older ones in SA three. Indeed, compared with both other neighborhood units and Yenimahalle covering the third SA, the share of dwelling units having 5 rooms is highest in Viranşehir, partly covering the tenth SA (Figure 13). Actually, compared with other neighborhood units, the majority of the dwelling units in both Yenimahalle and Viranşehir covering SA three and ten have generally 4 or 5 rooms, which is completely in line with our expectation for the area. Parallel to Halkkent neighborhood unit covering the seventh SA, it is also observed that the main building material in both Viranşehir and Yenimahalle is brick.

Qualitative interviews with doormen and real estate agents on site revealed that the recent buildings in the tenth SA had been constructed as regular apartment blocks for the upper-middle and upper classes. The attractiveness of this residential area seems to be positively influenced by the fact that the area, which contains remains of Soli Pompeiopolis, is now under protection with ongoing excavations. This archeological site covers quite a big area of approximately 0.73 square kilometers (around 0.47 km² of the respective area is scheduled as a first degree archaeological site and the remaining 0.26 km² are scheduled as a second degree archaeological site).[7] It has a park-like atmosphere and prevents any further lining in the respective area.

Today many of the former high quality apartments are leased or sold (Figure 11) to young couples and young families (with one or two children) of Mersin's middle-class (Figure 7, Figure 8). This functional change of Mezitli from leisure and recreation accommodation to permanent residence shows Mersin's ongoing elongation along the western coastline to the city of Erdemli.

Elite Segregation: Like the latter two, the forth SA (Figure 4) turns out as a project that had been built in accordance with the Urban Improvement Law (law no: 3194). The SA is located on former pasture land in the lower foothills of the Taurus, which reaches the western outskirts of Mersin. Its east-oriented exposition offers a panoramic view over the city center of Mersin and the Gulf of Iskenderun, while the orographic exposition ensures a comfortable microclimate under permanent influence of land-sea / sea-land breezes. Administratively, the SA is part of Ellinciyıl[8] neighborhood unit, which is part of the district of Yenişehir. Here, the planning process of the construction of residential units had been initiated in 1973 by the establishment of a housing cooperative named after the 50th anniversary of the Turkish Republic. According to our analyses, effective building started in 1987 (Figure 5) at the western end of the area of Ellinciyıl neighbor-

[7] The area covered by the archeological site is calculated according to the formal site boundaries given in Sarıkaya Levent (2008, 139).

[8] 'Ellinciyıl' means 'fiftieth anniversary' in Turkish.

hood (Figure 3): Here appears on site the campus of a private high school, named Palmiye Koleji, which was founded in 1987 and expanded further in the following years. Later on, several other private high schools were built right next to it. The construction of these educational complexes in the 1990s is identified to be especially causative for the appearance of 0.53 square kilometers of built-up area at a quite low building density of 8% in the SA from 1987 to 2000 (Figure 5, Figure 6). The building morphology of the respective area is functional: Spacious flat-roofed school-buildings with up to four floors and tarred schoolyards in between predominate.

Further north-east one finds three emerging complexes of residential areas, which are found to be the reason for the doubling of the built-up area in the SA after the year 2000, which reached 1.06 square kilometers in 2009 (Figure 5) and came along with a re-doubling of the building density up to-still moderate -16% (Figure 6). Being fenced in by massive walls and guarded by the permanent presence of private security services, the respective complexes are identified as gated communities (Webster et al. 2002). Starting in Turkey's western metropolises in the 1980s, gated communities nowadays appear all over the country (Baycan-Levent and Gülümser 2007). Realizing the favorable exposition of the area, the gated communities in Ellinciyıl comprise a variation of four to five different models of two- and three-storied villas with tile-covered pitched roofs. The main building material used in the construction of the dwelling units in the respective neighborhood is brick, which is in line with our expectation for the area (Figure 14). Each villa is enclosed by a small standard-type garden, comprising a little terrace followed by a small grassed area and some bushes and trees on the line to the neighbor's property. The respective houses were built relatively close to each other in lots with eight to ten rows, each of which accommodating 15 to 20 villas. As proved by qualitative interviews with watchmen on site, these houses have obviously been built in order to meet the standards of Mersin's ambitious upper middle-class families. It is well-known that the members of the earlier construction cooperatives were not from Mersin, but from other places in Turkey, which shows the projects' status as investment objects.

