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THE TRANSFORMATION OF URBAN BUILT-UP AREAS DURING SOUTH AFRICA'S DEMOCARTIC TRANSITION: A CASE OF PORT ELIZABETH CITY USING REMOTE SENSING

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ABSTRACT
The unprecedented urban growth has caused socio-economic and environmental challenges in the developing world. In South Africa, the democratic transition in the 1990s was the beginning of rural-urban influx due to abolishment of apartheid movement laws. Documentation and monitoring of urban growth is critical to urban planning and sustainable urban growth. Given the myriad challenges caused by using traditional land based mapping methods, this study used post-classification remote sensing techniques to monitor built-up areas in Port Elizabeth between 1990 and 2000. Landsat Thematic Mapper images for 1990, 1995, and 2000 were acquired, processed, and classified into built-up areas and other land cover types. Results show that there was no significant change in areas covered by water, sand dune, and sea waves land cover classes. However, there was a significant gain in areas covered by built-up areas at the expense of vegetation and open spaces. The increase in built-up areas is consistent with a surge in population numbers reported in literature. We conclude the that remote sensing is an effective tool for monitoring urban growth and can therefore be used for planning and managing urban areas and to a achieve sustainable urban growth.
Keywords: Urban; Built-Up Areas; Remote Sensing; Classification; Land Cover; Port Elizabeth

INTRODUCTION
Urbanization has been identified as one of the most important components of global transformations (Pickett, Cadenasso, Grove, Nilon & Pouyat, 2001). In the recent past, studies have shown that more than half of the global population is found in urban areas (Moeller & Blaschke, 2006). This proportion is expected to increase by one fifth in the next twenty years (Moeller & Blaschke, 2006). According to Montgomery & Hewett (2005) developing countries have particularly experienced higher rate of urban growth in the last 50 years. In the sub-Saharan Africa for instance, urban population grew from 15% in 1950 to 32% in 1990, a further 54-60% growth is expected by 2030 (United Nations Environmental Program, 2005). According to Xu, Liu, Yang, Sheng, Zhang & Huang (2010), built-up settlements and associated supportive physical infrastructure like roads, retail, and industrial parks are key features in major urban areas. Saff (1996) noted a rapid influx of

population and consequent sudden expansion of formal and informal physical infrastructure has significantly affected sustainable urban growth in sub-Saharan Africa.

Whereas most of the sub-Saharan Africa's urban areas have experienced unmitigated urban growth often caused by rural urban migration (Mundia & Aniya, 2005), South Africa's urban growth, for a long time, has been shaped by apartheid rural-urban movement restrictions. In 1951 for instance, "Prevention of Illegal Squatters Act" gave the apartheid government arbitrary powers to evict people and demolish houses in urban areas (Seekings, 2000). Between 1960 and 1983, about 860,000 people were moved from urban areas under the "Group Areas Act" (Platzky & Walker, 1985). The end of rural-urban movement restrictions in 1986 and the abolishment of the "Group Areas Act" in 1991 heralded a period of unprecedented increase in urban population. Kok & Collinson (2006) noted that South Africa's urban population grew by 4.3% to 56% between 1996 and 2001. Since 1994, South Africa has recorded one of the highest rates of urban growth in the world (Naude & Krugell, 2003). Like other major urban areas in South Africa, the city of Port Elizabeth experienced and influx of population and consequent significant change in built environment since the end of apartheid.

A better understanding of urban spatio-temporal patterns is critical for socio-economic and ecological optimization of urban spaces (Batty, 2008). According to Barnsley & Barr (1996) up-to date information on urban change is critical to sustainable urban land-use planning and management. Such information is invaluable in documenting urban growth and improving urban land use plans (Bullard & Johnson, 1999). Traditional survey and mapping methods have, for a very long time, been used for urban planning and management, they are often time consuming, tedious and expensive (Rawashdeh & Saleh, 2006). In the recent decades, remote sensing has emerged as a popular viable substitute due to its cost effectiveness and technological soundness (Rawashdeh & Saleh, 2006). According to Prakash & Gupta (1998), remotely sensed data offer permanent and authentic record of spatial patterns which is valuable for verification and assessment purposes.

