Spatio-Temporal Analysis of Land Use Changes in the Makassar Region Using GIS

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ABSTRACT

The impact of population growth on urban sprawl in many major cities in Indonesia has become a major issue in recent years. As the fifth fastest growing city in Indonesia, land use changes in the Makassar region have shown remarkable changes as the consequences of urban expansion during the last 15 years. This paper presents a development of land use maps from the available topographic maps. Based on the developed land use maps, details of land use changes have been simulated based on 50m grid-mesh scale to characterize land use transition in the Makassar region over the last 15 years. Land uses for the period of 1997-2012 have shown important changes, urban surface has grown up from 4,805 to 8,098 hectares which represents almost twice the urban expansion of a 15 years period. It is found that about 32% of agricultural fields and 41% of garden fields of 1997 are converted into urban area in 2012. The increasing phenomenon of urban area from 1997 to 2012 has leaded to the existence of the land covers of fishpond (13.5%) and swamp field (2.1%) in 2012. Moreover, about 79% of mangrove forests in Tallo River Area are converted into fishponds. This study has successfully pointed out the importance of understanding the dynamic of land use changes of the Makassar region in a spatial and temporal way to the protection of the environment.

INTRODUCTION

Indonesia is one of the fastest urbanizing countries in Asia and its future will be shaped by its cities. In 2011 the population was 51% urban and it is projected to become 85% by 2050 (Parasati, 2013). As the fifth fastest growing city in Indonesia, Makassar is the largest city in Eastern Indonesia and the capital of the province of South Sulawesi (Fig.1). Geographically, Makassar territory is roughly between 5° and 7° S, and 119°20′ and 120°30′ E, including the island of Selayar. In 2016, The Makassar's population was about 1.8 million, with an average population density of 8000 inhabitants per square kilometer. Fig. 2 shows the change in population from 1971 to 2016. Makassar covers total area of nearly 177 km^2 which is divided into 14 districts. It is part of the Mamminasata Metropolitan Area (covering the city of Makassar and the regencies of Gowa, Maros, Takalar) which has a population of about 2.5 million and is expected to grow to around 2.9 million in 2020.

This urbanization of the Makassar area for residential, industrial, commercial, infrastructure, etc. has followed a model characterized by a low density of built-up area, which has revealed itself as tremendously negative for natural habitats (Turner, 2005). The built-up area has expanded far faster than the population, indicating an increasingly lower density of the city. The urban sprawl is a major contributor to the lack of increase in the productivity of the landscapes of the Makassar area. These circumstances, inevitably, have led to a dynamic change in land uses composition and configuration, resulting in ecological processes changing at various spatio temporal scales (Wu et al., 2011).

Recently, the city government of Makassar proposes to create Tallo River Area where the city can strategically manage urban development in the land that is now undeveloped, because it is subject to regular flooding recently. Yet close to the city centre, it is the large area on downstream of Tallo River. Nevertheless, this is endorsed in the Mamminasata Spatial Plan (2006) and The Makassar City's Spatial Plan (2012) which identify the Tallo River as a special development area. Consequently, planning the Tallo River Area will require an spatial analysis of land use changes to ensure that the potential development arising from urbanization are optimized to protect the environment.

An integrated analysis methodology, including Geographical Information System (GIS), spatial statistics, and modeling methods, has made it possible to study spatial land uses and its change through time (Marull and Mallarach, 2005).

Fig. 1 Geographic location of the city of Makassar, Mamminasata region, and Tallo River area

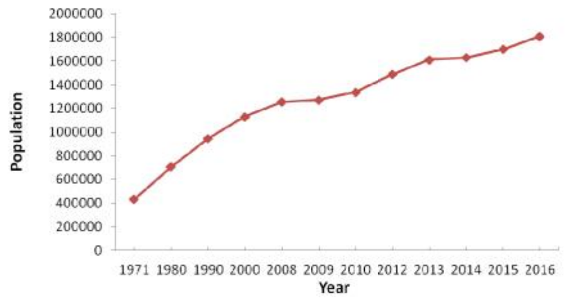


Fig. 2 Change in population of the Makassar City from 1971 to 2016

Therefore, the objective of this paper is to develop the land use maps from the topographical data of 1:50,000 scales and to analyze the land use changes of the Makassar area from 1997 to 2012 based on GIS technology. The methodology analysis of the land use changes with grid-mesh 50m is applied in order to simulate the detail of spatial and temporal land use changes. Results of land use changes analysis are discussed regarding to the Spatial Plan of Makassar City to create urban development on the Tallo River Area.

