Geographia Technica, Vol. 10, Issue 2, 2015, pp 50 to 58

THE SPATIO-TEMPORAL ANALYSIS OF IMPERVIOUS SURFACES IN CLUJ-NAPOCA, ROMANIA

Kinga IVAN [1]

ABSTRACT:
The remarkable increases of impervious surface areas are associated with urban land cover expansion and population growth. In the present study I intended to offer a retrospective look at urban land cover growth, particularly the extent of impervious surfaces, for a period of 28 years (1986-2014). The impervious surfaces for the reference period was analyzed using Landsat satellite imagery and the supervised classification method of Maximum Likelihood. Results showed an expansion of impervious surfaces from 33% in 1986 to 40% in 2014 and a population growth rate of 3% from 1986 to 2014. During the study period, impervious surfaces spread significantly in the southern and eastern parts of the city and more moderately in the northern parts.
Key-words: *Impervious surfaces, Landsat, Population, Spatio-temporal analysis, Cluj-Napoca.*

1. INTRODUCTION

Permeable surfaces in urban areas (parks, recreational lands, gardens) alternate with impervious surfaces (buildings, streets, parking lots). Due to population growth and urban land cover expansion impervious surfaces have spread significantly in recent years. This increase of impervious surface areas is primarily due to urbanization processes. According to the National Institute of Statistics (NIS, 2015) the urbanization trend in Romania was pronounced after 1970, when a decrease in rural population was recorded, whereas the urban population shows an increasing trend growing from 21% in 1930 up to 56 % in 2014. Urban population growth is a global phenomenon, according to World Health Organization (WHO, 2015) the urban population in 2014 accounted for 54% of the total global population, up from 34% in 1960, and continues to grow.

The processes of urbanization and industrialization have led to changes in land cover and land use over the years. To detect land cover change within an urban area I resorted to using remote sensing. Remote sensing allows us to quickly obtain information on the structure and extent of the city and the changes that occurred over the years. A number of studies have demonstrated the usefulness of remote sensing data to estimate the amounts of impermeable urban surfaces. Among the many extensively used methods for impervious surface extraction I would mention the Maximum Likelihood Classifier. This method was used by Hodgson et al. (2003), Parece & Campbell (2013), Xu (2007), Weng (2001) for the extraction of impervious surfaces in urban areas. In the present study we used this method to detect land cover and use changes that occurred between 1986 and 2014.

For this study the municipality of Cluj-Napoca was selected, a city located in south-east Europe, in the northwestern part of Romania (46 ° 46 'N and 23 ° 36' E) and in the heart of Transylvania at an average altitude of 360 m (**Fig. 1**). It is an important economic hub in Romania, the most important urban center of Transylvania and it is the county seat of Cluj.

[1] *Babeş-Bolyai University, 400006 Cluj-Napoca, Romania, ivan_kinga @yahoo.com;*

Cluj-Napoca experienced significant economic and social development in the past two decades thus becoming one of the most important cities in Romania. Naturally, economic development is accompanied by the continuous improvement of the transport network, the existing 5420 road segments (Nicoară & Haidu, 2014) often undergo rehabilitation and waterproofing processes.