Currently, remotely sensed data is used for data gathering, storage, retrieval, analysis, display, and output (Donnay, Barnsley & Longley, 2001). Analysis that involve change detection techniques have particularly proved valuable in urban studies. These techniques involve the use of imagery taken at different dates to quantify temporal effects of land use/cover. According to Lu, Mausel, Brondizios & Moran (2004), repetitive data acquisition, synoptic view, and formats processed by computers have made remotely sensed products suitable for change detection applications. Within the context of general land cover types; this study was aimed at detecting changes in a built-up area in the city of Port Elizabeth towards the end of apartheid and early years of South Africa's democratization (1990 to 2000) using Landsat Thematic Mapper imagery.

THE STUDY AREA

The city of Port Elizabeth was founded in 1820 by British settlers. The city is located at coordinates 33^{o}57'29" S and 25^{o}36'00" E on the south western part of the Eastern Cape Province (Figure 1). With a total area of 335km^2 and approximately 750,000 people (Statistics South Africa 2007), it is currently the fifth largest city in South Africa and the largest urban area in the Eastern Cape Province. The growing industrial sector and consequent increase in job opportunities has, in recent years been the cause of population influx to the city. Other important economic activities in and around the city are tourism and citrus processing plants that serve the surrounding citrus farms. According to a 50year weather history, the city has a mean annual daily maximum temperature of 22^{o}C, a mean annual daily minimum temperature of 14^{o}C and a mean annual precipitation of 624mm (South African Weather Service, 2010).

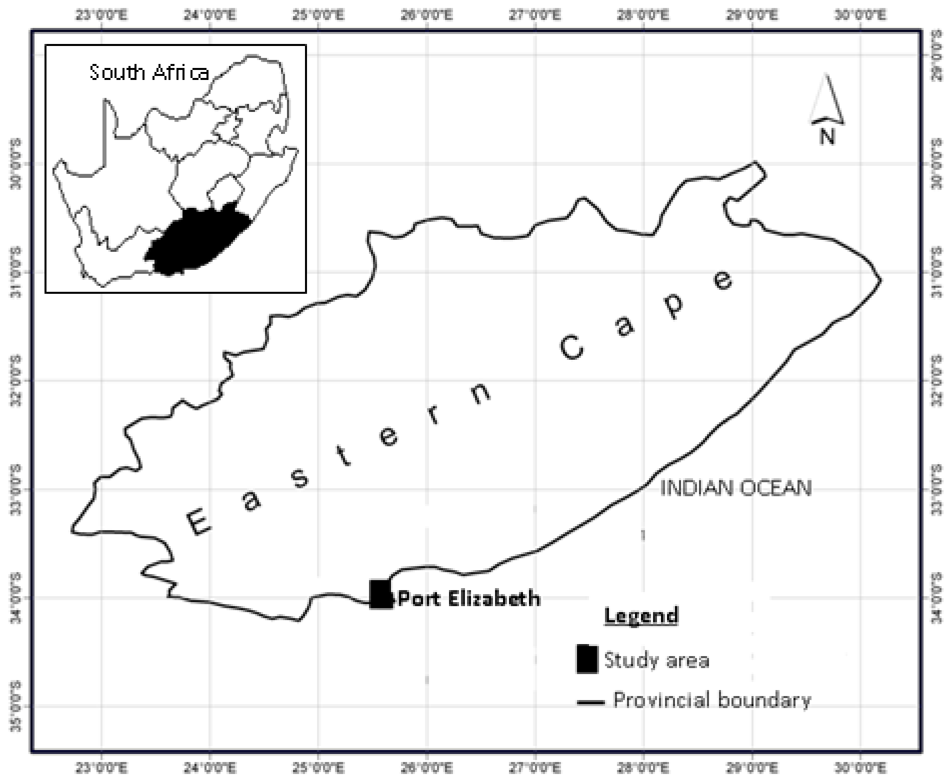


Figure 1. Location of the study area.

RESEARCH METHODOLOGY

Three sets of cloud free Landsat Thematic Mapper images with characteristics shown in Table 1 were acquired for this study. The three sets of images were geo-rectified to less than a pixel accuracy using common features from the available 1:50000 topographic-sheets of the city. Extents occupied by the city were delineated and extracted from the bigger 1990 image. Windows from the 1995 and 2000 images were then extracted using extents defined and extracted from the 1990 image. To enhance the accuracy of the final classification for detecting change, two more process were undertaken. First, the window from the 1990 image was used to resample the 1995 and the 2000 image and secondly, the images were normalized using Dark Object subtraction model (Chavez, 1996).