DEVELOPING LAND-USE MAPS USING GRID MESH SYSTEM BY GIS GEOPROCESSING

Geoprocessing is one of the most powerful components of a GIS. Geoprocessing is a framework and set of tools for processing geographic and related data. The large suite of geoprocessing tools can be used to perform spatial analysis in an automated way.

In this research, the digital topographic maps of 1:50.000 scales provided by the city government of Makassar were processed by using geoprocessing to create land use maps using grid mesh 50m. Land use division was determined based on land use boundary line of the topographic maps. The land use divisions for 1997 and 2012 were reclassified into 10 categories to provide identical class for spatial matrix analysis. Fig. 3 shows the GIS methodology for creating land use map with grid mesh 50m. In geoprocessing, the land use polygon from the topographic maps were intersected with grid-mesh 50m from grid division analysis in which the grid-mesh has orientation of the world grid system (Fig. 4). Intersected land use polygons were calculated to obtain the maximum area in each grid feature. Land use value for each grid was dissolved based on maximum area analysis in GIS.

Therefore, the grid-mesh 50m based land use values could be obtained. Furthermore, Fig. 5 shows the developed land use maps of 1997 and 2012 which is obtained from conversion of land use polygon into land use with grid-mesh 50m.

ANALYZING SPATIAL LAND-USE CHANGES BASED ON GRID MESH 50M

The land-use maps have been developed to carry out an analysis of land-use changes using a GIS technology. By utilizing land-use maps of 1997 and 2012, the analysis of land-use pattern changes in the Makassar area can be performed based on 50m mesh scale. In the land-use map of 1997, the existence of crop field, fishpond, swamp field has not been clearly visible. In that year, the population did not extensively affect urban area development. In the land-use map of 2012, big fishpond area is developed due to conversion of mangrove forest by local peoples to do fishery. Perhaps, the recent years' large scale regular flooding in the vicinity of Tallo river basin created natural drainage areas for the local peoples to make the fishpond as a livelihood. In 1997, Makassar was comprised of 27% urban area, 27.8% paddy fields, 26.7% garden fields, and 11.9% mangrove forests. (Table 1). It should be noted that in the Eastern part of Makassar, the land area was bordered by the sea, some of the sea area was assumed as future reclaimed land. In 2012, urban area has increased to 45.6% of the Makassar area, in contrast to the decrease of paddy fields to 16.3% and garden fields to 9.3%. The increasing phenomena of urban area from 1997 to 2012 have leaded to the existence of fishpond (13.5%) and swamp field (2.1%) land covers in 2012. In addition, the occurrence of swamp field and fishpond which was counted as 15.6% from the Makassar area, has transformed the pattern of low land mangrove forests and shrubs fields in the vicinity of Tallo River.

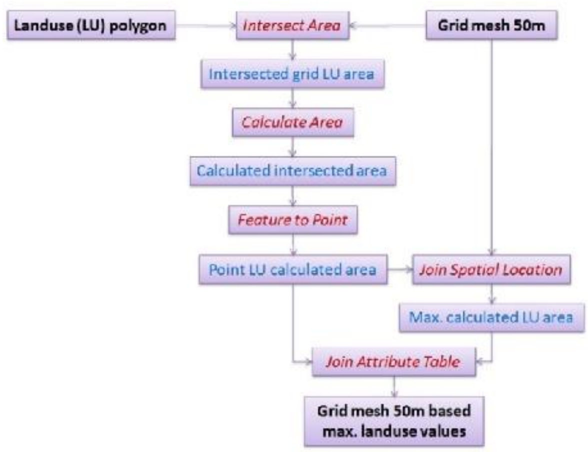


Fig. 3 Flow chart of developing land use maps with grid-mesh 50m using GIS geoprocessing

