

# Potential Application of Change in Urban Green Space as an Indicator of Urban Environmental Quality Change

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**Abstract** This paper presents the potential application of change in urban green space as an indicator of urban environmental quality change. At a pilot scale, Landsat images of 1990 and 2011 of Jackson county area of Kansas City were classified to produce land use land cover maps of the area. Further, NDVI was generated for these two periods. The goal is to extract greenness as a measure of environmental quality change. Preliminary results point towards a deterioration in environmental quality. However, we recommended that future studies include more parameters to provide a holistic view.

**Keywords** Land Use Land Cover Change, Environmental Quality, Urban, Green Space

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## 1. Introduction

Urban Environmental Quality is an abstract concept that is based on both human and natural factors operating at different spatial scales. It is multi-dimensional, multi-faceted and multidisciplinary in nature and is a difficult concept to define. However, a general definition is one that defines it as an urban planning process with attention to social, economic, cultural, physical and emotional indices in both mental and visible forms [1,2]. Several studies on urban environmental quality have been carried out [3-8]. Many of these studies have used quantitative methods, qualitative description, attitudinal explanations; and landscape features [9]. Despite these studies, Urban Environmental Quality is still very vague and elusive and still requires a complete understanding. It requires the integration of a variety of elements as only one indicator alone cannot measure environmental quality. Many studies have therefore advocated for an integrated approach to the subject [10,11]. Some have even opined that different viewpoints which considers local knowledge about aspects of their neighborhood and its conditions should be integrated with environmental assessment [12-14], however, according to Liang & Weng, [9], a major challenge in Urban Environmental Quality is that there is no simple way to

model and to predict the interaction of all these aspects and variables of Urban Environmental Quality.

Other studies have explored the use of objective and subjective elements to better understand urban environmental quality [10, 11]. They pointed out that the use of objective conditions alone do not convey true quality, emphasizing the need to integrate different types and forms of knowledge in the assessment of urban environmental quality. Moore, et al [15], explored urban environmental quality within three UK's major cities: London, Sheffield and Manchester. The aim of their work was to provide a detailed understanding of urban environmental quality. They developed and employed an innovative multi-method approach combining qualitative and quantitative data collection techniques in their study. The result of their work proved that combining varying objective and subjective approaches in urban environmental quality can provide a comprehensive knowledge base for certain environmental issues. Their work also draws attention to the complex nature of environmental quality, emphasizing that a holistic approach needs to be taken in future studies, focusing on the wider relationships and connections between the environment, society and the economy.

Other works such as by Nichol & Wong, [7] have demonstrated the ability of current satellite-based sensing systems to depict parameters of urban environmental quality over large areas at detailed level, using 3D Virtual Reality models. They described a method for increasing the spatial detail and spectral accuracy of Landsat ETM+ thermal data, by fusing with an IKONOS image representing vegetation. Their work also demonstrated that by depicting the complete radiating surfaces involved in the energy exchange between the surface and atmosphere, including vertical walls, as well as the horizontal surfaces 'seen' by the satellite, a more accurate representation of the urban thermal environment is obtained. Indeed, urban thermal comfort is an important parameter of urban environmental quality. Further, their method permits 3D visualization and fly-through animation to represent urban environmental quality, based on quantifiable image parameters, and assist in the understanding of complex and dynamic factors controlling urban environmental quality. However, they noted that

future studies on similar works need to improve on data analysis techniques especially in data storage structures, in order to utilize the full dimensionality of data available from remote sensing platforms in the context of visualization. This will permit automated interpolation of multi-temporal satellite data into three-dimensional and ultimately, four dimensional models, allowing for the variable sun angle and azimuth according to seasonal and diurnal cycles e.g. linkages of database facets to image patches [16]. Such linkages were created semi-manually in the model developed by Nichol & Wong [7] following the method of Nichol [17]. The relationship between topography, the urban heat island, biomass and air pollution within the urban boundary layer are complex and dynamic and only superficially understood [7]. Improved object orientation storage structures which facilitate 3D visualization in the context of each city's unique topographic setting, would improve this understanding.