Table 1. Characteristics of the imagery used

	1990 image	1995 image	2000 image
Path/Row	171/83	171/83	171/83
Acquisition date	29/05/1990	12/06/1995	11/07/2000
Acquisition time	07:30:40	07:16:48	07:47:34
Spatial/spectral resolution	30m/7 bands	30m/7 bands	30m/7 bands
Sun azimuth/Elevation	E41.88/22.36	E43.94/18.90	E39.91/23.12

Red, Green, and Blue color combinations of bands 4 (0.7-0.9µm), 3 (0.55-0.7µm) and 2 (0.45-0.55µm) False Color Composites (FCC) that accentuate the spectral differences for different land cover types were developed for the three sets of images. To gain an insight of the available and related land cover types on the images, unsupervised land cover classes were generated from the images. After identifying all the cover types that were considered built-up areas, the FCCs were used to identify training sites and respective geo-rectified ortho-photos used to generate supervised classes. The accuracy of the classes were assessed using areas from aerial photographs (to represent true ground areas) and the supervised land cover results (to represent mapped areas). An accuracy of 82.01%, 84.32%, and 79.20% as we as a kappa coefficient of 0.801, 0.814, and 0.772 were achieved for the 1990, 1995, and 2000 images respectively. The AREA module using pixel counts in Idrisi remote sensing software was used to compute the built-up area. Surface covers were calculated by multiplying the result of pixel dimensions (30m x 30m) by the total number of pixels on respective surfaces. To extract built-up areas from other land cover types, Boolean images were generated from the three image sets. The Boolean images were then used to show multi-temporal change in built-up area in Port Elizabeth.

RESULTS AND DISCUSSION

Initial examination during imagery pre-processing showed some readily identifiable built-up area cover change on the three datasets (Figure 2). Figures 3 and 4 show the distribution of major land cover types and the surfaces covered by built-up area respectively.

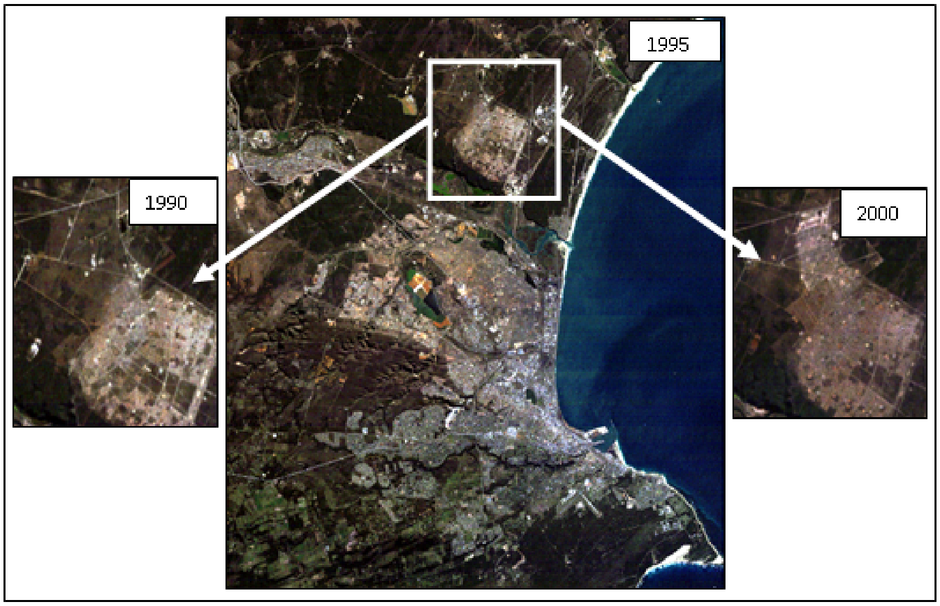
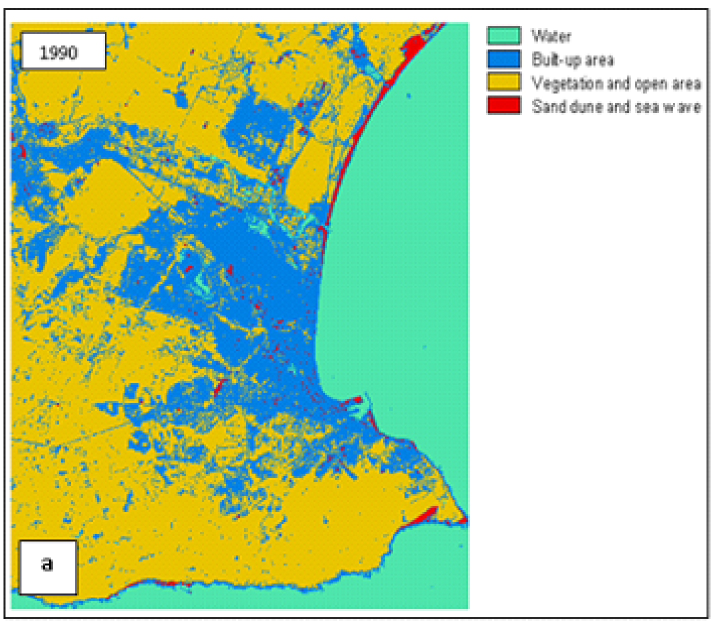


