A NEW INDEX FOR THE DIFFERENTIATION OF VEGETATION FRACTIONS IN URBAN NEIGHBORHOODS BASED ON SATELLITE IMAGERY

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ABSTRACT

Urban areas are the economic and social centers of our modern life. These areas are characterized by a number of dense artificial man made objects making these regions very complex and efficient. Urbanized areas have been developed to that extend we can observe today over the last 100 years. However, people living in those regions are still 'sophisticated and highly evolved animals' and truly a part of nature. As a consequence, a natural environment is still necessary for feeling comfortable. Just the amount of surrounding green, vegetated places are very important for feeling well. This vegetation can be estimated from several remote sensing sources, because remote sensing image data provides an overview over a large area on a synoptical basis. This study uses Quickbird multispectral and pan-sharpened imagery, acquired over an area of the city of Scottsdale, AZ, USA for the estimation of surrounding vegetation. Each individual building has been extracted first from the multi-spectral image by using object based image analysis tools. In a second step vegetation could be separated into surface vegetation and higher vegetation. Finally the fraction of surrounding vegetation (FSV) has been calculated in several distance fringes in a GIS.

INTRODUCTION

Urban areas are usually the most densely populated regions on earth. They do provide all necessary factors for our modern life such as a wealthy economy, short communication and transportation paths and a dense social network. All these achievements are mainly from an artificial nature, e.g. buildings are made from massive concrete, roads are covered with asphalt. The natural human environment represents only a small amount in these urban areas. But people as human beings -and still closely related to our animal ancestors- also need green spaces, vegetated areas for feeling comfortable and well. As a consequence the amount of surrounding vegetation is an important measurement for a quality of life index. Medium resolution remotely sensed imagery from space-borne sensors like Landsat Thematic Mapper (TM) or from the ASTER sensor (Advanced Spaceborne Thermal Emission and Reflection Radiometer) can give a first estimation on an application scale basis of about 1:50.000 and those data is very useful for the monitoring of large areas. But for the analysis of detailed and very diverse structured urban neighborhoods -especially on a building by building basis- imagery with a much finer resolution have to be considered. Schoepfer et al. (2005) combined several satellite image data sources from the Ikonos and ASTER sensors and additional cadastral data for the calculation of a complex green index. Moeller and Blaschke (2006) used only aerial imagery without any additional data for the analysis of vegetation in build up areas and introduced the index fragmentation of surrounding vegetation (FSV). The FSV is an index which is calculated for each building individually and as a consequence it provides a direct measurement for the people living in this particular building.

This study can be seen as an extension of this research. It is based on very high resolution multi-spectral (ms) satellite imagery instead of true color aerial imagery. Satellite imagery does not only provide the visible portion of the electromagnetic spectrum, but the sensor also records the infrared wavelength. The infrared information in combination with the red band is used for the calculation of several vegetation indices and as a consequence allows the estimation of vegetation amount present in the image (Sabins 1996, Jensen 2004).

AREA OF INTEREST AND SATELLITE REMOTE SENSING IMAGERY

The test area or this research is located in the center of the Phoenix metropolitan area and belongs to the City of Scottsdale. The extend of this area is 2 x 2 km. The site is characterized mainly by residential buildings. Several types of different building stages can be observed as well. Buildings in the north-western part of the subset do not show a very regular and planned shape and have been built some 30 – 40 year ago. Some open parcels can be detected too in that area. A shopping mall complex can be found in the north-eastern part of the image subset. The entire area has been developed over the last three decades and is mainly covered by residential buildings (figure 1b).

a) Western States in the US

b) Quickbird subset of Scottsdale, located in the Phoenix metropolitan area 2 x 2 km

Figure 1. Area of Interest located in Central Arizona.