In an attempt to further understand the concept of urban environmental quality, Nichol and Wong, [18] carried out a study which attempted to map urban environmental quality using satellite data and multiple parameters. Their goal was to map or monitor urban environmental quality at a detailed level, or as a holistic concept comprising multiple parameters. Their work examined methods and scales for integrating six parameters of urban environmental quality, which are measured in different units and operate at different scales, into a single index for mapping urban environmental quality differences over an urban area in Hong Kong. The parameters they used comprise of vegetation density, heat island intensity, aerosol optical depth, building density, building height, and noise. They examined two approaches for spatial data integration-principal component analysis (PCA) and GIS overlay at three different levels of detail. At all the three levels of detail mapped, the GIS overlay method was found to be more representative of urban environmental quality as perceived in the field than when parameters were combined by principal component analysis.

Like most other geographical phenomena and environmental process, urban environmental quality is dependent on both spatial and temporal scales [9]. Unfortunately, not many studies have attempted to study urban environmental quality using these two parameters. Some very few attempts which explored the subject along spatial and temporal dimensions such as by Liang & Weng, [9] failed to integrate local knowledge. Indeed, in the context of urban environmental studies, within specific geographical areas, the public may be considered 'local experts' [15]. The incorporation of local knowledge and multiple viewpoints in such research as noted by Moore et al., 2006 may therefore improve our understanding of urban environmental quality. Indeed, many studies have shown how 'expert' accounts of physical conditions have conflicted with local people's knowledge and that rather than local knowledge being inferior or defective, it has proven in some cases more sensitive to local situations [12-13].

Because remote sensing technology is a suitable technique

for measuring spatial variability over an area at multiple scales and at different times, it is therefore an appropriate tool for studying urban environmental quality given its unique characteristics [4, 9, 19, 20-22]. Remote sensing can provide time-synchronized data coverage over a large area with both high spatial detail and high temporal frequency at a low cost [9]. The relevance of remote sensing in urban environmental quality is further enhanced by geographic information system (GIS) which makes it possible to integrate remote sensing data with other socio economic variables and in situ data.

### 1.1. Aim

The aim of this paper is to explore the potential of using urban green areas derived from land use land cover changes of Jackson County as a preliminary means of investigating Urban Environmental Quality Change in the Kansas City Metropolitan area.

### 1.2. Problem Statement

The world's population has been on the increase at an alarming rate with the direct effect of the increase more pronounced in major urban cities. Unfortunately, as urban cities grow due to increased population, adequate development planning is lacking. Cities have become more stressful due to poor environmental conditions triggered by anthropogenic pressure on the environment in an unsustainable manner. Because urban environment is not being utilized in a sustainable way, the quality of its environment is being compromised leading to deterioration in several environmental variables such as natural vegetation, energy, climates (regional and local), wetlands, and wildlife among many others. There rises the need to develop a means to indicate changes in the state of the urban environment.

Indicators are used in qualifying and simplifying phenomena and to help us understand complex realities. It usually tells us something about changes in a system. They usually quantify and aggregate data that can be measured and monitored to determine whether change is taking place. The urban environment is a complex system and only with the aid of indicators can change in the urban environmental quality measured.

Many indicators have been used in the past for determining urban environmental quality change using Remote Sensing approaches [3-8]. Many of these indicators have been grouped into two major categories of Physical (Geospatial) and socioeconomic indicators. Notable among the geospatial indicators are percentage of impervious surfaces, percentage of forest/grass land, percentage of water body and apparent surface temperature. The majority of these indicators have been derived from the classification of satellite imagery into land use and land cover types. The information obtained from this often serves as the basis for which environmental variables that will show the condition of the physical environment in question are derived.

Systematic assessment of each of these environmental variables is necessary for a proper understanding of urban environmental quality. Also, many of the socio economic variables needed for an understanding of urban environmental quality can be derived from census data. However, attention in this paper will be devoted to extracting greenness through the assessment of land use land cover change of Jackson County. This will serve as a preliminary means of investigating Urban Environmental Quality Change in Kansas City Metropolitan area.

### 1.3. Objectives

- Develop land use land cover maps of Jackson County area of Kansas City.
- Determine the extent of each land use land cover category.
- Determine the annual rate of land use land cover change.
- Generate an NDVI for the area to determine change in greenness.
- Examine the implication of change for environmental quality change.