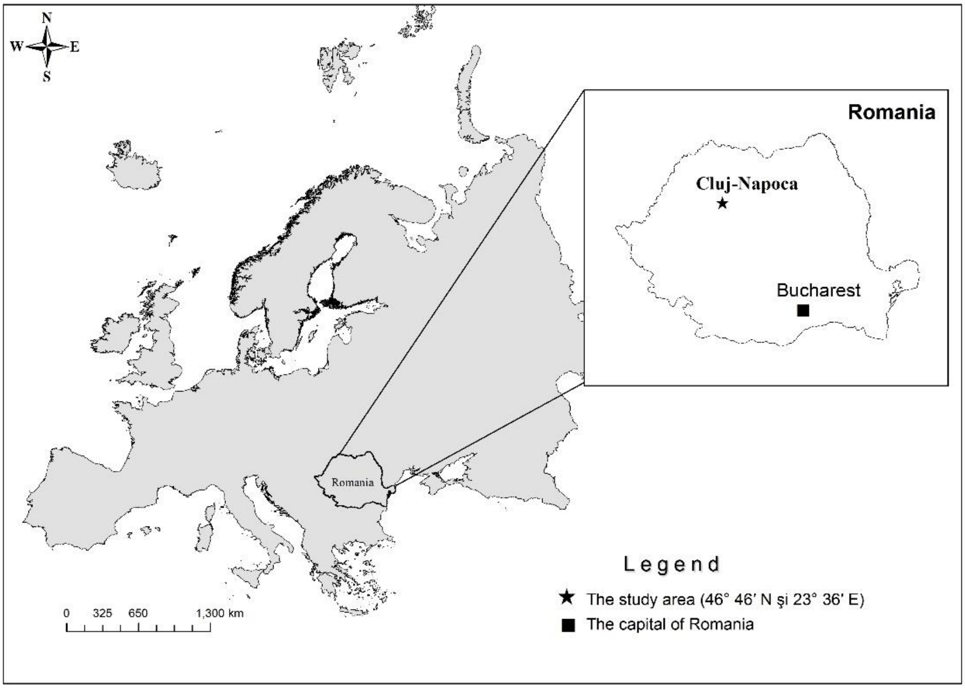

Fig. 1 Location of the study area.

For the assessment of the spatio-temporal evolution of impervious surfaces in Cluj-Napoca between the years 1986 and 2014 we used remotely-sensed satellite data and the supervised classification method of Maximum Likelihood.

2. DATABASE

Land cover changes that occurred in the urban area of Cluj-Napoca were investigated by using of remote sensing. There are several remote-sensing data sources available for the extraction of impervious surfaces including sets of lower-, medium- or higher-resolution data. Medium spatial resolution images are provided by Landsat satellites. Higher spatial resolution satellite images can offer more accurate results, though these have to be purchased. Therefore, to conduct this study we relied on Landsat satellite imagery due to program's rich archive of data that can be accessed free of charge.

The satellite images from four different years used in the study were procured from the free USGS database (USGS, 2014) in order to detect changes in land cover that occurred over time.

Thus to monitor the changes in the expansion of the studied urban area in the period from 1986 to 2014 four Landsat cloud- and fog-free (**Table 1**) scenes were selected from the spring-summer season. This set was selected from Landsat 5, Landsat 7 and Landsat 8 images. (Path 185 / Row 27).

Table 1. Used Landsat database.

Date of image capture	Types of sensor
08 august 1986	TM
21 april1993	TM
28 august 2002	ETM +
14 march 2014	OLI_TIRS

In estimating and monitoring changes in land cover for the period 1986-2014 the use of Landsat images acquired for each reference year was critical. All images acquired went through a series of preprocessing operations (Level 1 dataset), they were radiometrically and geometrically corrected and orthorectified. In the study we used 6 spectral bands, bands 1-5 and 7 for Landsat 5 and Landsat 7 images, bands 2-7 for Landsat 8 images, all with 30 m spatial resolution. The scene was larger than the area of our interest so in our study we only included an area of 251 km^2 which corresponds to the municipality of Cluj-Napoca **(Fig. 2)** and to validate results we used images from the archives of Google Earth from the years 2002 and 2014.

