EVALUATING URBAN EXPANSION USING REMOTELY-SENSED DATA IN LEBANON

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ABSTRACT

Over the last decades, continuous urban expansion at rates much higher than population growth has resulted in a massive urban footprint all over the world. In Lebanon, a civil war in the mid 70's has resulted in a low density and fragmented urban sprawl. Nearly after 1990, when the declaration of Taaef ended the Lebanese war, a major reconstruction and reforms have taken place. This peaceful atmosphere launched a massive construction of roads and buildings, water and sanitation facilities, and energy and transport systems, which transformed eternally land cover and cities of Lebanon. This study aims to follow the evolution of urbanization from 1963 till 2005 in Lebanese major cities by processing and interpreting topographical maps and satellite images acquired by different space platforms. One examines urban growth trends in Lebanon between different years and provide a characterization of Lebanese urban development per governorate and per district. Also, we inspect urban agglomeration in Greater Beirut Area (GBA), which is the main urban center in the country, as well as seven major Lebanese cities (i.e. Tripoli, Zahle, Saida, Tyre, Baalbek, Nabatiye and Jounieh). Some cities show a positive trend (e.g. Zahle illustrates a urban expansion from 3 percent of its district region in 1963 to 10 percent in 2005, Tripoli grows from 20 to 56 percent of the district in 2005, etc.). While Nabatiye, and South Lebanon region in general, reveal a high rate of urbanization, a weak rate of urban expansion is shown particularly in North Lebanon. Political favoritism is one of the main reason to blame. Anyhow, the adequacy of the remote sensing in evaluating urbanism is proven again, particularly in unstable countries and regions. This research intends to provide policy makers in Lebanon an essential decision tool, given the absence of a comprehensive population survey, to build and support sustainable urban planning.

Keywords: urban expansion, agglomeration, Lebanon, remote sensing

INTRODUCTION

Population dynamics, which includes trends and changes in population growth, migration, urbanization, and population density, influence consumption and availability of natural resources (UNDESA & UNFPA, 2013), by fragmenting rural space, blocking ecosystem services and increasing the demand for transport and energy. It appears to pose a substantial threat to the future of humanity. In fact, as late as 1938, Louis Wirth (1938) stated that the urbanization of the world is one of the most impressive facts of modern times and has brought profound changes in virtually every phase of social life.

Lebanon is located on the eastern shore of the Mediterranean Sea, and has a heritage almost as old as the earliest evidence of mankind. Its geographic position as a crossroad linking the Mediterranean Basin with the great Asian hinterland has conferred on it a cosmopolitan character and a multicultural legacy (Collelo & Smith, 1989). As in much of the contemporary Middle East, and at different periods of its history, Lebanon has come under the domination of foreign rulers, including Assyrians, Babylonians, Persians, Greeks, Romans, Arabs, Ottomans, and French (Faour, 2013). However, population growth in Lebanon, as with many of the other demographic parameters, is uncertain. The World Bank quotes a current rate of 1.2 percent per annum. In actual fact, real growth is difficult to determine due to the lack of demographical statistics as well as the Lebanese emigration which is embedded in its history, during peace time as well as during conflict (UNDP & MOE, 2010).

Several approaches have addressed urban change detection by using remotely sensed imagery (Qiong *et al*., 2006; Mahesh *et al*., 2008; Linard *et al*., 2013; Zhonghao *et al*., 2013; Fusilli *et al*., 2014) since 1977 which is a reliable data collector and analysis, presenting a cost effective and technologically sound method (Qiong *et al*., 2006); it seems the only accessible and adequate mean to evaluate urbanization, specifically in a hot regions like our study area. Anyhow, in the earliest years, aerial photographs and SPOT images were used (Weismiller *et al*., 1977; Ramesh, 1989). However, some studies try to model urban growth (Clarke *et al*., 1996; Weber & Puissant, 2003; Luo *et al*., 2009). Others assess the population growth over the last few decades (Beale, 1976; Chan Xueqiang, 1985; Moriconi-Ebrard, 1993). While using and developing of "new urbanism" guidelines and policies has bounced in recent years (Katz *et al*., 1994; Smith, 2002; Song & Gerrit-Jan, 2003) in a way to keep up with the fast evolution trend in the large cities. Besides, Lebanon has undergone several studies on the urban growth, including studies on fragmented urbanism (Glasze, 2003), a reflection on the urbanism state in this country (Haddad, 2007), and an exhibition of urban growth scenario for Greater Beirut area (Faour & Mhawej, 2014). Others researches conducted by the Observatory Research on Beirut debate the urbanization in the Metropolitan Area of Greater Beirut (Huybrechts & Verdeil, 2000; Davie, 2001; Verdeil, 2002; Faour *et al*., 2005).