### 1.4. Study Area

Jackson County is a county located in west central Missouri in the United States. As of the 2010 U.S. Census, the county had a population of 674,158. Jackson County is the focus city of Kansas City Metropolitan Area. According to the 2000 census, the county has a total area of 616.41 square miles (1,596.5 km<sup>2</sup>), of which 604.84 square miles (1,566.5 km<sup>2</sup>) (or 98.12%) is land and 11.57 square miles (30.0 km<sup>2</sup>) (or 1.88%) is water.

The Missouri River comprises Jackson County's northern border (with the exception of one small portion north of the river around the intersection of highway 291 and highway 210 as well as all of the 291 bridge).

## 2. Materials and Methods

The first task was to develop a classification scheme for our classification. The first three objectives and the general characteristics of the area informed the scheme developed. Four important categories shown in table 1 were identified.

**Table 1.** Classification scheme

Land Use Land Cover Categories	
1	Urban Impervious Surface
2	Urban Cropland/Grassland
3	Thick Vegetation/Forestland
4	Open Water

### 2.1. Data

The following data sets were used for this pilot study.

1. Landsat Image – 1990 (30m), 2011 (30m). Source: Global Land Cover Facility
2. Previous Land Cover map for Kansas City Missouri from the National Land Cover Database (NLCD) – used as a guide in training the software and crosschecking the random reference points used for accuracy assessment

### 2.2. Data Analysis

The following methods of data analysis were adopted for this

Study:

- (i) Maximum Likelihood Classification
- (ii) Accuracy Assessment with 250 reference points
- (iii) Calculation of the Area in hectares of the land use/land cover types obtained for each study year and subsequently comparing the results.
- (iv) Annual Rate of Change - % Change/100 \* # of Study years (21 yes)
- (v) An additional transformed image through Normalized Differential Vegetation Index (NDVI) was derived from the images to determine change in greenness of the study area.

### 2.3. Results and Discussions

Table 2 represents the static land use land cover category for the periods between 1990 and 2011. A total of 321.48 ha. (0.1%) of the area of interest were unclassified in 1990. Thick vegetation/forest land and urban cropland/grassland had the highest percentage of 48.3% and 28.3% respectively while water had just 0.1% of the total area of interest and impervious surface represented 21.4% of the total land area under classification.

**Table 2.** Land use land cover distribution

Land Use/Land Cover Categories	1990		2011	
	Area (ha.)	%	Area (ha.)	%
Urban Impervious	61338.9	21.4	88358.5	30.9
Urban Cropland/Grassland	138117	48.3	146528	51.2
Thick vegetation/Forest land	81038.5	28.3	44245.2	15.4
Open Water	5287.68	1.9	6650.37	2.3
Unclassified	321.48	0.1	643.14	0.2
Total	286103.56	100	286425.21	100

In 2011, thick vegetation/forest had reduced to 14.4% while urban crop/grass land had increased to 51.2%. Also, impervious surfaces had also increased to 30.9%. The overall accuracy for 1990 image classification is 68.80% while for 2011 is 61.20%. Producer's accuracy is the

probability of a reference pixel being correctly classified and is a measure of omission error while User's accuracy describes the probability of a pixel classified on the map actually representing that category on the ground (commission error).

**Table 3.** Accuracy Assessment

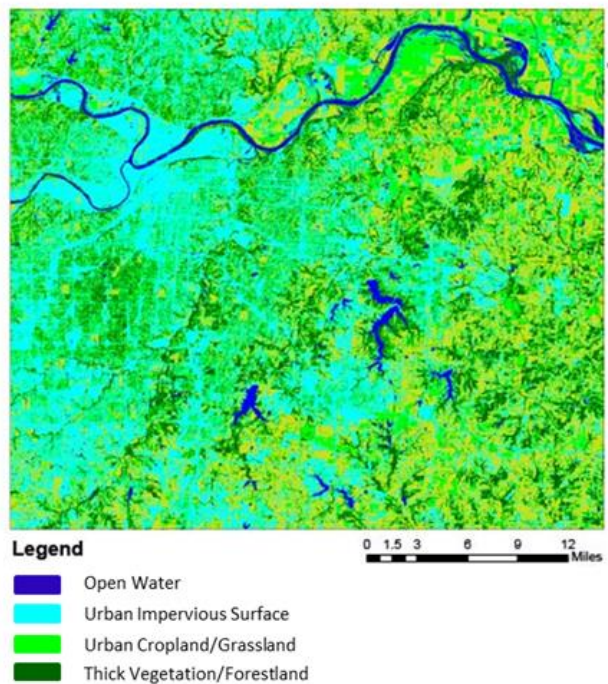
Land Use/Land Cover Categories	1990		2011	
	P.A	U.A	P.A	U.A
Urban Impervious	60.7	90.57	70.18	51.95
Urban Cropland/Grassland	74.22	78.51	67.18	68.75
Thick vegetation/Forest land	75.76	75.76	47.92	58.97
Open Water	57.14	80.00	25.00	33.33
Overall Accuracy	68.80%		61.20%	