[9] Here the term 'quarter' is used in order to refer to the Turkish term 'semt', which usually defines an area that does not have a clear boundary unlike formal districts (such as Akdeniz, Mezitli, Yenişehir ve Toroslar in Mersin) and neighborhood units (such as Çilek, Özgürlük, Hürriyet and Yeni neighborhood units in Mersin).

Tertiarisation: A totally different process is causative for the detected extreme increases in settlement density within the SAs eight and nine, which are located in the west of the old city center. These SAs are covered by Güvenevler and Hürriyet neighborhood units, which are located within the quarter[9] of Pozcu. The development of the respective quarter as a business and housing district of the middle-class started during the 1970s and 1980s. A great change came in 2006 with the beginning of the construction of Forum Mersin, a shopping mall of 66,000 square-meters base area on an undeveloped area in Hürriyet. It was opened in October 2007 after a total investment of approximately € 200 million (ICSC 2009). The mall contains more than 200 commercial units on a gross leasable area of 71,500 square-meters; most of them are branches of international and national clothing and accessories companies in the middle and upper price segment, as well as different kinds of catering and leisure time facilities. Furthermore, a supermarket and a big store for consumer electronics are included. The architects planned spacious open-air areas between the sales buildings, which are amended by various fountains and water features, sails used for shading over grassed areas with palm trees and wooden bridges that connect upper floors of neighboring buildings. The mall is visited by approximately 3.4 million people p.a. and offers about 2,500 job opportunities (ICSC 2009). At repeated inspections on site, we could not detect any vacancies. The regular presence of significant numbers of cars from Syria and the Lebanon in the consumers parking areas indicates the reach of the mall's effect on the neighboring countries.

The building of this intact shopping and leisure center, which seems to fit well into the neighborhood district, actually led to an upgrading of the surrounding area, which, in turn, resulted in investments in further business and housing objects in the district, especially in Hürriyet and Güvenevler (Figure 5, Figure 6). As a consequence of this functional reassessment, Pozcu became Mersin's currently biggest sub-center. Majority of the dwelling units in both Hürriyet and Güvenevler have 4 rooms (Figure 13), which confirms the development of the respective area as a district for middle income group who can afford to buy relatively big houses. The upgrading of the area surrounding *Forum Mersin* can also be seen in Figure 14 in terms of transforming nature of building material in Güvenevler. Indeed, although the main building material used in the construction of the dwelling units in Hürriyet accommodating *Forum Mersin* is brick, it is observed that the share of buildings constructed by using hol-

low concrete block and brick is close to each other in Güvenevler (Figure 14).

According to our outcome, the interdisciplinary cooperation of remote sensing and social science is of high efficiency for analyzing quickly developing urban areas in space and time. The employment of methods of remote sensing provides the chance to effectively monitor the development of urban areas in total by detecting high activity areas. These can be assessed in detail on site concerning their genesis, allowing the directed use of limited ground resources for classical field work.

Conclusion and Outlook

In this paper we have shown that contemporary methods of remote sensing offer tools to sophisticatedly analyze the spatial spread and the densification of urban spaces. Owing to the availability of high spatial resolution satellite images, it is possible to identify growing or shrinking areas on a small-scale level. This enables us to revise the results on site and to further study selected areas concerning the causal economic, social and demographic processes by employing both quantitative and qualitative methods of regional analyses. In this respect, one of the basic contributions of this study can be considered the employment of remote sensing technology in combination with the socio-economic databases for the analysis and contextualization of the urban sprawl and growth of Mersin City.

In the case of Mersin, we have been able to show the city's growth during the period between 1987-2009 - particularly in terms of the spread of the built-up areas and the building density at the neighborhood level. We furthermore exposed the spatially fragmented and socially segregated structure of the city by analyzing the processes that led to growth in different districts of Mersin. These can be described as rural-to-urban migration and re-settlement; planned social housing; functional change of a holiday district to a residential area of the middle-class; elite segregation in the context of emergence of gated communities and private schools, and lastly tertiarisation of a district by the emergence of a shopping and leisure mall.

As our results reflect a high degree of spatial and functional heterogeneity, we support the hypothesis that the physical urban fabric is a reflection of the society that created it (Gonzalez and Medina 2004). Thus, an isolated analysis of social questions detached from geospatial questions does not do justice to the capabilities of the two research disciplines – remote sensing and social science. Indeed, as it is evident from this study, similar patterns of urban density change detected by employing remote sensing tools may stem from quite different sources and motivations.