This study evaluates urban expansion in Lebanon between 1963 and 2005 using topographic maps and multi-date high spatial resolution satellite images. Diachronic analysis of urban GIS layers will assist in identifying the development of this growth, as well as an assessment of urban expansion in the major cities of Lebanon. Accordingly, this research aims to attain, for the first time in Lebanon, an accurate information about the spatial analysis of urban growth in this country at a national level.

STUDY AREA

The Lebanese Republic, which gained independence from France in 1943, is located approximately at 34° N and 35° E. It is bordered by Syria to the north and east, and by occupied Palestine to the south. Lebanon, with a total area of 10 452 km² stretches about 210 km along the coast and 50 km inland. This country is divided into six governorates (*i.e*. Beirut, Mount Lebanon, North, Bekaa, South and Nabatiye) which are further subdivided into twenty-five districts (qadaa or caza).

Topographically (Fig. 1), Lebanon can be divided from west to east into four parallel parts:

• A flat, narrow coastal strip parallel to the sea; a narrow fertile plain less than 5 km wide;

• The Mount-Lebanon chain, the highest crest of which is just over 3 000 m;
• The Bekaa Valley at a height of around 900 m and 8-10 km wide;
• The Anti-Lebanon Mountains chain, along the border with Syria, which rises to 2800 m, in the east.

Lebanon's last population census, conducted in 1932, indicated that the population was 875 252. Other censuses were conducted unofficially; for instance, in 1956 it was estimated that the population was 1 411 416. Conducting a census has been a very sensitive issue due to the sectarian divisions in the country and due to the pressure that some groups could practice in case statistics showed a wide shift in the population demographics (Lebanese Information Center, 2013). All population estimates have since been based on surveys and extrapolations. Anyhow, according to the 2008 update, Lebanon's resident population in 2007 was 3.7 million, excluding an estimated 425,000 Palestinian refugees. Actually, the Lebanese people represent 93.4 percent of the population, with 6.6 percent being non-Lebanese (Yamout & El-Fadel, 2005).

Lebanon's four major coastal cities, Beirut, Jounieh, Saida and Tripoli, structure the basic concentration areas of population allocation. Beirut and its suburbs, corresponding to 2.2% of the Lebanese territory, is home to half of the country's population (CDR, 2002). Anyhow, these regions are engaged predominantly in commerce, tourism and banking due to their location on the seafront and the presence of seaports. In consequence, coastal areas constitute the highest population density in Lebanon while it represent only 27 per cent of its total surface (Pumain *et al*., 1992).

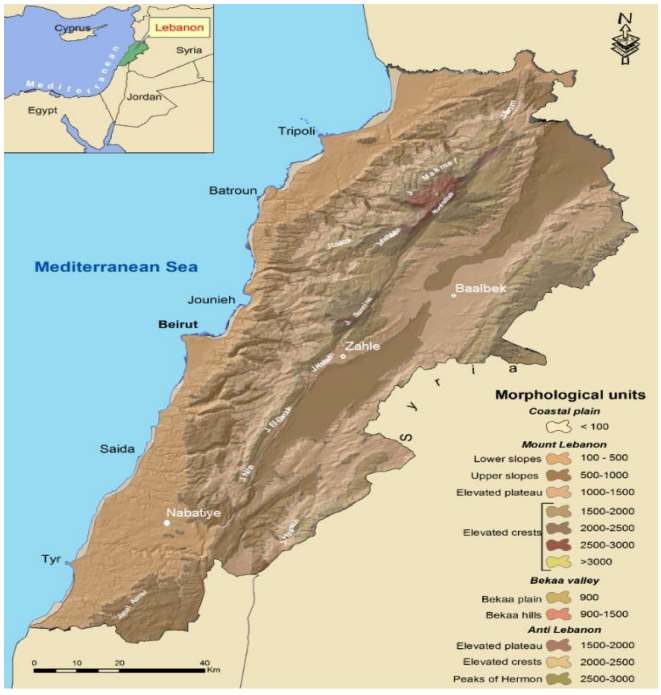

Figure 1. Lebanon's morphological map.