\*P.A = Producer's accuracy, U.A = User's accuracy

**Table 4.** Change analysis

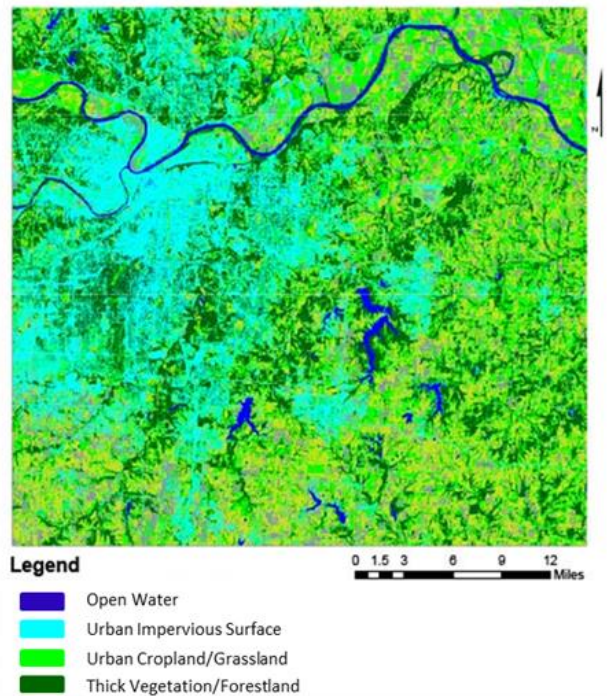
Land Use/Land Cover Categories	1990-2011		Rate of Change 1990-2011
	Change in Hectares	% Change	
Urban Impervious	27019.6	9.5%	2.0
Urban Cropland/Grassland	8411	2.9%	0.7
Thick vegetation/Forest land	-36793.3	-12.9%	2.7
Open Water	1362.69	0.4%	0.08

**Kansas City - 2011 Land Use Classification**



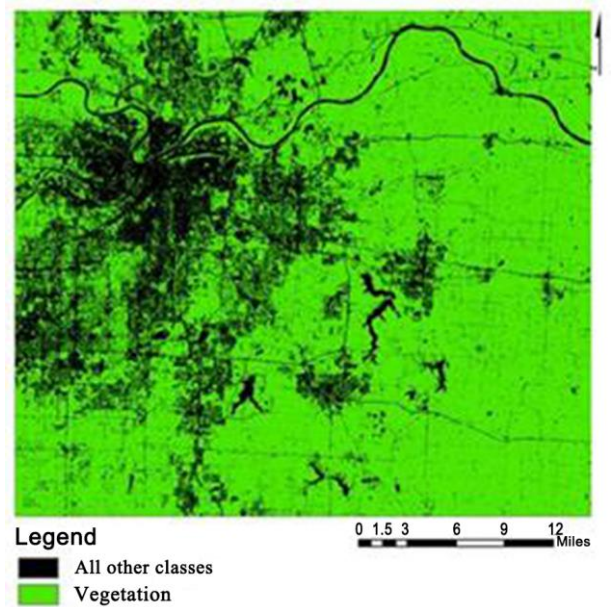
**Figure 1.** Land cover map of Jackson County, Kansas City in 2011

**Kansas City - 1990 Land Use Classification**



**Figure 2.** Land cover map of Jackson County, Kansas City in 1990

From these classified maps, we extracted the vegetation classes (figure 3 & 4). This is because information about green space is important for urban environmental quality. Vegetation is very useful in filtering air, water and sunlight; cooling urban heat; recycling pollutants; moderating local urban climate; providing shelter to animals and recreational areas for people.