The image subset as seen in figure 1b has been acquired by the Quickbird sensor in March 2003 (04MAR17180320-P3DS-000000117283_01_P001.TIF). The original data consists of a panchromatic band and a multi-spectral (four band) set. Those data have been corrected for atmospheric influences (haze, dust) first. In a next step the two different kinds of data (pan and ms) have been merged using the IHS (Intensity - Hue - Saturation) pan sharpening algorithm (Moeller 2003). The resulting image provides the 0.61 m spatial resolution of the pan band and the spectral information of the four ms bands. Directly compared with a standard digital orthophoto product used by Moeller and Blaschke (2006) for the calculation of the FSV, impressive differences of image quality are obvious. Figure 2 shows an enlargement of both image products in a true color band combination. The left image, the Quickbird product appears much crisper and more detailed compared to the aerial image and the overall detect ability and separability of small features can be performed much clearer in the Quickbird image too.

a) Quickbird true color b) Aerial Orthophoto visible
size of the subset: 2 x 2 km, spatial resolution 0.61 m

Figure 2. Comparison Quickbird pan-sharpened vs. Aerial Orthophoto.

The satellite image does not only provide a more detailed feature representation, it also records the electromagnetic spectrum of the infrared (ir) portion. Combined with the red band, the ir band can be used as a vegetation index for a differentiation of vegetation from non-vegetated areas.

SATELLITE IMAGE ANALYSIS

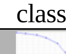
Object Based Classification Approach

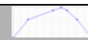
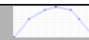
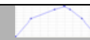
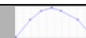
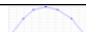
After preprocessing of the satellite data, an object-based image analysis approach has been used for the classification into several urban land use land cover (LULC) classes. In this software a segmentation and later classification process have been combined into one working package. The software has been proofed successfully for the analysis of human settlements with their very detailed, small scale objects (Hoffmann and Reinhardt 2000). Image pixels were segmented into homogeneous objects (table 1 a) on two different levels first. In a next step a complex rule-based classification tree has been created (table 1b). Therefore the software package provides a large selection of different tools for the most precise description of the desired output classes. For a detailed description of the generation of sophisticated classification rules see Baatz and Schaepe 2000, Blaschke et al. 2000, Moeller and Blaschke 2006.

Table 1a. Segmentation Parameter

level	segmentation mode	weighting	scale parameter	shapefactor	compactness	smoothness
2	Normal	b,g,r,ir -> 1	35	0.1	0.9	0.1
1	Normal	b,g,r -> 1	35	0.3	0.3	0.7

Table 1b. Rule Based LULC Classification

major class	sub classes	class definition	class definition	class definition	class definition
buildings		level I	not exist. higher vegetation level II	not exist. surface vegetation level II	 Area 0 – 600m²
	bright roof grey roof, commercial grey roof, residential red roof residential	NN class. four bands mean, brightness, border length, shape index, GLMC Homogeneity			
	streets bright	NN class. four bands mean, brightness			
	streets dark	NN class. four bands			

		mean, brightness			
bare soil		level 1	 Brightness 71-107	 GLMC Homo-geneity 0,26-0,73	 mean IR 72-107
		 Area 250-10.000m²			
vegetation		level II	 brightness 65-97	 mean red 60-88	 mean IR 75-147
	surface vegetation	 mean IR 86-145	 GLMC Homo-geneity 0,17-0,84		
	higher vegetation	 mean IR 59-122	 GLMC Homo-geneity 0,18-0,43		