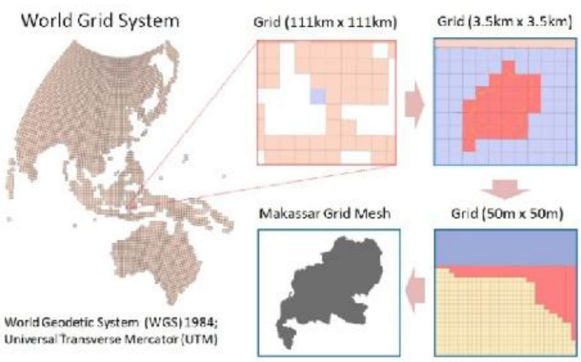
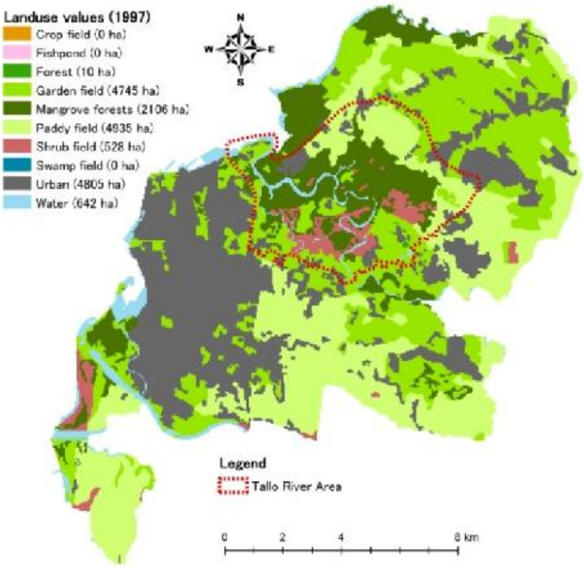
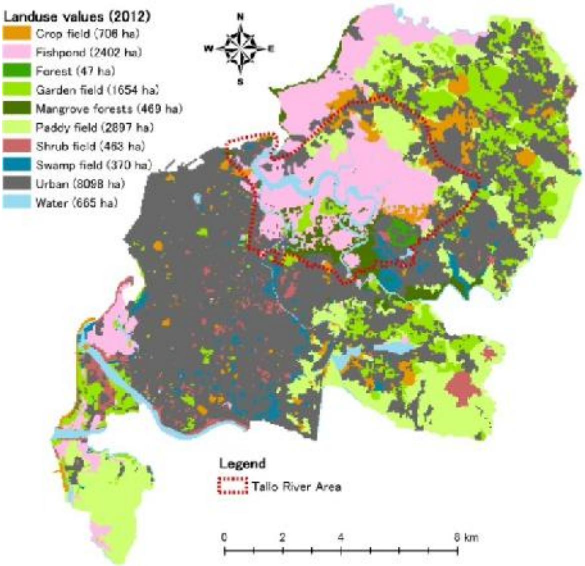


Fig. 4 Illustration of grid-mesh development from world grid system using UTM projection



a). Land use map in 1997



b). Land use map in 2012

Fig. 5 Created grid-mesh 50m of the land use maps of the Makassar area

Table 1 Land use values in the Makassar (1997-2012)

Land use values	1997		2012	
	ha	%	ha	%
Crop field	0	0.0	706	4.0
Fishpond	0	0.0	2402	13.5
Forest	10	0.1	47	0.3
Garden field	4744	26.7	1654	9.3
Mangrove forest	2106	11.9	469	2.6
Paddy field	4935	27.8	2897	16.3
Shrub field	528	3.0	463	2.6
Swamp field	0	0.0	370	2.1
Urban	4805	27.0	8098	45.6
Water	643	3.6	665	3.7
Total	17771	100	17771	100

In 2012, mangrove forest area reduced to 2.6% and the crop land increased to 4.0% of the Makassar area. The total mangrove area has declined, according to the spatial land use transition pattern analysis.

Land Use Change of Paddy Fields

Fig. 6 shows that the paddy fields in 1997 have changed to other land-use categories in 2012. In 2012, urban area increased to occupy 32.0% of the total area of paddy field. The increasing phenomena of urban area from 1997 to 2012 leaded to the existence of the crop fields (4.2%), fishponds (4.3%) and swamp fields (3.4%) in 2012. Spatial distribution of paddy fields converted into urban areas is shown in Fig. 7. It is shown in the maps that agricultural fields are mostly occupied by urban area in the South and East part of the Makassar City. This is because during the past one and half decade, Makassar City has experienced rapid urban transformation, represented by significant changes and large-scale expansion of the urban landscape over the agricultural fields. Declines in the intensity of agricultural land use and farmland abandonment have been discovered in many areas. This has posed additional challenges for the preservation of natural agriculture ecosystems.