MATERIALS AND METHOD

Diachronic Urban Maps were derived from a variety of sources ranging in scale and resolution. Data sources included topographic maps and satellite images (Table 1). Based on the available materials, three urban layers between 1963 and 2005 were compiled for the assessment of the Lebanese urban regions.

TABLE 1

Description of Used Data

Data Used	Date	Spatial Resolution	Source	Method	Problems
Topographic Map	1963	1:20000	Lebanese Army	Visual Interpretation	Different scale of aerial photography
Russian KVR-1000	1994-1996	2 m.	CDR (Council for Development and Reconstruction)	Visual Interpretation	Black and white images
IKONOS	2005	1 m.	CNRS (National Council for Remote Sensing)	Visual Interpretation	No problem

Urban continuity is identified by their color bluish to white color, their straight edge and their regular geometric form in the multispectral satellite imageries (IKONOS, RapidEye). While urban settlements in KVR-1000 images can be identified if they have satisfactory contrast with the background reflectance brightness. In fact, urban settlements surrounded by eroded bare lands are very difficult to identify. Clouds coverage within satellite images masks urban settlements completely. Lebanese topographic maps typically use a grey tint to indicate urban areas. These areas are defined by building and road network density.

Digital geo-referenced color topographic maps scale 1:20.000 were collected from the Directorate of Geographic Affairs (DAG). Urban settlements map of 1962 were delineated from these topographic maps composed of 121 topographic sheets that cover the whole Lebanese territory.

Then, Orthorectified KVR-1000 Russian Satellite Imageries with 2 meter resolution acquired between 1994 and 1996 by the Council for Development and Reconstruction (CDR) for the whole Lebanon were processed. These Russian imageries provide highly detailed panchromatic photographs of the earth surface that were used to produce accurate urban maps of Lebanon for 1996.

High spatial resolution IKONOS imagery of Lebanon were provided by Dubai-based Space Imaging Middle East (SIME). These satellite images were collected in 2005 and

were used to extract the urban map of Lebanon in 2005. All these dataset were registered using the Lebanese stereographic coordinate system.

The choice of the distance from urban agglomeration plays a significant role in the determination of the built environment in cities. The threshold value can vary from 50 to 200 m, but commonly, the threshold of 200 m between buildings is preferred (World Bank and the United Nations, 2013), especially in European cities having the same characteristic as Lebanon. Thus, this same value was selected in this study.

RESULTS AND DISCUSSION

Urban expansion

Proportion of urbanization is calculated by dividing urbanized areas for a year over total surface of that country. Results for years 1963, 1994, and 2005 are displayed in Table 2. It shows that the urbanized area doubled between 1963 and 1994 and between 1994 and 2005.

TABLE 2

Proportion of Urbanization in Lebanon

Year	Urbanized areas in $\mathbf{km^2}$	Proportion of urbanization in percent
1963	221.47	2.16
1994	464.98	4.53
2005	741.20	7.22

Figure 2 illustrates urban growth in the major cities between 1963, 1994, and 2005. Beirut shows the highest extent of red color which indicate that this city has begun his urban development at a high rate since 1963. Moreover, development spreads to the bordering towns and villages (*i.e.* Jdaide, Baabda, Beit-Meri, Broumana, Bikfaya, and even Damour which is located 24 km away from Beirut). Tripoli continues to sprawl year over year, conquering Zgharta in 2005, which is 11 km away. The same goes to Sour (or Tyre), which appears to be evolving almost homogenously between these years. Saida, which is on the Mediterranean Sea like the precedent cities, indicates an enormous urban expansion. Nahr El Kalb, to the south, and Nahr Ibrahim, to the north, are the two rivers bordering urban expansion for Jounieh's city in 2005. Zahle and Baalbek are located in the Bekaa valley. Urban sprawl in Zahle is expanded Northeast and Southwest, whereas in Baalbek it is characterized by a concentration of development along major transportation arteries, and primarily roads. Nabatiye shows the same pattern as Baalbek. Beirut and Saida represent a low-density sprawl, which is a phenomenon caused by outward spreading of low-density suburban land use (Torrens & Alberti, 2000). Zahle, Baalbek, and Nabatiye show a ribbon sprawl which occurs on land adjacent to the major roads. While Tripoli, Sour and Jounieh illustrate a combination of both type of urban expansion: low-density and ribbon sprawl.