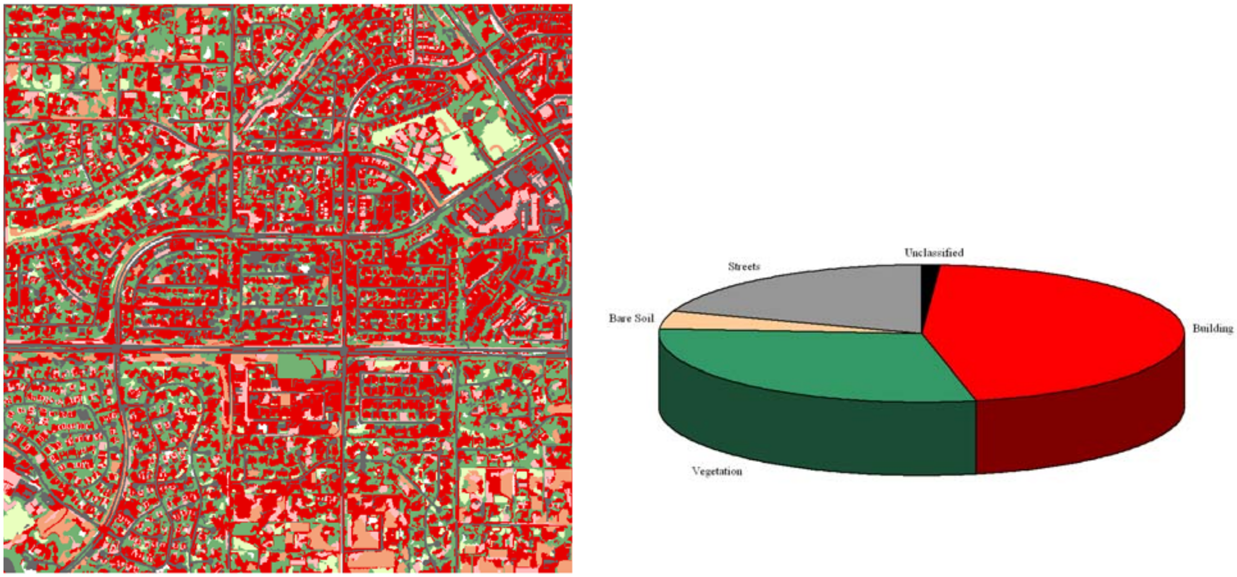
Classification Result and Accuracy

The results of the final classification can be seen in figure 3a. Figure 3b represents the charted percentages for the major LULC classes. A detailed statistical list of the classification results for the subclasses is given in table 2. The classification procedure using the object based image analysis approach is an iterative self-improving process with a permanent enhancement of the overall classification accuracy.

The final result of the classification process presented below has been analyzed for its accuracy by the evaluation of 100 randomly distributed points. The overall accuracy came out with 83%, which is acceptable for an entire automated image analysis approach based only on the image data without any additional background or a priori knowledge.

Table 2. LULC Classification Statistics

LULC major Class	LULC subclass	Area in m²	% of the area subclasses	% of the area major classes
unclassified		39192,48		0,98
building				45,7
	red roof residential	817249,68	20,36	
	gray roof residential	85843,80	2,14	
	bright roof	732296,52	18,24	
	gray roof commercial	199139,04	4,96	
vegetation				29,44
	surface vegetation	151849,44	3,78	
	higher vegetation	1030376,16	25,66	
bare soil		170541,00		4,25
streets				19,65
	streets bright	671934,60	16,73	
	streets dark	117209,52	2,92	



Classified area of interest LULC percentages

Figure 3. LULC Classification.

a. CIR Quickbird subset 140 x 120 m

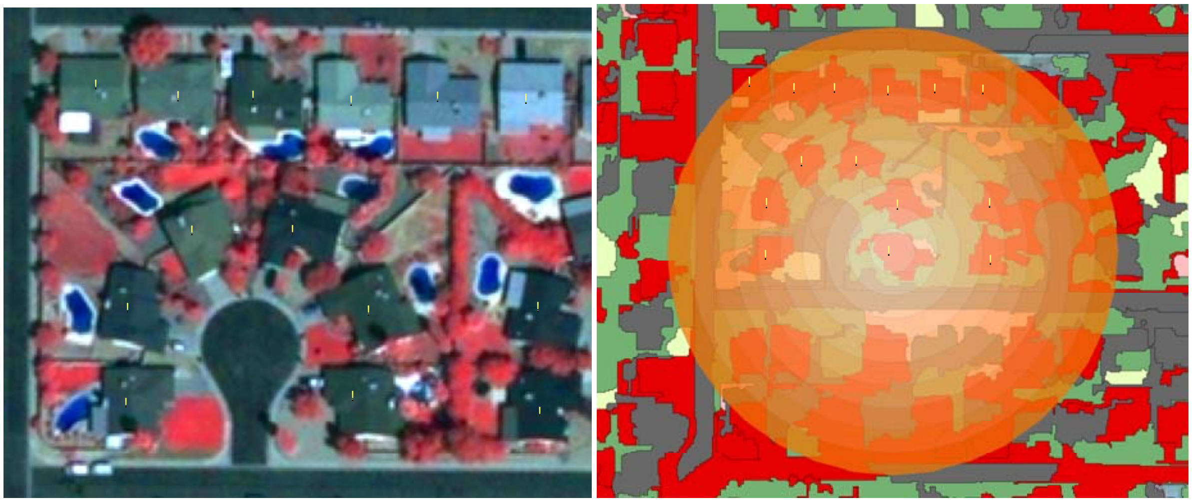
b. Classification results for the subset. Notice the appearance of the building footprints.