Considering the fact that social construction of space is manifested in different dimensions and scales, in this study SAs subject to increasing building density have been analyzed by conducting on site excursions and mapping the available statistics for the respective areas. Even today, high-resolution remote sensing data and object-oriented methods of classification (Blaschke et al. 2000; Neubert and Herold 2008) bear the potential to monitor not only the spectral characteristics, but also the geometrical, neighborhood- and context-related characteristics (Baatz and Schäpe 2000; Benz et al. 2004; Esch et al. 2006) of urban spaces. This renders the possibility to hyper-accurately extract the urban land coverage and its structure. There is no doubt that this line of research is completely in line with the basic rationale behind socio-spatial dialectic thesis.

Postulating that the society in contemporary growing urban agglomerations of developing regions, like megacities, is highly segregated, which is reflected in fragmented building morphologies, methods of remote sensing can differentiate urban spaces by the parameters "structure" and "position". Further postulating the validity of Soja's hypothesis of the socio-spatial dialectic (Soja 1980), the structure of urban space can be understood as a crucial parameter in the explanation of social behavior (Anas et al. 1998; Hoffmeyer-Zloytnik 2000; Wlodarczyk 2005). In socio-spatial dialectic, as Plummer and Sheppard (2006) remark, interactions between agents are conditioned by not only social structure, but also spatial configuration. This can only be made visible by assigning equal analytical priorities to space and time, as it is done in this paper. In other words, socio-spatial dialectic thesis urges a socio-spatial representation of real world events and processes.

Although a historical analysis of the social processes tends to reveal causal relations between not only agents but also agents and social structure, a socio-spatial representation has the capacity to reveal the contingent factors decisive in the formation of the urban fabric in a city. Within this context, the analysis of the building density change in Mersin for the period between 1987 and 2009 under the light of the available statistics and on-site excursions have revealed the role played by the contingent factors in the development of the urban fabric of the city. Restructuring and formation of certain parts of the city in relation to the respective contingent factors have manifested them-

selves in the form of rural-to-urban migration and resettlement, planned social housing, functional change of a holiday district to a residential area of the middle-class, elite segregation in the context of emergence of gated communities and private schools, and lastly tertiarisation of a district by the emergence of a shopping and leisure mall.

Departing from the fact that socio-spatial dialectic actually calls for a search in the representation of the socio-spatial processes by assigning equal analytical priorities to not only space and society, but also space and time, in this study it has also been exposed that any socio-spatial representation should be based on not only causal, but also contingent explanations which create an open-endedness that prevents the problem of mismatching of theories and realities. In order to represent socio-spatial, a conceptualization exposing that space should be considered as part and condition of any piece of real world events and processes is required. Inevitably this brings about an open-endedness embracing contingencies. This is due to not only the spatiality, but also the increasing roles of the actors shaped by and shaping that spatiality. In other words, as it is hypothesized in socio-spatial dialectic, human beings do not only exist over space, but also constitute part of it. Within this framework, formative powers of actors through space over social structure necessitate that a socio-spatial representation should balance not only analytical priorities of time and space, but also formative powers of actors and structure.

Overall, the quest for socio-spatial representation necessitates that in order to understand real world events and processes, spatiality should be considered as part of the processes through which explanations are constructed. The basic thrust behind this necessity can be described as the desire to account for contingencies embedded in social processes (Beyhan, 2007). Studies pointing out the inadequacy of social theory to account for spatial dimension directly or indirectly express this necessity (Soja 1985 and 1989; Urry 1985; Sayer 1985; Lefebvre 1996; Harvey 1997). Following this concept, as is done in this paper, correlating socio-demographic and socio-economic data of the urban population with parameters of the building morphology bears a high potential of achieving information of not only the morphological, but also the social structure of urban agglomeration areas by methods of remote sensing. Thus, explicitly searching for a broader perspective that encompasses several disciplines, we strongly plead in favor of an interdisciplinary cooperation of remote sensing and social science in this field.