**Figure 3.** Vegetation image for 1990

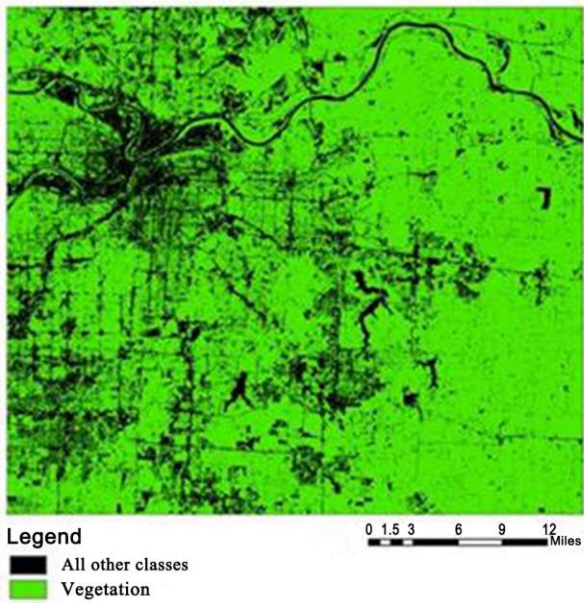


Figure 4. Vegetation image for 2011

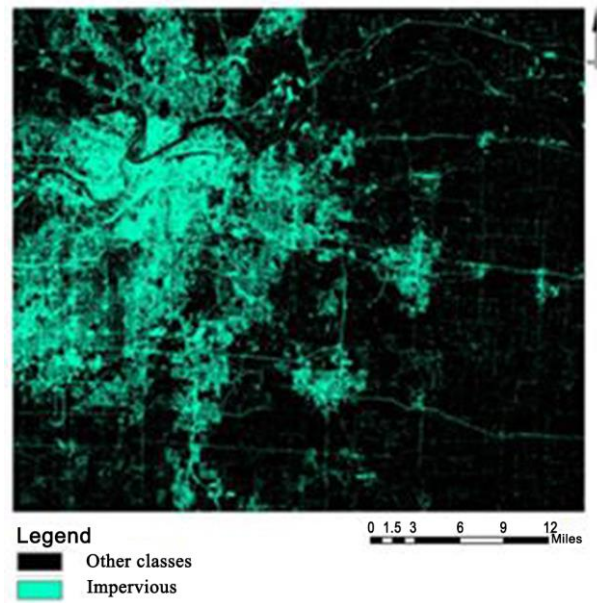


Figure 6. Impervious surface in 1990

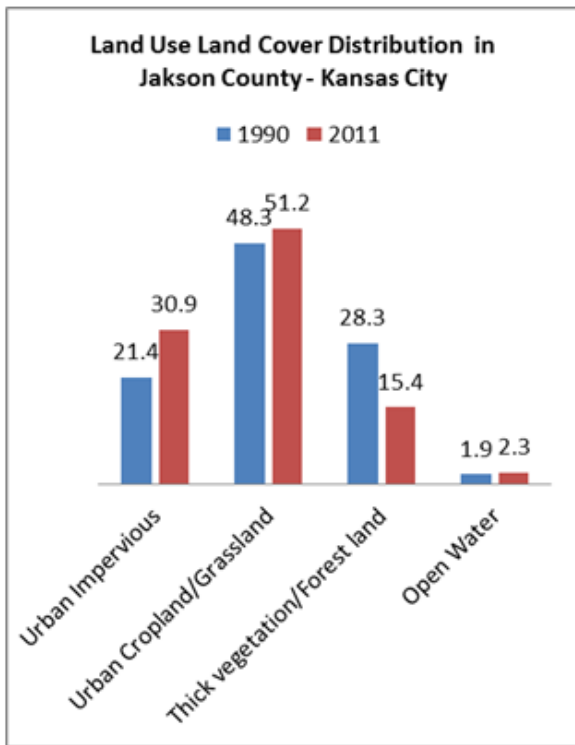


Figure 5. Percentage distribution of Land Use Land Cover in 1990 & 2011

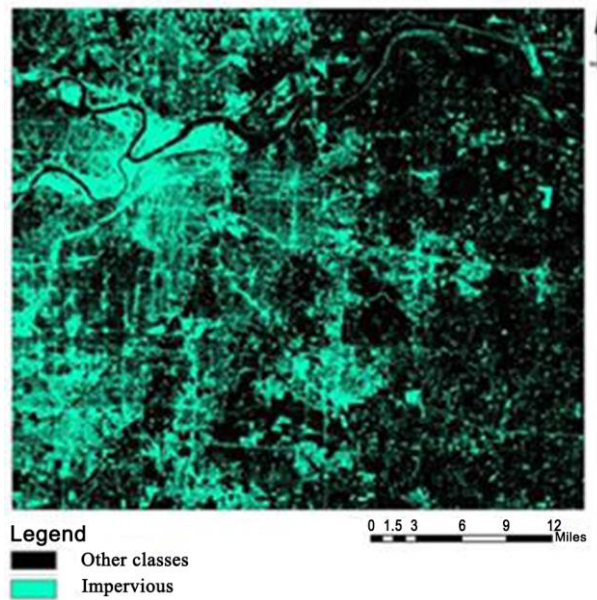


Figure 7. Impervious surface in 2011

In support of greenness information derived from the land cover maps, we generated NDVI images (Figure 8 & 9). A Normalized Difference Vegetation Index (NDVI) is an equation that takes into account the amount of infrared reflected by plants. Live green plants absorb solar radiation, which they use as a source of energy in the process