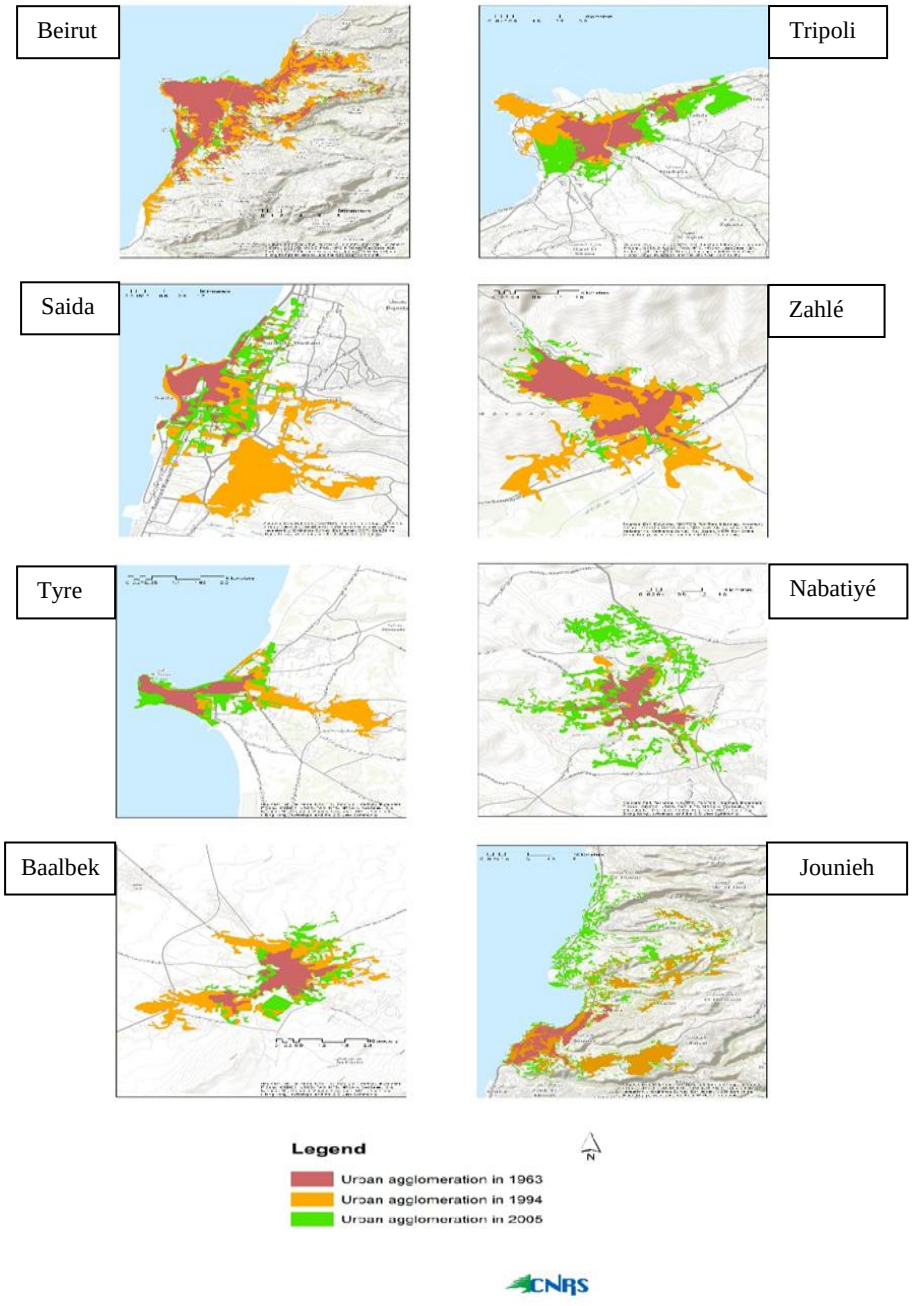

Figure 2. Urban expansion in main Lebanese cities, 1964 till 2005.