In this respect, as it is already revealed by Xu, Wang and Xiao (2000), integration of remote sensing with GIS particularly seems to offer interesting insights for the exploration and explanation of socio-spatial processes occurring in growing cities and metropolitan regions. Cross fertilization of remote sensing and geographic information systems can provide us with a better understanding of the interaction between physical and socio-spatial processes. For example, analyzing the urban growth patterns in the Zhujiang Delta of South China by using a GIS-based modelling approach in combination with remote sensing techniques, Weng (2001) reveals the impact of urban growth on surface temperatures. In a similar vein, Wedding et al. (2011) combine remote sensing with GIS project database in order to better understand the coral reef ecosystems for spatial management in West Hawai'i. The integration of remote sensing and GIS in the analysis of the sprawl of cities is also gaining importance (see for example Hasse's (2008) study). Future studies on the analysis of urban growth and sprawl may particularly follow this line of research and look for the possibilities of cross fertilization of remote sensing and geographic information systems, which also provides us, as Hasse (2008) remarks, with the tools that can be used in order to steer urbanization towards less problematic forms. Indeed, the integration of remote sensing and GIS can help us develop sprawl analytical methods that can be employed not only by academics, but also by policy makers and practitioners.

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References

Abelen S, Taubenböck H, Stilla U (2011) Interactive classification of urban areas using decision trees. In Stilla U., Gamba P., Juergens C., Maktav D. (Eds) JURSE 2011 - Joint Urban Remote Sensing Event, Munich, Germany, April 11-13, pp. 373-376.

Alphan H (2003) Land use change and urbanization of Adana, Turkey. Land Degradation and Development 14: 575–586. Abelen S, Taubenböck H, Stilla U (2011): Interactive classification of urban areas using decision trees. In: Stilla U., Gamba P., Juergens C., Maktav D. (Eds) JURSE 2011 - Joint Urban Remote Sensing Event --- Munich,

Germany, April 11-13, pp. 373-376.

Anas A, Arnott R, Small K (1998) Urban Spatial Structure. Journal of Economic Literature 36: 1426–1464.

Angel S (2011) Making room for a planet of cities. Cambrigde.

Angel S, Sheppard SC, Civco DL (2005) The dynamics of global urban expansion, 102. Transport and Urban Development Department, the World Bank, Washington, D.C.

Baatz M, Schäpe A (2000) Multiresolution segmentation – an optimization approach for high quality multiscale image segmentation. Paper presented at Angewandte geographische Informationsverarbeitung XII: Beiträge zum AGIT-Symposium, Salzburg, Austria.

Batty M, Howes D (2001) Predicting temporal patterns in urban development from remote imagery. In JP Donnay, MJ Barnsley, PA Longley (Hrsg.), Remote Sensing and urban analysis. London: Taylor and Francis, 185–204.

Baycan-Levent T, Gülümser AA (2007) Gated Communities in Istanbul: The New Walls of the City. Paper presented at the Third Conference "Diversity in cities: Visible and invisible walls", UCL, London, UK.

Benediktson JA, Pesaresi M, Arnason K (2003) Classification and feature extraction for remote sensing images from urban areas based on morphological transformations. IEEE Transactions on Geoscience and Remote Sensing 41: 1940–1949.

Benz, U, Hofmann P, Willhauck G., Lingenfelder I, Heynen M (2004) Multi-resolution, object-oriented fuzzy analysis of remote sensing data for GIS-ready information. ISPRS Journal of Photogrammetry and Remote Sensing 58: 239–258.

Beyhan B (2007) Evrim Benzetisi, Kurumsal İktisat ve Çağdaş Bölge-Mekan Bilimi (Evolutionary Metaphor, Institutional Economics and Contemporary Regional-Spatial Science). In Özveren, E. (ed.), Kurumsal İktisat, İmge, Ankara, 401-440.

Beyhan B (2009) Mersin Hotels: A Chronological and Spatial Inquiry. In Mersin the Mediterranean World, and the Twentieth Century - Intersecting Trajectories, Başak Ofset, Mersin, 191-236.

Blaschke T (2010) Object based image analysis for remote sensing. ISPRS Journal of Photogrammetry and Remote Sensing 65: 2–16.

Blaschke T, Lang S, Lorup E, Strobl J, Zeil P (2000) Object-oriented image processing in an integrated GIS/remote sensing environment and perspectives for environmental application. In: Cremers A, Greve K (eds) Environmental Information for Planning, Politics and the Public Volume II, Metropolis-Verlag, Marburg, 555–570.