of photosynthesis. The reason NDVI is related to vegetation is that healthy vegetation reflects very well in the near-infrared part of the electromagnetic spectrum.

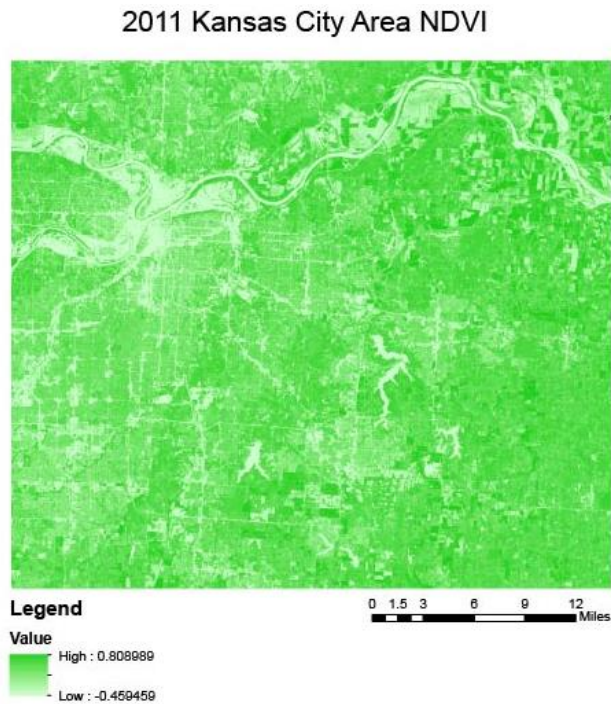


Figure 8. NDVI Image of Kansas City in 2011

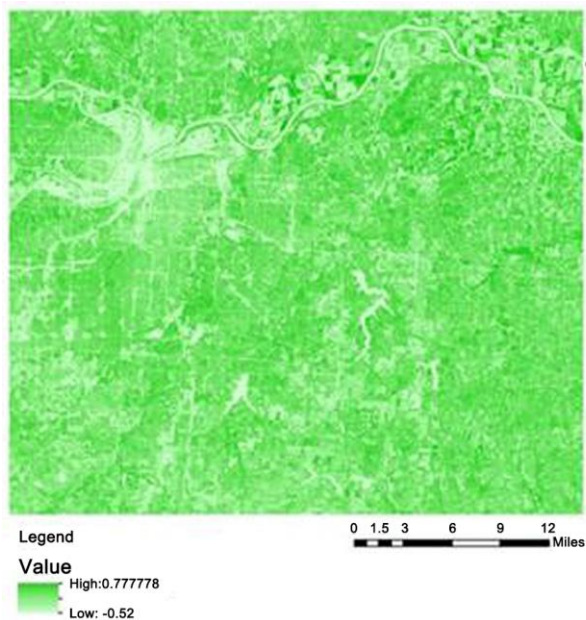


Figure 9. NDVI Image of Kansas City in 1990

Green leaves have a reflectance of 20% or less in the 0.5 to 0.7 micron range (green to red) and about 60% in the 0.7 to 1.3 micron range (near-infrared). These spectral reflectance are themselves ratios of the reflected over the incoming radiation in each spectral band individually; hence, they take on values between 0.0 and 1.0. Thus, the NDVI itself varies between -1.0 and +1.0.