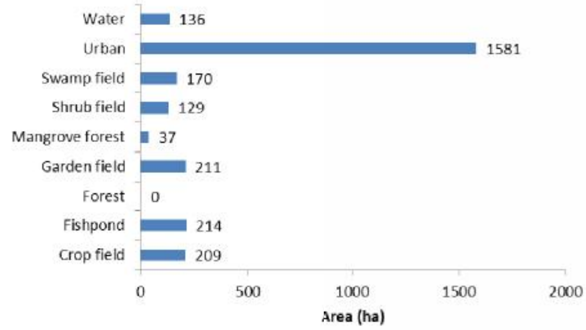


Fig. 6 Paddy field converted into other land use values

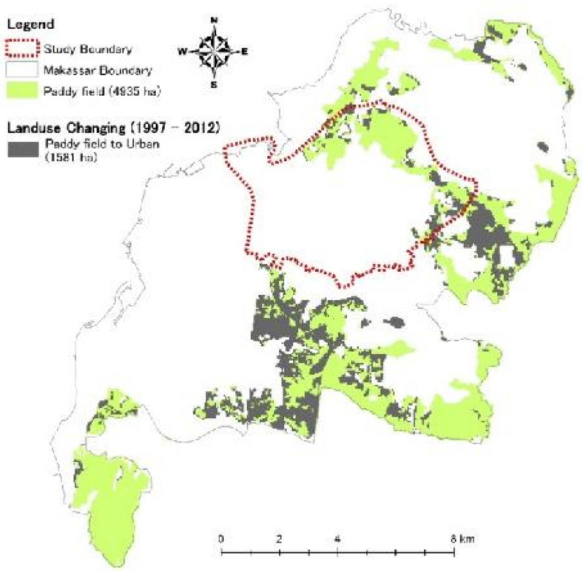


Fig. 7 Spatial distribution of paddy field converted into urban area

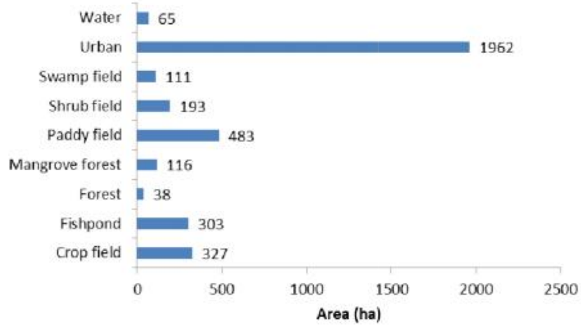


Fig. 8 Garden field converted into other land use values

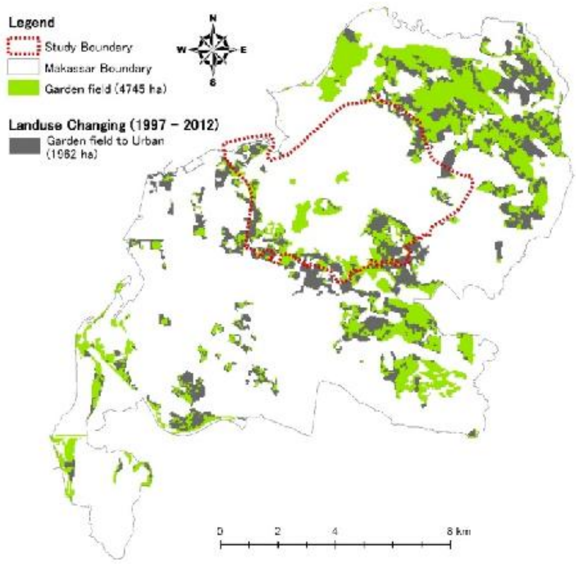


Fig. 9 Spatial distribution of garden field converted into urban area

Land Use Change of Garden Fields

Fig. 8 depicts that the garden fields of 1997 have changed to other land-use categories in 2012. From the land-use transition analysis, it is found that about 41.3% of garden fields have changed into urban areas. At the same time, some of garden fields converted into paddy fields (10.2%). The increasing phenomena of urban area from 1997 to 2012 have leaded to the existence of crop field (6.9%), fishpond (6.4%), mangrove forest (2.4%) and swamp field (2.3%) land covers in 2012. Spatial distribution of garden fields converted into urban areas is shown in Fig. 9. It is shown in the maps that urban area spread evenly in the area of garden field in the Makassar City. However, urban expansion can lead to a rise in the off-farm garden opportunities and the resulting food shortage in the garden.