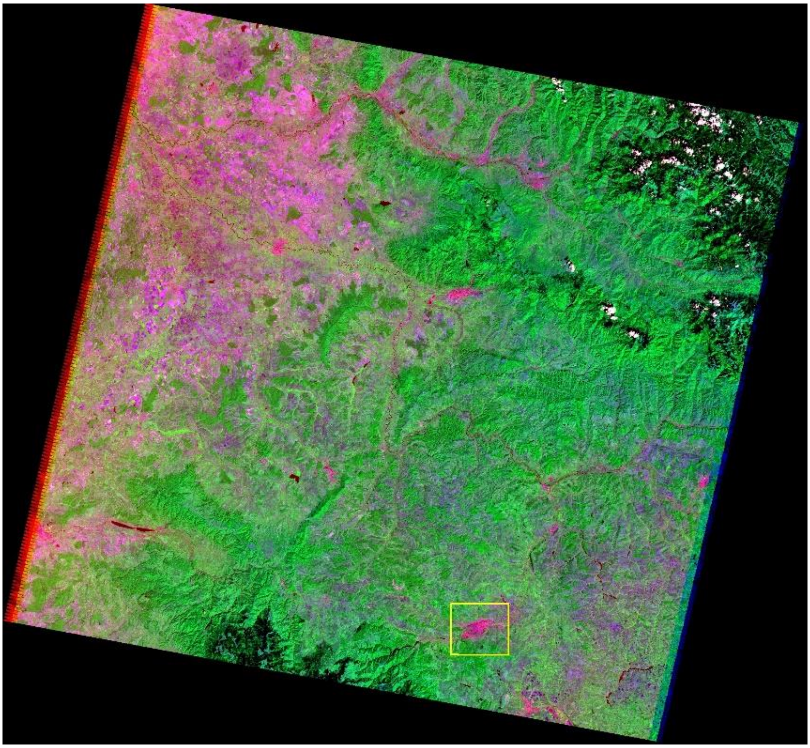

Fig. 2 Landsat ETM+(2002) satellite image.

3. METHODOLOGY

For the extraction of impervious surfaces from remotely sensed data several methods of classification can be used: supervised, unsupervised or logical classification. The purpose of using one of these methods is to achieve results close to reality, accurate classifications are imperative to ensure precise change-detection results for the whole surface of the city. In this study in order to extract impervious surfaces we resorted to using a supervised classification method.

In the context of supervised classification it is necessary to know the land cover types in order to classify them. The identification of land cover types in the study area was based on high resolution satellite images, aerial photographs and personal experience. After identifying land cover types the next step was to select the target land cover classes (representative samples) for extracting thematic information. Four land cover classes of interest were chosen: forest, herbaceous vegetation, soil and impermeable surfaces. Water bodies were masked out during the classification process and were not included in the sample classes because their spectral features are similar to those of dark and shadowed impervious surfaces (Deng, Fan & Chen, 2012; Lu & Weng, 2009; Xu, 2007; Lu et al., 2008). Masking out water bodies allowed us to separate them from low-albedo training sites. The masking out of water bodies during classification was carried out using a shapefile.

Four sample land cover classes were chosen to obtain higher accuracy when compared to the results obtained in the case of two sample classes, impervious and pervious surfaces. The target land cover classes were chosen very carefully by creating polygons for the most representative areas covered by forest, herbaceous vegetation, soil and impermeable surfaces. In the case of impervious surfaces the created polygons correspond to road networks, buildings and residential areas.

After selecting the most representative samples of land cover classes, the next step was to choose the most suitable method of classification that allows the most accurate extraction of impervious urban surfaces. In the study we used the Maximum Likelihood classification method to extract impervious surfaces of Cluj-Napoca for the four reference years.

The selected classification algorithm has been applied in numerous studies over the years for the extraction of impervious surfaces in urban areas. This simple method is based on the previously selected samples of land cover classes and its use produced reliable and accurate results for all four reference years.

Image classification was implemented using ENVI 5.1 software. After running the classification algorithm a thematic map was generated which corresponded to the selected land cover classes. Afterwards the land cover classes of forest, herbaceous vegetation and soil were grouped into the class of pervious surfaces, which resulted in a thematic map consisting of only two classes: pervious and impervious surfaces.

