Int J Appl Earth Obs Geoinformation 71 (2018) 95–108

Contents lists available at ScienceDirect

Int J Appl Earth Obs Geoinformation

journal homepage: www.elsevier.com/locate/jag

Urban environmental quality assessment using remote sensing and census data

Monica Alejandra Musse[a], Daniel Alberto Barona[b], Luis Marino Santana Rodriguez[c,*]

[a] Urban Mobility Secretariat, Municipality Mayor´s Office, Cali, Colombia
[b] Independent consultant. Cali, Colombia
[c] Departamento de Geografia, Universidad del Valle, Cali, Colombia

ARTICLE INFO

Keywords:
Remote sensing
Environmental quality
Urban studies
Multivariate analysis
Principal components analysis
Cali
Colombia

ABSTRACT

Urban planning to solve environmental problems in Latin American cities requires information that commonly does not exist or, if it does exist, is at different scales, which makes the information incomparable. Therefore, a quantitative approach is proposed to assess an urban environmental quality index (UEQI) for Cali, Colombia, integrating remote sensing and census data. Landsat TM images were used to extract biophysical indicators: land surface temperature (LST), normalized difference vegetation index (NDVI), soil adjusted vegetation index (SAVI), leaf wetness content index (LWCI), normalized humid index (NHI), normalized difference built-up index (NDBI), and normalized difference impervious surface index (NDISI). These seven indicators were integrated with seven socioeconomic indicators obtained from census data using multivariate statistical analysis to determine the UEQ index at the commune level. The results showed consistent correlation among the indicators, and the highest values of UEQI occurred in communes with less built-up areas and more green areas. There were statistically significant differences among the index at the commune level. Therefore, communes were categorized into five classes (very good, good, moderate, poor and very poor environmental quality) according to the index to determine the most critical interventions to be made by planning and decision-making institutions. This method could be applied to similar cities using large-scale administrative units.

1. Introduction

Urbanization, according to Dawson et al. (2009), is one of the most powerful and visible anthropogenic forces of change on Earth. Since the second half of the twentieth century, the world has experienced its greatest rate of urban growth, especially in developing countries (Cui and Shi, 2012), reaching 50% in 2008. An estimated 70% of the population is projected to live in cities by 2050 (UN, 2007).

Latin America, with a population of 623 million in 2014, has a higher urban population percentage than the world average. The region was predominantly rural until the early 1960 s, but due to the industrialization strategy to reduce product importation and the absence of reforms in the country, the migration of inhabitants from rural areas to large urban centres increased. Currently more than 80% of the population lives in cities and towns (CEPAL, 2015). Colombia has experienced an accelerated process of urbanization in the last fifty years. According to census data, between 1951 and 2005, the percentage of population living in cities and small towns increased from 39.5% to 75%, and this percentage will continue to rise. In 2020, the percentage of the population living in cities and small towns is expected to reach 77% (DANE, 2005).

Urban areas encourage economic development, provide employment opportunities and offer public services, such as education, health and transport, that create changes in living standards and lifestyles (WHO, 2010); hence, rural migration occurs in search of a better quality of life. However, cities are also associated with environmental degradation, congestion and social and economic exclusion (EU, 2010). The largest current challenges for planners and city authorities are achieving a balance between economic and social development, reducing poverty, promoting and maintaining income and work opportunities, and achieving more democratic and peaceful societies. However, the urbanization process also creates environmental problems, such as industrial emissions, traffic and pollution (Cui and Shi, 2012).

Unplanned urbanization has negative effects on the biophysical and social conditions of cities. Among the most significant adverse impacts of urbanization is decreasing vegetation cover and increasing impervious surfaces, which produce changes in the hydrological cycle (decreased infiltration and evapotranspiration), alter the air and surface temperature, put pressure on water and energy supplies, the infrastructure (Chudnovsky et al., 2004; Voogt and Oke, 2003; Santana,

* Corresponding author.
E-mail address: luis.santana@correounivalle.edu.co (L.M. Santana Rodriguez).

https://doi.org/10.1016/j.jag.2018.05.010
Received 17 October 2017; Received in revised form 11 May 2018; Accepted 14 May 2018
0303-2434/

Table 1
Summary of works about urban environmental quality assessment.