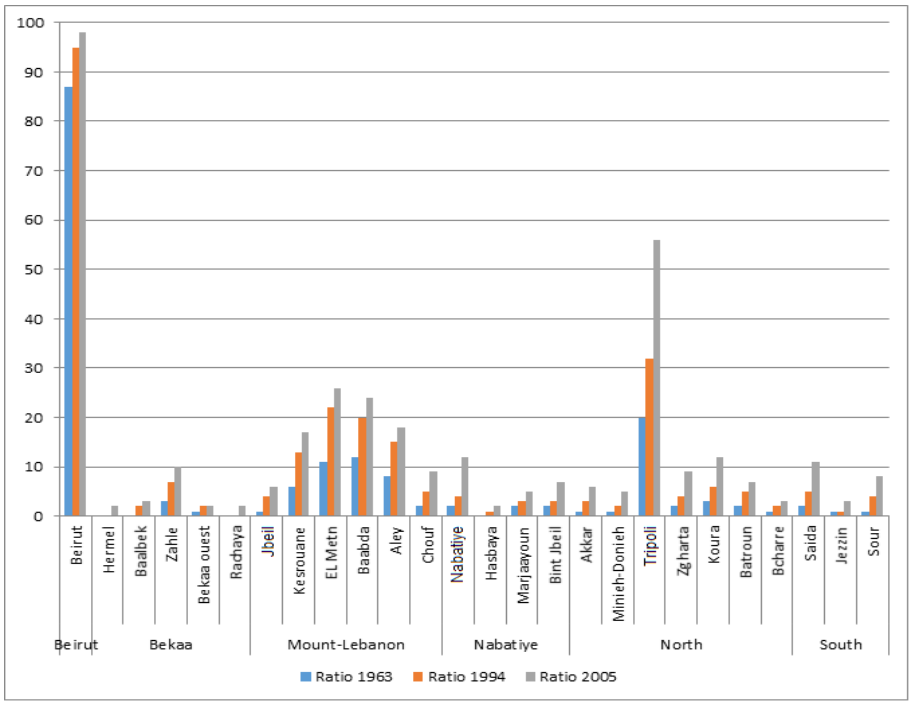

Figure 3. Ratio of urbanization per district.

Ratio of urbanization per district was produced (Fig. 3). It shows that: 1) all district reveals an increasing rate of urbanization; 2) nowadays, Beirut is nearly saturated (98% of its total area is urbanized); 3) Tyre, Saida, Nabatiye, Jbeil, and Hermel express a very high rate of urban growth exceeding five times what the urbanization was in 1963; 4) Kesrouane, El Metn, Baabda, and Aley represent areas with very low to low rate of urban development mainly due to the saturation effect. In fact, lands which can be converted to urban have been reduced critically. The leading reasons for this urban sprawl is either their locations adjacent to the capital, Beirut, (*i.e.* Jounieh, Jbeil), or the establishing of developing plans and reconstruction strategies funded by international donors and organizations (*i.e.* Tyre, Saida, Nabatiye).

According to Table 3, Beirut agglomeration represents the largest urban area with approximately 121 km^2 in 2005. It is followed by Jounieh agglomeration (38 km^2) and Tripoli agglomeration (14 km^2). Nabatiye and Sour agglomerations came in the last place (3.8 km^2 *vs.* 3.3 km^2). In consequence, a huge difference is shown between Beirut and the second largest urban agglomeration (*i.e.* Jounieh) in term of urban area. It emphasizes the role of Beirut as the vibrant financial, commercial, and administrative hub of the country. It is important to mention that Jounieh has the highest growth factor (*i.e.* 7.1).

TABLE 3

Urban Area in Km^2 of Major Urban Cities, 1963 till 2005 (Blue = Largest Urban Area; Green = Second Place; Orange = Third Place)

Agglomeration	1963	1994	2005	Growth factor
Beirut	63.139	113.191	121.421	1.92
Tripoli	4.377	8.376	14.113	3.22
Zahle	1.849	4.699	5.287	2.85
Baalbek	1.54	4.366	5.967	3.87
Saida	0.764	3.278	4.178	5.46
Sour	0.85	2.3	3.34	3.92
Nabatiye	0.966	1.298	3.829	3.96
Jounieh	5.366	23.929	38.101	7.1