Based on the obtained thematic maps, the percent variance of impervious surfaces in the city was determined as follows (Ahn, 2007; Ray, Duckles & Pijanowski, 2010):

$$I = \frac{(i_1 - i_o)}{i_o} \text{ x } 100 \qquad (1)$$

Where,

i_1 - represents impervious surfaces from the following year

i_0 - represents impervious surfaces from the previous year

4. RESULTS AND DISCUSSION

The spatio-temporal analysis allowed the identification of land cover changes in the city of Cluj-Napoca for the four reference years. The results showed a growth in coverage by the impervious surfaces over the years.

It can be stated in **Fig. 3** that impervious surfaces have expanded significantly in the southern and eastern parts of the city and more moderately in the northern parts of the city. Impervious surface areas showed an expansion from 33% in 1986 to 40% in 2014. The increase of impervious surfaces in an urban basin directly affects the volume and speed of water flowing on its surface. The lack of vegetation and the quick runoff result in reduced water losses by infiltration and evapotranspiration and lead to water quality degradation.

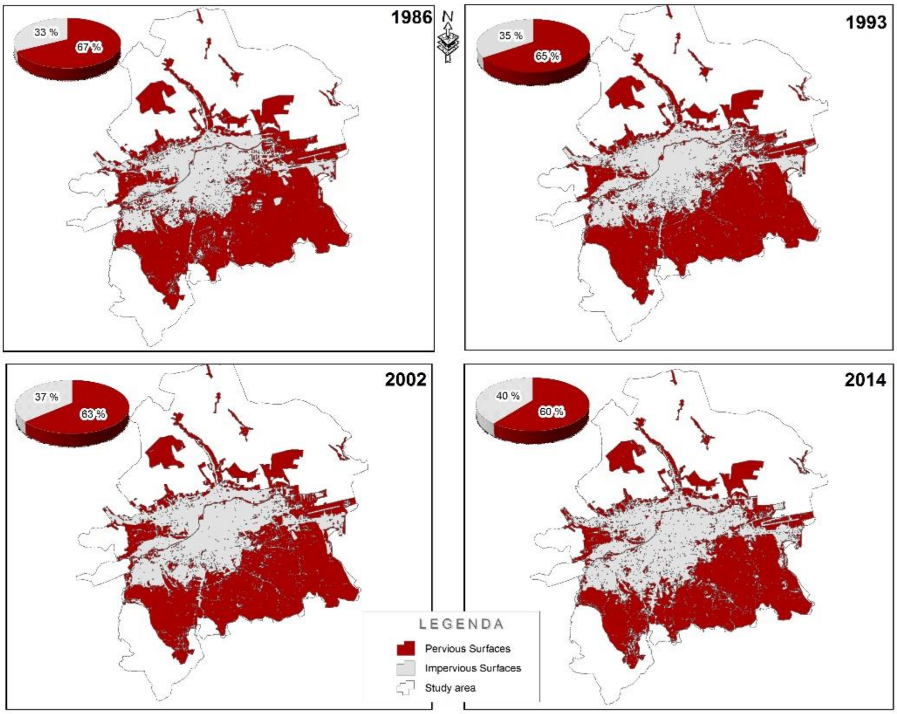

Fig. 3 The increase of impervious surfaces in the period 1986-2014, Cluj-Napoca.

When calculating the percent variance of impervious surfaces in Cluj-Napoca, the results showed increases of 6% (1986-1993), 5% (1993-2002) and 8% (2002-2014) and for the entire study period between the years 1986 and 2014 there was an increase of 21%.

The spatio-temporal increase of impervious surfaces within an urban basin is primarily due to population variability. The expansion of impervious surfaces in Cluj-Napoca is related to the population growth characteristic for this period.