Method	Author(s)	ID	City and country	Type of variable* and quantity of indicator used.			Total
				Sec-Cen	Eco-Cen	Bio-RS	
Multivariate statistical technique	Lo (1997)	A	Georgia (USA)	4	1	2	7
	Li and Weng (2007)	B	Indianapolis (USA)	8	0	2	10
	Nichol and Wong (2009)	C	Hong Kong (China)	2	1	2	5
	Escobar Jaramillo (2010)	D	Cali (Colombia)	5	7	0	12
	Santana et al. (2010)	E	Cali (Colombia)	0	0	5	5
	Liang and Weng (2011)	F	Indianapolis (USA)	13	0	6	19
	Ogneva-Himmelberger et al. (2012)	G	Massachusetts (USA)	9	7	0	16
	Rao et al. (2012)	H	Uttarakhand (India)	4	0	3	7
	de Deus et al. (2013)	I	Uberlandia (Brazil)	7	3	4	14
O	Rahman et al. (2011)	J	New Delhi (India)	4	2	2	8
t	Stathopoulou et al. (2012)	K	Athens (Greece)	5	0	3	8
h	Joseph et al. (2014)	L	Port-au-Prince (Haitf)	5	6	1	12
e	Stossel et al. (2015)	M	Haifa, Tel Aviv and Beer Sheva (Israel)	1	19	0	20
r	Silva and Mendes (2012)	N	Viana do Castelo (Portuguese)	0	7	0	7

* Sec-Cen and Eco-Cen mean socioeconomic and ecological variables obtained by census; Bio_RS are biophysical indicators from remote sensing.

Table 2
Specific socioeconomic indicators used to assess urban environmental quality.

	ID used in Table 1.													
Socioeconomic indicators (Sec-Cen)	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Population density	✓	✓		✓		✓	✓	✓	✓	✓	✓			
Housing density		✓		✓			✓	✓		✓		✓		
Household						✓					✓			
Building density			✓									✓		
Public space per capita													✓1	
Median population age						✓								
House units		✓				✓								
Vacant house units						✓								
Owner-occupied house units						✓								
Median house value	✓	✓				✓	✓	✓						
Median house income		✓				✓	✓		✓					
Median family income						✓								
Per capita income	✓	✓				✓	✓	✓						
Mean gross rent							✓							
Median number of rooms							✓							
Poverty rate							✓							
Percentage of families below the poverty level						✓								
Electricity coverage rate				✓										
Housing gas rate				✓										
Percentage of college graduates	✓	✓				✓	✓				✓			
Unemployment rate						✓				✓	✓			
Number of deaths by traffic accident s				✓										
Percentage of employers											✓			
Rate of head of household literacy									✓					
Rate of literacy of people older than 5 years									✓					
Rate of head of households without income									✓					
Mean income of head of household		✓							✓					
Mean building height			✓											
Distance to public market												✓		
Distance to cemetery												✓		
Distance to slum												✓		
Rate of population near roads										✓				
Distance from roads												✓		
Residential density									✓					

2007; Santana et al., 2011; Zhou et al., 2004; Kato and Yamaguchi, 2007; Liang and Weng, 2011; Senanayake et al., 2013) and the treatment of solid waste. These impacts result in deterioration in health and human comfort (EPA, 2008).

However, urban environmental quality is a complex parameter that varies in space and time and results from the interaction between ecological factors, including urban heat islands (UHI), the distribution of green areas, the density and geometry of buildings, and air and water quality (Nichol and Wong, 2005), together with human characteristics that positively or negatively impact the quality of life (Kamp et al., 2003) or are prone to natural disasters (Joseph et al., 2014). This interrelationship between biophysical and socioeconomic variables generates heterogeneous conditions that are difficult to interpret because many are subjective; however, standardization through indicators and indexes provides an efficient tool to develop sustainable urban development policies (Liang and Weng, 2011).