CONCLUSION

Since the last comprehensive population census dates back to 1932, there continues to be no agreement on the actual size of the Lebanese population today, and therefore there is no clear quantification of urbanization. Remote sensing techniques show a reliable and cost effective method to quantify and assess urban sprawl. In this research, it was demonstrated that most of the population is resident on the coastal zone which is characterized by being very narrow and comprised between the west mountainous chain and the sea. Around 1.5 million people live in the region known as Greater Beirut. Other major cities are Tripoli (250,000), Saida (80,000), Zahle (80,000) and Tyre (30,000) (DG environment, 2006). One concludes that:

- Lebanon's urban expansion keeps rising in the major cities;
- Proportion of urbanization has grown by a factor of 3 from 1994 till 2005;
- Beirut initiated his urban development at a high rate since 1963; in consequence, it is nearly saturated (98% of its total area is urbanized);
- Beirut agglomeration represents the largest urban area with approximately 121 km^2 in 2005; in fact, all political and juridical activities are centralized in this region. It is followed by Jounieh (38 km^2) and Tripoli (14 km^2) in the same year;
- Establishing many developing programs, funded locally and internationally, increased urban sprawl in South Lebanon.

This research reflects the situation of Lebanon's urban growth, using remotely sensing data, which appear to be the most adequate and effective method in this study area characterized by a perpetually unstable situation. However, up-to-date investigations, census and remote sensing data should be held. A country's sustainable development plans, taking into account effective integration of social, economic, environmental, health and safety factors should be set to overcome uncontrolled urban expansion.

REFERENCES

Beale, C.L. 1976. A further look at nonmetropolitan population growth since 1970. *American Journal of Agricultural Economics*, 58(5): 953-958.

CDR in collaboration with the Lebanese Directorate of Geographic Affairs (DGA) 2002. *Schéma directeur d'aménagement du territoire libanais (SDATL*). Report of phase 1, diagnosis and problematic, Beirut/Paris, Dar IAURIF Group, 188 pages + 6 vol. annexes.

Chan, K.W. and Xueqiang, X. 1985. Urban population growth and urbanization in China since 1949: Reconstructing a baseline. *The China Quarterly*, 104: 583-613.

Clarke, K.C., Hoppen, S. and Gaydos, L. 1996. Methods and techniques for rigorous calibration of a cellular automaton model of urban growth. In: *Third International Conference/Workshop on Integrating GIS and Environmental Modeling*, Santa Fe, New Mexico.

Collelo, T. and Smith, H.H. 1989. *Lebanon, a country study*. 3d edition, prepared by the Library of Congress, Federal Research Division.

Davie, M. 2001. Beyrouth 1825-1975: un siècle et demi d'urbanisme. Beyrouth: ordre des ingénieurs et architectes.

DG Environment 2006. Support to DG Environment for the development of the Mediterranean De-pollution Initiative "Horizon 2020". December, URL: http://ec.europa.eu/environment/enlarg/med/pdf/review_report08_en.pdf

Faour, G., Haddad, T., Verdeil, E., and Velut, S. 2005. Beyrouth: quarante ans de croissance urbaine. *M@ppemonde*, 3: 79.

Faour, G. and Mhawej, M. 2014. Mapping urban transitions in Greater Beirut area using different space platforms. *Land Journal*, 3(3): 941-956..

Faour, G. 2013. *Lebanon demographic assessment*. Part of a project led by ITAN, European Union.

Fusilli, L., Marzialetti, P., Laneve, G., Santilli, G. 2014. Urban growth assessment around Winam Gulf of Kenya based on satellite imagery. *Acta Astronautica*, 93: 279-290. ISSN 0094-5765, http://dx.doi.org/10.1016/j.actaastro.07.008, published online July 26, 2013.

Glasze, G. 2003. Segmented governance patterns—fragmented urbanism: the development of guarded housing estates in Lebanon. *The Arab World Geographer*, 6(2): 79-100.

Haddad, E. 2007. What went wrong? reflections on the condition of architecture and urbanism in Lebanon. Enquiry/*The ARCC Journal of Architectural Research*, 4(1).

Huybrechts, E., Verdeil, E. 2000. Beyrouth entre reconstruction et métropolisation. *Villes en Parallèle*, 32: 83-103. Nanterre: éditions de l'Université de Paris X-Nanterrre,

Katz, P., Scully, V.J. and Bressi, T.W. 1994. *The new urbanism: toward an architecture of community.* Vol. 10, New York: McGraw-Hill.