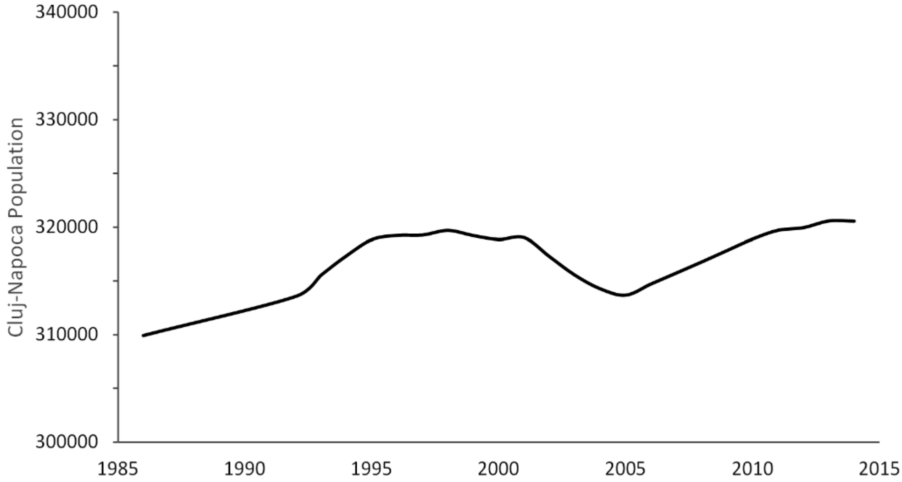

Fig. 4 Population change for the period 1985–2014 in the Cluj-Napoca city (data source: NIS, 2015).

According to the statistical data provided by the NIS (NIS, 2015), the population of Cluj-Napoca showed a 3% growth rate in the period 1986-2000 and a 2% growth rate between the years 2005 and 2014, with a decrease of about -2% in the period 2000-2005 (**Fig. 4**). This decline is due to a negative birth rate and massive migration to other countries.

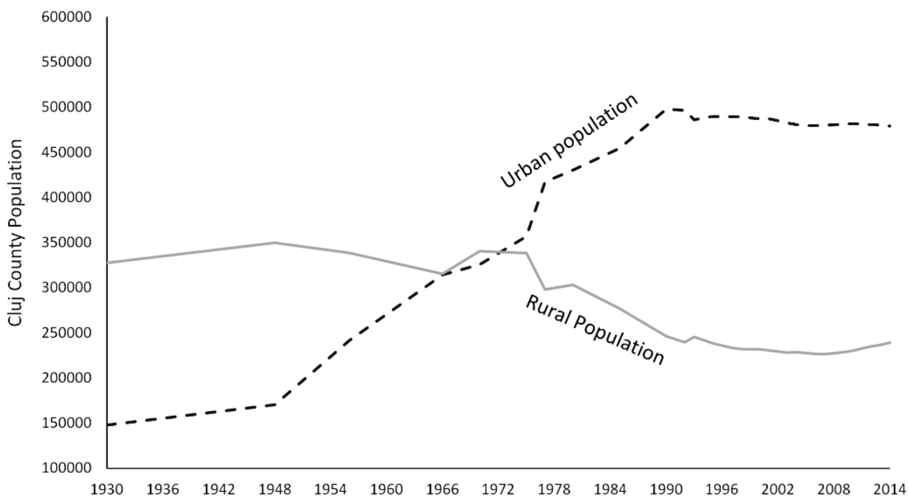

Fig. 5 Population change for the period 1930–2014 in the Cluj County (data source: NIS, 2015).

The population growth of Cluj-Napoca has led to the expansion of the city and also to the spread of constructed surfaces. In the county of Cluj urbanization trends are noticeable after 1970, the rural population witnessed a decline from 340,554 in 1970 to 239,250 in 2014, while the urban population showed an increasing trend growing from 147 986 in 1930 to 479383 in 2014 according to NIS data (**Fig. 5**).

The population growth led to the expansion of constructed surface areas, which also implied the expansion of impervious surfaces, water quality degradation, increased runoff water volume and increased urban flood risk.