Borsdorf A, Coy M (2009) Megacities und Globaler Wandel – Beispiele aus Lateinamerika [Megacities and global change – examples from Latin America]. Technologiefolgenabschätzung – Theorie und Praxis 18: 17–26.

Brenner N, Keil R (2010) The Global Cities Reader. Routledge, New York.

Breunig M (2008) Potentiale hoch auflösender Radardaten im urbanen Raum [Potentials of high resolution radar data in urban spaces]. Diploma Thesis, Chair of Remote Sensing, Institute of Geography, Julius-Maximilians Universität Würzburg-Germany [unpublished].

Coşkun MZ, Saroğlu M, Bektaş E (2005) Land Use Patterns In Eastern Istanbul, Turkey. Paper presented at the 5th International Symposium Remote Sensing of Urban Areas URS-2005, 14-16 March 2005, Arizona, USA.

Doğan AE (1999) Küreselleşme ve kentlerin dönüşümü: Mersin örneği [Globalisation and the transformation of cities: The case of Mersin city]. Master's Thesis, Department of Administrative Sciences, Graduate School of Social Sciences, Mersin University, Mersin-Turkey [unpublished].

Doygun H, Alphan H (2006) Monitoring urbanization of İskenderun, Turkey and its negative implications. Environmental Monitoring and Assessment 114: 145–155.

Erengezgin BC (2009) Class and consciousness formation in a local setting: A Socio-Spatial Approach to the case of Bursa industrial workers. Lap Lambert Academic Publishing.

Esch T, Roth A, Dech S (2006) Analysis of Urban Land Use Pattern Based on High Resolution Radar Imagery. Paper presented at the Geoscience and Remote Sensing Symposium, IGARSS 2006, Denver, USA.

Esch T, Thiel M, Schenk A, Roth A, Mehl H, Dech S (2010) Delineation of urban footprints from TerraSAR-X data by analyzing speckle characteristics and intensity information. IEEE Transactions on Geoscience and Remote Sensing, 48: 905–916.

Esch T, Schenk A, Ullmann T, Thiel M, Roth A, Dech S (2011). Characterization of land cover types in TerraSAR-X images by combined analysis of speckle statistics and intensity information. IEEE Transactions on Geoscience and Remote Sensing IEEE Xplore. doi:10.1109/TGRS.2010.2091644 15 pp.

Ewing R (1997) Is Los Angeles-style sprawl desirable?, Journal of the American Planning Association, 63: 107-126.

Geymen A, Baz İ (2008) Monitoring urban growth and detecting land-cover changes on the İstanbul metropolitan area. Environmental Monitoring and Assessment 136: 449–459.

Galster G, Hanson R, Ratcliffe MR, Wolman H, Coleman S, Freihage J (2001) Wrestling Sprawl to the Ground: Defining and Measuring an Elusive Concept, Housing Policy Debate 12: 681-717.

Gonzalez RR, Medina JS (2004) Theories, Models and Urban Realities. From New York to Kathmandu. Dela 21: 64–81.

Griffiths P, Hostert P, Gruebner O, van der Linden S (2010) Mapping megacity growth with multi-sensor data. Remote Sensing of Environment 114: 426–439.

Harvey D (1997) Between Space and Time: Reflections on the Geographical Imagination. In: Barnes T, Gregory D (eds) Reading Human Geography, Arnold, London, 256–279.

Hasse JE (2008) Using remote sensing and GIS integration to identify spatial characteristics of sprawl at the building-unit level. In Mesev V (ed) Integrating Remote Sensing and GIS, John Wiley & Sons, London, 117-147.

Hoffmeyer-Zlotnik JHP (2000) Das 'Wohnquartier' als Hintergrundmerkmal zur Erklärung von Umfragdaten [The

residential quarter as an attribute for the explanation of polling data]. Festschrift für Max Kaase. ZUMA, Mannheim.

ICSC (2009) ICSC European Shopping Center Awards 2009. Retrieved January 15, 2010 from http://www.icsc.org/euroawards.

Jensen JR (2005) Introductory Digital Image Processing: A Remote Sensing Perspective, Pearson Education.

Ji W, Ma J, Twibell RW, Underhill K (2006) Characterizing urban sprawl using multi-stage remote sensing images and landscape metrics. Computers, Environment and Urban Systems 30: 861–879.

Kaya S, Curran PJ (2006) Monitoring urban growth on the European side of the İstanbul metropolitan area: A case study. International Journal of Applied Earth Observation and Geoinformation 8: 18–25.