Land Use Change of Mangrove Forests

Fig. 9 shows the mangrove forests of 1997 have changed to other land-use categories in 2012. Based on the spatial data analysis, it is found that about 79.1% mangrove forests have changed into fishpond areas. At the same time, some of mangrove forests have converted into urban areas (4.6%). The Makassar City has lost around 2036 hectares (ha) of mangroves since 2012, equivalent to 96.7% loss of total mangrove areas according to land use changes assessment study.

Land Use Values Converted Into Urban Areas

Land uses for the period of 1997-2012 have shown important changes, urban surface has grown up from 4,805 to 8,098 hectares which represents almost twice the urban expansion of a 15 years period. Table 2 shows that the land use values in 1997 converted into urban area in 2012. From the land-use transition analysis, it can be noted that in 2012, garden fields (24.2%) and paddy field (19.5%) are mostly occupied by urban areas of the Makassar City. Spatial distribution of land use values in 1997 converted into urban areas in 2012 is shown in Fig. 12. It is illustrated that most of areas in the Makassar City occupied by urban settlement since 2012. Increased economic development and population pressure on Makassar City are the major drivers for the transformation of land use values to urban areas. Moreover, the influences of cross-regional migration in the Mamminasata region are recent issues.

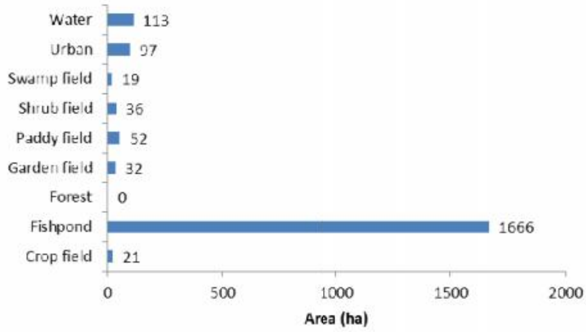


Fig. 10 Mangrove forest converted into other land use values

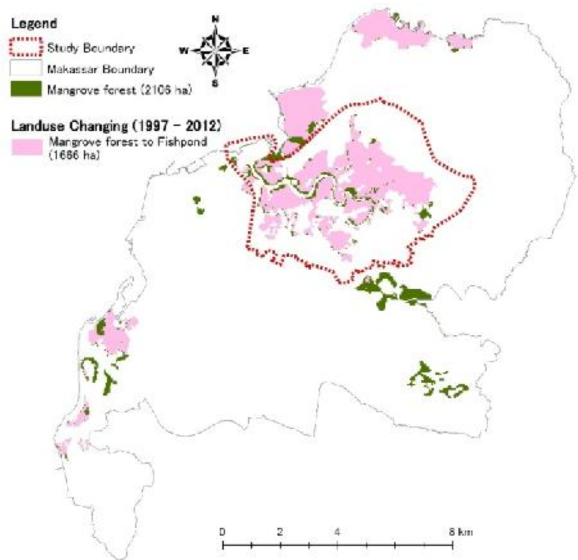


Fig. 11 Spatial distribution of mangrove forest converted into urban area

Table 2 Urban area in 2012 resulted from the changed of land use values in 1997.

LU Value			LU Changing	
Name	Area (ha)	Area (%)	Name	Area (ha)
Crop field	0	0.0		
Fishpond	0	0.0		
Forest	1	0.0		
Garden field	1962	24.2		
Mangrove forest	97	1.2	Urban	8098
Paddy field	1581	19.5		
Shrub field	56	0.7		
Swamp field	0	0.0		
Urban	4292	53.0		
Water	109	1.3		
Total	8098	100.0		

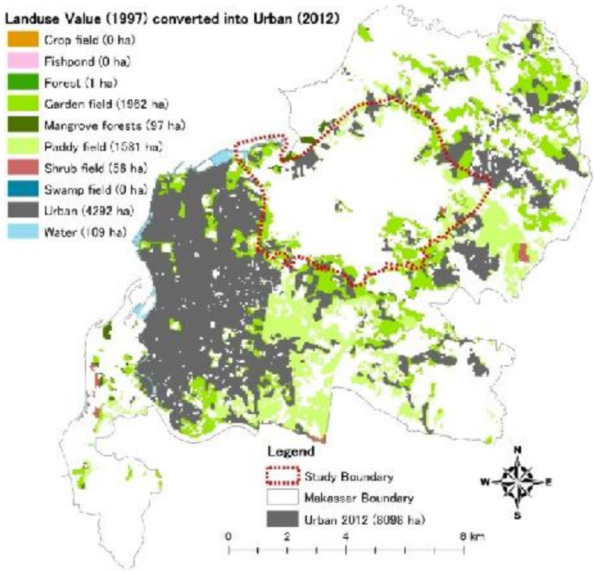


Fig. 12 Spatial distribution of land use values of 1997 converted into urban area in 2012