5. VALIDATION OF RESULTS

In the present study, validation was carried out only on two target land cover classes: pervious surfaces (obtained by grouping together the classes of soil, vegetation and forest) and impervious surfaces, which were the results of the supervised classification method. Field data corresponding to the two classes were identified using images from the archives of Google Earth (Google Earth, 2014). For the validation process we used Arc Gis software and Microsoft Excel. Random points were created in ArcGis, a total of 290 points, and for each point the corresponding field data was extracted from Google Earth images.

The validation process involved comparing the relation between the information provided by the thematic map for each point and the corresponding field data. Thus field data with their corresponding points on the thematic map was validated using Google Earth images for 2014 and 2002 respectively.

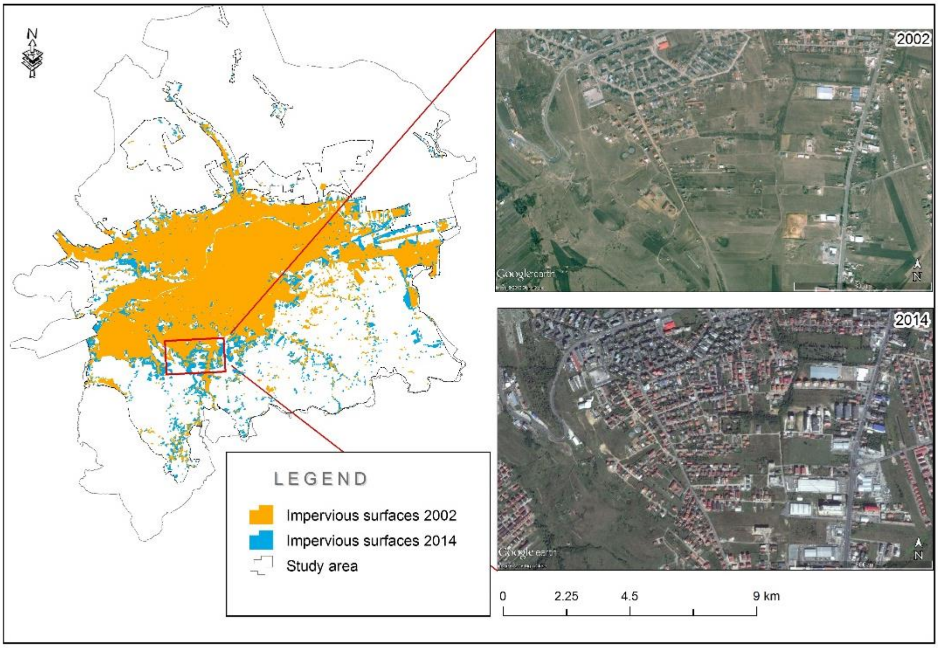

Fig. 6 Highlighting the increase of impervious areas in the southern part of the city, in 2002 and 2014.

Validation results showed high classification accuracy, classification images significantly corresponded to the reality on the fields, a fact also confirmed by an overall accuracy of 90.34% for 2014 and of 93.22% for 2002.

For an overall view of results obtained in the study and the reality on the fields, we created an overlay within the present city boundaries based on the thematic maps obtained for the four reference years. The first layer corresponds to the year 2014 and was highlighted in blue on the map, and the second layer corresponds to 2002 and was highlighted in orange on the map. **Fig. 6** highlights the fact that the expansion of impervious surfaces in the southern part of the city corresponds to the expansion evidenced by satellite images from the archives of Google Earth.

6. CONCLUSIONS

Remote sensing and the Maximum Likelihood classification method allowed us to obtain information on land cover types in the studied area for the years 1986, 1993, 2002 and 2014. This information formed the basis for our analysis of the spatial and temporal evolution of surface types in Cluj-Napoca. Results revealed an increasing impervious surface coverage in the study area from 33% in 1986 to 40% in 2014. The impervious surface coverage in Cluj-Napoca recorded growths of 6% (1986-1993), 5% (1993- 2002) and 8% (2002-2014), an overall increase of 21% from 1986 to 2014. The spread of impervious surfaces was more pronounced in the southern and eastern parts of the city and less significant the northern parts.