Keith, C.K., Hoppen, S. and Gaydos, L. 1996. Methods and techniques for rigorous calibration of a cellular automaton model of urban growth. *Third International Conference/Workshop on Integrating GIS and Environmental Modeling*, Santa Fe, New Mexico.

Lebanese Information Center. 2013. *The Lebanese demographic reality*. January 14, URL: http://www.lstatic.org/PDF/demographenglish.pdf

Linard, C., Tatem, A.J., Marius, G. 2013. Modelling spatial patterns of urban growth in Africa. *Applied Geography*, 44: 23-32. ISSN 0143-6228, October, http://dx.doi.org/ 10.1016/j.apgeog.2013.07.009.

Luo, J. and Wei, Y.H. 2009. Modeling spatial variations of urban growth patterns in Chinese cities: the case of Nanjing. *Landscape and Urban Planning*, 91(2): 51-64.

Mahesh, K., Garg, P.K., Khare, D. 2008. Monitoring and modelling of urban sprawl using remote sensing and GIS techniques. *International Journal of Applied Earth Observation and Geoinformation*, 10(1): 26-43. February, ISSN 0303-2434, http://dx.doi.org/10.1016/j.jag.2007.04.002.

Moriconi-Ebrard, F. 1993. *L'urbanisation du monde: depuis 1950*. Economica-Anthropos, Collection Villes, Paris, 372 p. 1993.

Pumain, D., St Julien, T., Cattan, N., Rozenblat, C. 1992. Le concept statistique de la ville en Europe. Eurostat, theme 3, Series E, Office for Official Publications of the European Communities, Luxembourg, 89 pages.

Qiong, W., Hong-qing L., Ru-song, W., Juergen, P., Yong, H., Min, W., Bi-hui, W., Zhen, W. 2006. Monitoring and predicting land use change in Beijing using remote sensing and GIS. 28 November, *Landscape and Urban Planning*, 78(4): 322-333. ISSN 0169-2046, http://dx.doi.org/10.1016/j.landurbplan.2005.10.002

Ramesh, B. 1989. Urban land use change detection using sequential aerial photographs and spot image case study: Chiangmai, Thailand. *Journal of the Indian Society of Remote Sensing*, 17(3): 101-108.

Smith, N. 2002. New globalism, new urbanism: gentrification as global urban strategy. *Antipode*, 34(3): 427-450.

Song, Y. and Gerrit-Jan, K. 2003. New urbanism and housing values: a disaggregate assessment. *Journal of Urban Economics*, 54(2): 218-238.

Torrens, P.M. and Alberti, M. 2000. *Measuring sprawl*. Working paper no. 27, centre for advanced spatial analysis, University College, London, URL: http://www.casa.ac.uk/working papers/

UNDESA and UNFPA 2013. *Population dynamics in the context of the post-2015 development agenda.* February.

UNDP and MOE 2010. *State of the environment report 2010*. URL: http://www.moe.gov.lb/The-Ministry/Reports/State-Of-the-Environment-Report-2010.aspx

Verdeil, E. 2002. *Une ville et ses urbanistes: Beyrouth en reconstruction*. PhD in geography, univ. de Paris I Sorbonne, 646 pages.

Weber, C. and Puissant, A. 2003. Urbanization pressure and modeling of urban growth: example of the Tunis Metropolitan Area. *Remote Sensing of Environment*, 86(3): 341-352.

Weismiller, R.A., Kristof, S.J., Scholz, D.K., Anuta, P.E. and Momin, S.A. 1977. Change detection in coastal zone environments. *Photogrammetric Engineering and Remote Sensing*, 43: 1533-1539.

Wirth, L. 1938. Urbanism as a way of life. *American Journal of Sociology*, 44: 1-24.

World Bank and the United Nations 2013. *Lebanon economic and social impact assessment of the Syrian conflict.* September 17.

Yamout, G., and El-Fadel, M. 2005. An optimization approach for multi-sectoral water supply management in the Greater Beirut area. *Water Resources Management*, 19(6): 791-812.

Zhonghao, Z., Shiliang, S., Rui, X., Diwei, J., Jiaping, W. 2013. Identifying determinants of urban growth from a multi-scale perspective: a case study of the urban agglomeration around Hangzhou Bay, China. *Applied Geography*, 45: 193-202. December. ISSN 0143-6228, http://dx.doi.org/10.1016/j.apgeog.2013.09.013.