RESULTS AND DISCUSSION

From the spatial land-use transition analysis, it can be noted that in 1997, agriculture played a predominant role, particularly in the plain area in the Makassar city. Moreover, the availability of water from the river to agriculture irrigation has determined the agriculture development pattern. The population in 1997 was small and distributed in the agricultural villages established to take advantage of the possibilities of irrigation from the Tallo River basin. The population of some sub-districts reflected the urban settlements in the Makassar area. All of the sub-district development was carved out of potentially useful agricultural and garden field; although the area was very large and was dominated by sub-districts at that time. In addition, a decrease in agriculture and garden fields use intensity implies more future urban expansion at the expense of other ecosystems. Therefore, understanding how urban land expansion affects agricultural land use intensity will facilitate a better examination of the environmental impacts and the sustainability of the utilization of land resources (Forman, 1995; Benedict and McMahon, 2006). The increasing phenomenon of urban area from 1997 to 2012 has leaded to the existence of fishponds (13.5% of the Makassar area) in 2012. Moreover, a large area of fishpond is developed due to conversion of mangrove forest for local peoples to do fishery. It is perhaps that in the recent years, the impact of regular flooding has turned the Tallo River basin into a natural drainage catchment area, supporting the local peoples to create the fishpond as a livelihood. In addition, the occurrence of swamp fields and fishponds were counted as 15.6% from the Makassar region, has transformed the pattern of mangrove forest and shrubs field in the vicinity of Tallo River Area. Mangroves are important forested wetlands in Makassar City and now it is banned to conversion mangroves into fishpond because environmental impact assessment is required beforehand. The rate of mangrove loss is significantly higher than the loss of any other types of forests. If deforestation of mangroves continues, it can lead to severe losses of biodiversity and livelihoods, in addition to salt intrusion in coastal areas (Fahrig, 2003). Makassar City needs to engage in a more effective conservation and sustainable management of the mangroves and other wetland ecosystems especially around Tallo River Area. Environmental damages caused by the loss of mangroves in Tallo River Area in Makassar City should be urgently addressed recently, calling for better mangrove protection and management programs.

CONCLUSION

In this paper, land use changes analysis has been introduced to investigate pattern of change in the Makassar City. GIS geoprocessing model was used to develop the land use maps from the available topographical data, and GIS integrated analysis is applied to simulate the spatio-temporal land use changes from 1997 to 2012 based on grid mesh 50m. The results of the spatio-temporal analysis showed that there has been an important change in land use in the 1997-2012 periods. GIS analysis results showed that urban land expansion is associated with a decline in most of agricultural land and garden field. The area of fishponds, a measurement of crops field, is existed with increased urban land use. We also find that urban expansion has a large negative impact on mangrove forest.

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REFERENCES

Parasati, H. (2013). Program Pembangunan Perkotaan Nasional. Konferensi e-Indonesia Initiative forum IX/2013.

Turner, M.G. (2005). Landscape ecology: what is the state of the science? Annu. Rev. Ecol. Syst. 36, 319–344.

Wu, J., Buyantuyev, A., Jenerette, G. D., Litteral, J., Neil, K., & Shen, W. (2011). Quantifying Spatiotemporal Patterns and Ecological Effects of Urbanization: A Multiscale Landscape Approach. In M. Richter & U. Weiland (Eds.). Applied Urban Ecology. A global Framework, Blackwell.

Marulli, J. & Mallarach, J.M. (2005). A GIS methodology for assessing ecological connectivity: application to the Barcelona Metropolitan Area. Landscape Urban Plan. 71, 243–262.

Forman, R.T.T. (1995). Land Mosaics: The Ecology of Landscapes and Regions. Cambridge, UK: Cambridge University Press.

Benedict, M.A. & McMahon, E.T. (2006), Green Infrastructure: Linking Landscapes and Communities, Washington, DC: Island Press.

Fahrig, L. (2003). Effects of habitat fragmentation on biodiversity. Annu. Rev. Ecol. Syst. 34, 487–515.