Negative values of NDVI (values approaching -1) correspond to deep water. Values close to zero (-0.1 to 0.1) generally correspond to barren areas of rock, sand, or snow.

Low, positive values represent shrub and grassland (approximately 0.2 to 0.4), while high values indicate temperate and tropical rainforests (values approaching 1). The typical range is between about -0.1 (for a not very green area) to 0.6 (for a very green area).

Overall, NDVI provides a crude estimate of vegetation health and a means of monitoring changes in vegetation over time, and it remains the most well-known and used index to detect live green plant canopies in multispectral remote sensing data. The NDVI ratio is calculated by dividing the difference in the near-infrared (NIR) and red color bands by the sum of the NIR and red colors bands for each pixel in the image as follows:

$$NDVI = (NIR-RED) / (NIR+RED)$$

In this particular NDVI image, the shades of white represent manmade surfaces (concrete, roofs, roads) and water bodies, light green represents grassy fields of varying health, and dark green represents healthy, vigorous tree crowns (circular features in the campus fields). The pixel values of 1990 NDVI image ranges from around (negative) 0.52 for none and not very vegetated surfaces to values of (positive) 0.777778 for vegetated surfaces. For 2011, the pixel values for the NDVI image ranges from (negative) 0.459459 for none and not very vegetated surfaces to values of (positive) 0.808989 for vegetation surfaces.

The derivation of greenness information through NDVI from the satellite data to assess Urban Environmental Quality was measured by a vegetation index and supported by the amount of vegetation cover. This gives a general information of the spatial variability of green space in the study area. Future work will make use of these variables to calculate the mean and entropy of the NDVI. The result as it is now shows a general decrease in the spatial distribution of green space from 1990 to 2011. This situation is also true if we look at the classified data where there is a reduction in urban thick vegetation/forest land by 12.9% and only a slight increase of 2.9% in the urban crop land/grass land. However, we cannot quickly conclude that the environmental quality based on greenness shows a deterioration in environmental quality as the study cannot be interpreted in isolation. There is a need to have a holistic integration of many more indicators to reach a logical conclusion. Average temperature information between these periods will for instance give us a look into the human thermal condition in this area. Also, there is a general increase in the impervious surfaces by 9.5%. The implication of this is an increase in population density because of the relationship between total population and total area. In some cases, social condition may also be derived from this. There can however not be a straight forward conclusion now based on this. But it gives a direction of what we are likely to expect with a more holistic work. The comparison between the percentage increases in impervious surface as against the reduction in greenness might signify that there is a deterioration in the quality of environmental.

### 3. Conclusions

This paper provides an insight into the likely result of a holistic study of urban environmental quality in Kansas City Metropolitan Area. We demonstrated the potential of greenness derived from land use land cover change studies as an indicator of urban environmental quality change. Preliminary conclusions about environmental quality in Jackson County though requiring more work points toward deterioration.

As shown in the accuracy assessment in table 3, the producer's and user's accuracy were low for some classes. This is a result of mixed pixels in these classes which can be improved upon with intensive field work and careful picking of training sites. Of course, this would be necessary if this study is undertaken at a full scale. However, based on the overall accuracy, the result is a fair representation of the actual situation.

Future work would make use of data from remote sensing with socio-economic variables from census data and public perception to determine change in urban environmental quality. It is recommended that, attention be given to the inclusion of other physical variables such as water and air quality. A multi scale approach (high and medium resolution image) would also probably yield a better result.