Kraas F (2007) Megacities and Global Change: Key Priorities. Geographical Journal 173: 79–82.

Landgrebe, DA (2003) Signal Theory Methods in Multispectral Remote Sensing, New York, Wiley.

Lefebvre H (1996) The Production of Space. Blackwell, Oxford.

Long H, Tang G, Li X, Gerhard KH (2007) Socio-economic driving forces of land-use change in Kunshan, the Yangtze River Delta Economic Area of China. Journal of Environmental Management 83: 351–364.

Maktav D, Erbek FS (2005) Analysis of urban growth using multi-temporal satellite data in İstanbul, Turkey. International Journal of Remote Sensing 26: 797–810.

Martinuzzi S, Gould WA, Ramos-González OM (2007) Land development, land use, and urban sprawl in Puerto Rico integrating remote sensing and population census data. Landscape and Urban Planning 79: 288–297.

Mas JF (1999) Monitoring land-cover changes: A comparison of change detection techniques. International Journal of Remote Sensing 20: 139–152.

Mather, PM (2004) Computer Processing of Remotely-Sensed Images: An Introduction. 3rd ed., New York, John Wiley.

Mayring P (2008) Qualitative Inhaltsanalyse. Grundlagen und Techniken. 10th ed. Basel.

Meçin M (2004) The question of urban integration and forced migration from east and southeast Anatolian regions after 1980: The case of Mersin. Master's Thesis, Department of Urban Policy Planning and Local Government, Graduate Schools of Social Sciences, Middle East Technical University, Ankara-Turkey [unpublished].

NASA Landsat Program (1987) Landsat TM scene p175r35_5t19871008, USGS, Sioux Falls, 10/26/2003.

NASA Landsat Program (2000) Landsat ETM+ scene p175r035_7k20000613_z36, USGS, Sioux Falls, 10/26/2003.

Nemmour H, Chibani Y (2006) Multiple support vector machines for land cover change detection: An application for mapping urban extensions. ISPRS Journal of Photogrammery and Remote Sensing 61: 125-133.

Neubert M, Herold H (2008) Assessment of remote sensing image segmentation quality. Paper presented at the GEOBIA 2008, Calgary, Canada.

Özen Turan S, Kadıoğulları Aİ, Günlü A (2010) Spatial and Temporal Dynamics of Land Use Pattern Response to Urbanization in Kastamonu. African Journal of Biotechnology 9: 640–647.

Plummer P, Sheppard E (2006) Geography matters: agency, structures and dynamics at the intersection of economics and geography. Journal of Economic Geography 6: 619-637.

Ridd MK, Liu J (1998) A comparison of four algorithms for change detection in an urban environment. Remote Sensing of Environment 63: 95-100.

Sancar C, Özen Turan S, Kadıoğulları Aİ (2009) Land Use-Cover Change Processes in Urban Fringe Areas: Trabzon Case Study, Turkey. Scientific Research and Essay 4: 1454–1462.

Sarıkaya Levent Y (2008) Conservation of Archaeological Sites in Urban Areas in Turkey: Soli-Pompeiopolis as a case study. PhD thesis, Department of City and Regional Planning, Graduate School of Natural and Applied Sciences, Middle East Technical University, Ankara-Turkey [unpublished].

Sayer A (1985) The Difference that Space Makes. In: Gregory D, Urry J (eds) Social Relations and Spatial Structures, Macmillan, London, 49–66.

Schneider A, Woodcock CE (2008) Compact, dispersed, fragmented, extensive? A comparison of urban growth in twenty-five global cities using remotely sensed data, pattern metrics and census information. Urban Studies 45: 659–492.

Seton-Williams MV (1954) Cilician Survey. Anatolian Studies 4: 121–174.

Shackelford AK, Davis CH (2003) A combined fuzzy-pixel based and object based approach for classification of high resolution multi-spectral data over urban areas. IEEE Transactions on Geoscience and Remote Sensing 41: 2354–2363.

Soja EW (1980) The soci-spacial dialectic. Annals of the Association of American Geographers 70: 207–225.

Soja EW (1985) Regions in context: spatiality, periodicity, and the historical geography of the regional question. Environment and Planning D: Society and Space 3: 175–190.

Soja EW (1989) The reassertion of Space in Critical Social Theory. Verso, London.