Figure 4. LULC Classification Example.

GIS BASED ANALYSIS OF THE FSV FROM THE CLASSIFICATION RESULT

A multi-step GIS analysis is necessary for the calculation of the Fraction of Surrounding Vegetation (FSV) for each individual building. As an example we will present this process for one building located in the classification subset (figure 5a). At first the area centroid has been calculated for each individual building. Figure 5a outlines the centroids in the test area and those represent the center of each building very accurate. However, buildings with a complex footprint could result in mismatching of the centroid. In some cases the centroid is located outside the building footprint itself (Moeller and Balschke 2006).

The building centroid is buffered with 10 fringes in a next step. Those fringes range from 10 - 100 m in diameter. Underlying LULC information from the classification is clipped for each single fringe and the amount of vegetation, separated into classes surface and higher vegetation, can then be calculated for each fringe individually. This enables a direct measurement of surrounding vegetation for each building and people living in that building.



a. CIR Quickbird subset with centroids

b. Classification with superimposed centroids and fringes for one building in the center of the subset.

Figure 5. Building Centroids and Buffer Fringes.

Table 3. Fraction of Surrounding Vegetation

	Fringe distance in (m)									
	90-100	80-90	70-80	60-70	50-60	40-50	30-40	20-30	10-20	10
FSV (surface) in % of the fringe area	0.61	2.59	3.35	2.63	0.00	3.68	3.97	0.00	0.00	0.00
FSV (high) in % of the fringe area	26.41	21.04	17.36	21.13	38.01	38.61	36.98	31.39	54.60	18.20
FSV in % of the fringe area	27.02	23.63	20.72	23.75	38.01	42.29	40.95	31.39	54.60	18.20

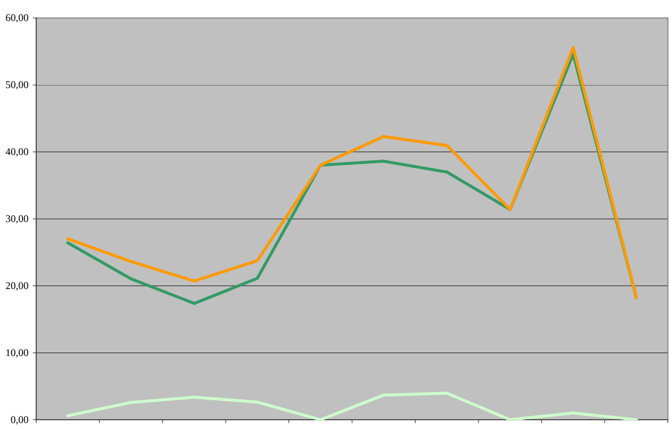


Figure 6. Fraction of Surrounding Vegetation for each Fringe.

For a demonstration of the method the FSV for just one building, the building located exactly in the center of figure 5b, is listed in table 3 and in figure 6. The highest amount of vegetation (54.6 %) relative to the area can be found in fringe number two with a 10 – 20 m diameter. More than 50 % are covered by higher vegetation like trees and bushes. This distance is the typical range private yards can be found in residential areas. The second largest amount of vegetation -in relation to the fringe area- can be found in a distance from 40 through 50 m. In that range a number of neighboring yards can be detected. Figure 6 outlines the distance relation for the FSV in a very efficient way for this specific building.

CONCLUSIONS

In this study we could extend the approach developed by Moeller and Blaschke (2006) based on aerial imagery and could demonstrate the usability of multi-spectral satellite imagery for an effective calculation of the FSV. Future analysis of the FSV will make advantage of the new generation of object based image analysis working with entire classification processes. Those processes do provide a high degree of transferability and so will enable the adjustment of the method to other urban areas in different natural environments. The whole procedure is still based only on satellite image data, meaning no additional data is required for the calculation. This is an important advantage, because satellite remote sensing imagery is available for most region of the world.

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