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### REFERENCES

- [1] G. Jian., Hokao, Kazunori. Research on residential lifestyles in Japanese cities from the viewpoints of residential preference, residential choice and residential satisfaction, *J. Landscape and Urban Planning*, pp.165-178, 2006.
- [2] Profect, Michuel and Power, Gorden. *Planning for urban quality*, London, 1992.
- [3] S. H. Bederman, T. A. Hartshorn. "Quality of life in Georgia: The 1980 experience," *Southeastern Geographer*, vol. 24, pp. 78-98, 1984.
- [4] T. Fung, W.L. Siu. "Environmental quality and its changes; an analysis using NVDI" *International Journal of Remote Sensing* 21 1011 – 1024, 2000.
- [5] Z. Hossain. *Urbanization: Present Trend and Proposals for Change*. Journal of FPC, Chittagong, 2000.
- [6] N. Islam, S. R. Hasan. *People Perception of Urban Environmental Quality in Bangladesh*, *Journal of The Bangladesh National Geographical Association*, Vols 30 Nos. 1&2, pp.76-82, 2002.
- [7] J.E. Nichol, M.S. Wong. "Modelling urban environmental quality in a tropical city" *Landscape and Urban Planning*, Vol. 73, pp 49 – 58, 2005.
- [8] G. Li, Q. Weng. "Integration of remote sensing and census data for assessing urban quality of life: Model development and validation," in *Urban Remote Sensing*, Q. Weng and D. A. Quattrochi, Eds. Boca Raton, FL: Taylor and Francis Group, LLC, CRC Press, pp.311–336, 2007.
- [9] B. Liang, Q. Weng. *Assessing Urban Environmental Quality Change of Indianapolis, United States*, by the Remote Sensing and GIS Integration. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, Vol. 4, No. 1, 2011.
- [10] I. van Kamp, K. Leidelmeijer, G. Marsman, A. de Hollander. *Urban Environmental Quality and Human Well Being Towards a Conceptual Framework and Demarcation of Concepts; a literature study*, *Landscape and Urban Planning*, 65, pp.5-18, 2003.
- [11] R. W. Marans. *Understanding Environmental Quality through Quality of Life Studies: The 2001 DAS and its Use of Subjective and Objective Indicators*, *Landscape and Urban Planning*, 65, pp. 73-83, 2003.
- [12] S. Yearley, S. Cinderby, J. Forrester, P. Bailey, P. Rosen. *Participatory modelling and the local governance of the politics of UK air pollution: A three-city case study*, *Environmental Values*, 12, pp. 247-262, 2003.
- [13] R. Forrest, A. Kearns. *Joined up places? Social Cohesion and Neighborhood Regeneration*, York Publishing Services Ltd: York, 1999.
- [14] B. Wynne. *Misunderstood misunderstandings: social identities and public uptake of science*, in Irwin, A. and Wynne, B, eds, *Misunderstanding science? The public reconstruction of science and technology*, Cambridge University Press: Cambridge, 1996.
- [15] G. Moore, B. Croxford, M. Adams, M. Refaee, T. Cox, S. Sharples, *Urban environmental quality: perceptions and measures in three UK cities. The Sustainable City IV: Urban Regeneration and Sustainability*, WIT Transactions on Ecology and the Environment, vol. 93, pp. 785 -794, 2006. WIT Press.
- [16] E.P. Baltsavias, A. Gruen. *Resolution convergence: a comparison of aerial photographs, LIDAR and IKONOS for monitoring cities*. In: Mesev, V. (Ed.), *Remotely Sensed Cities*. Taylor and Francis, London, pp. 474–482, 2003.
- [17] J.E. Nichol. *Visualization of urban surface temperatures derived from satellite images*. *Int. J. Remote Sens.* 19 (9), 1639–1649, 1998.
- [18] J.E. Nichol, M.S. Wong. "Mapping urban environmental quality using satellite data and multiple parameters" *Environment and Planning B: Planning and Design* 36(1) 170 – 185, 2009.
- [19] T. Fung, W.L. Siu. "A study of green space and its changes in Hong Kong using NDVI" *Geographical and Environmental Systems* 5 111 – 122, 2001.
- [20] C. P. Lo, B. J. Faber. "Integration of Landsat Thematic Mapper and census data for quality of life assessment" *Remote Sensing of Environment* 62 143 – 157, 1997.
- [21] J.E. Nichol, M.S. Wong. "Assessment of urban environmental quality in a subtropical city using multispectral satellite images," *Environment and Planning B Planning and Design*, vol. 33, pp. 39–58, 2006.