Taubenböck H (2008) Vulnerabilitätsabschätzung der Megacity Istanbul mit Methoden der Fernerkundung [Assessing the vulnerability of the megacity Istanbul by methods of remote sensing]. Würzburg, Germany: University of Würzburg Web site at http://www.opus-bayern.de/uni-wuerzburg/volltexte/2008/2804/

Taubenböck H, Esch T, Felbier A, Wiesner M, Roth A, Dech S (2012) Monitoring of mega cities from space. In Remote Sensing of Environment 117: 162-176.

Taubenböck H, Esch T, Wurm M, Thiel M, Ullmann T, Roth A, Schmidt M, Mehl H, Dech S (2008) Urban structure analysis of mega city Mexico city using multi-sensoral remote sensing data. Paper presented at the SPIE – The interna-

tional Society for Optical Engineering, Cardiff, Wales, UK.

Taubenböck H, Wurm M, Setiadi N, Gebert N, Roth A, Strunz G, Birkmann J, Dech S (2009a) Integrating Remote Sensing and Social Science – The correlation of urban morphology with socioeconomic parameters. Paper presented at the Urban Remote Sensing Joint Event, Shanghai, China.

Taubenböck, H, Wegmann M, Roth A, Mehl H, Dech S (2009b) Urbanization in India -Spatiotemporal analysis using remote sensing data. Computers, Environment and Urban Systems 33: 179–188.

Thiel M, Esch T, Dech S (2008a) Object oriented detection of settlement areas from Terra SAR-X Data. In: Jürgens C (ed) Remote Sensing – New Challenges of High Resolution, CD-ROM, 242–248.

Thiel M, Taubenböck H, Esch T, Roth A, Wurm M, Dech S (2008b) Classification of urban environments with TerraSAR-X and ALOS-PALSAR data. Paper presented at the SPIE – The international Society for Optical Engineering, Cardiff, Wales, UK.

TUIK (Turkish State Institute of Statistics) (2009a) Population Census 2000.

TUIK (Turkish State Institute of Statistics) (2009b) Building Census 2000.

Türel A (2001) Housing and Housing Industry in Mersin. Paper presented at the 31st Annual IUFA Conference: The Problems of Urban Growth: Preserving While Developing, Mersin, Turkey.

United Nations, Department of Economic and Social Affairs, Population Division (2009) World Urbanization Prospects: The 2009 Revision (POP/DB/WUP/Rev.2009/1/F2) (New York)

Urry J (1985) Social Relations, Space and Time. In: Gregory D, Urry J (eds) Social Relations and Spatial Structures, Macmillan, London, 20–47.

Webster C, Glasze G, Frantz K (2002) The global spread of gated communities. Environment and Planning B: Planning and Design 29: 315–320.

Wedding LM, Gibson BA, Walsh WJ, Battista, T (2011) Integrating remote sensing products and GIS tools to support marine spatial management in West Hawai'i. Journal of Conservation Planning 7: 60-73.

Wedel H (2004) Alltagsleben und politische Partizipation - Gecekondu-Viertel als gesellschaftlicher Ort [Everyday life and political participation - gecekondu-neighborhoods as social places]. European Journal of Turkish Studies 1, Web site at http://ejts.revues.org/index140.html.

Weng Q (2001) A remote sensing-GIS evaluation of urban expansion and its impact on surface temperature in the Zhujiang Delta, China. International Journal of Remote Sensing 22: 1999-2014.

Wlodarczyk D (2005) Structural Analysis of urban space in residential areas. In: Vestbro DU, Hürol Y, Wilkinson N (eds) Methodologies in Housing Research, Urban International Press, Newcastle upon Tyne, 173–187.

Xu H, Wang X, Xiao G (2000) A remote sensing and GIS integrated study on urbanization with its impact on arable lands: Fuqing City, Fujian Province, China. Land Degradation and Development 11: 301-314.

Zeng Y, Zhang J, van Genderen J L, Zhang Y (2010) Image fusion for land cover change detection. International Journal of Image and Data Fusion. 1: 193-215.

Zhou W, Troy A, Grove M (2008) Object-based Land Cover Classification and Change Analysis in the Baltimore Metropolitan Area Using Multitemporal High Resolution Remote Sensing Data. Sensors 8: 1613-1636; doi:10.3390/s8031613.