This expansion of impervious surfaces is mostly due to the growing urban population. The population of Cluj-Napoca recorded a 3% growth rate in the period 1986-2000, a decrease of approximately -2% between 2000 and 2005 and a 2% growth rate in the period 2005-2014. In the county of Cluj urbanization trends became more noticeable after the year 1970 when the rural population witnessed a decline whereas the urban population showed a continually increasing trend.

In order to reduce the extent of impervious surface areas, durable solutions must be implemented by local authorities, such as the expansion of recreational lands, parks and green areas near roads and pavements.

ACKNOWLEDGMENT

This paper is a result of a doctoral research made possible by the financial support of the Sectoral Operational Programme for Human Resources Development 2007-2013, co-financed by the European Social Fund, under the project POSDRU/159/1.5/S/132400 - “Young successful researchers – professional development in an international and interdisciplinary environment”.

R E F E R E N C E S

Ahn, G. (2007) *The effect of urbanization on the hydrologic regime of the big Darby Creek Watershed, Ohio*. PhD Thesis, The Ohio State University, Columbus.

Deng, Y., Fan, F. & Chen, R. (2012) Extraction and Analysis of Impervious Surfaces Based on a Spectral Un-Mixing Method Using Pearl River Delta of ChinaLandsat TM/ETM+ Imagery from 1998 to 2008. *Sensors 2012*, 12, 1846-1862.

Google Earth (2014) *Google Earth Image*. [Online] Available from www.google.com/earth/ [Accessed August 2015].

Hodgson, M. E., Jensen, J. R., Tullis, J. A., Riordan, K. D. & Archer, C. M. (2003) Synergistic use of LiDAR ad color aerial photography for mapping urban parcel imperviousness. *Photogrammetric Engineering and Remote Sensing*, 69, 973–980.

Nicoară P-S. & Haidu I. (2014) A GIS based network analysis for the identification of shortest route access to emergency medical facilities. *Geographia Technica*, 9 (2), 60-67.

NIS (2015) *National Institute of Statistic, Romania.* [Online] Available from: www.insse.ro [Accessed July 2015].

Lu, D. & Weng, Q. A (2009) Extraction of urban impervious surfaces from IKONOS imagery. *International Journal of Remote Sensing*, 30(5), 1297–1311.

Lu, D., Song, K., Zeng, L., Liu, D., Khan, S., Zhang, B., Wang, Z. & Jin C. (2008) Estimating impervious surface for the urban area expansion:Examples from changchun, northeast China. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science*s, 36 (Part B8), 385-391.

Parece, T. E. & Campbell, J. B. (2013) Comparing Urban Impervious Surface Identification Using Landsat and High Resolution Aerial Photography. *Remote Sensing*, 5, 4942-4960.

Ray, D. K., Duckles, J. M. & Pijanowski, B. C. (2010) The impact of future land use scenarios on runoff volumes in the Muskegon river watershed. *Environmental Management*, 46(3), 351-366.

USGS (2014) *U.S. Geological Survey*. [Online] Available from www.landsat.usgs.gov [Accessed May 2014].

Weng, Q. (2001) Modelling urban growth effects on surface run-off with the Integration of Remote Sensing and GIS. *Environ. Manage*., 28, 737–748.

WHO (2015) *World Health Organization*. [Online] Available from: www.who.int/gho/urban_health [Accessed September 2015].

Xu, H. Q. (2007) Extraction of urban built-up land features from Landsat imagery using a thematic-oriented index combination technique. *Photogrammetric Engineering & Remote Sensing*, 73(12), 1381–1391.