Figure 2. An example of an area with readily visible settlement change in Port Elizabeth.



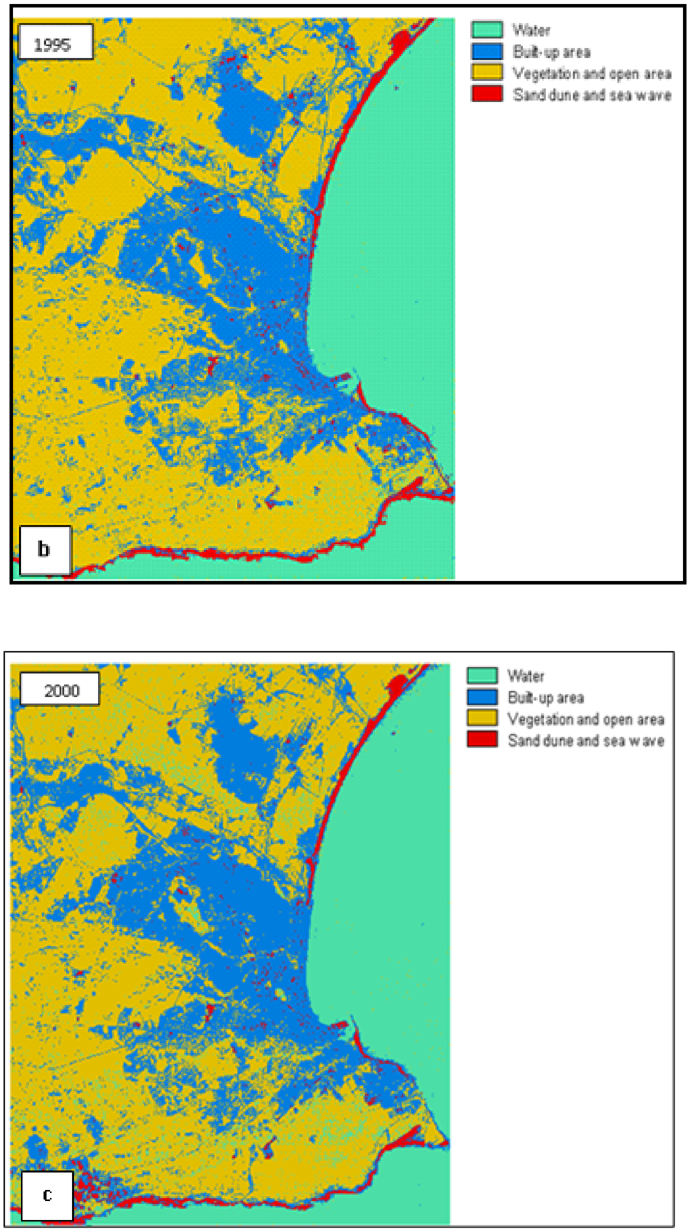


Figure 3 (a-c). Major land cover classes within Port Elizabeth.

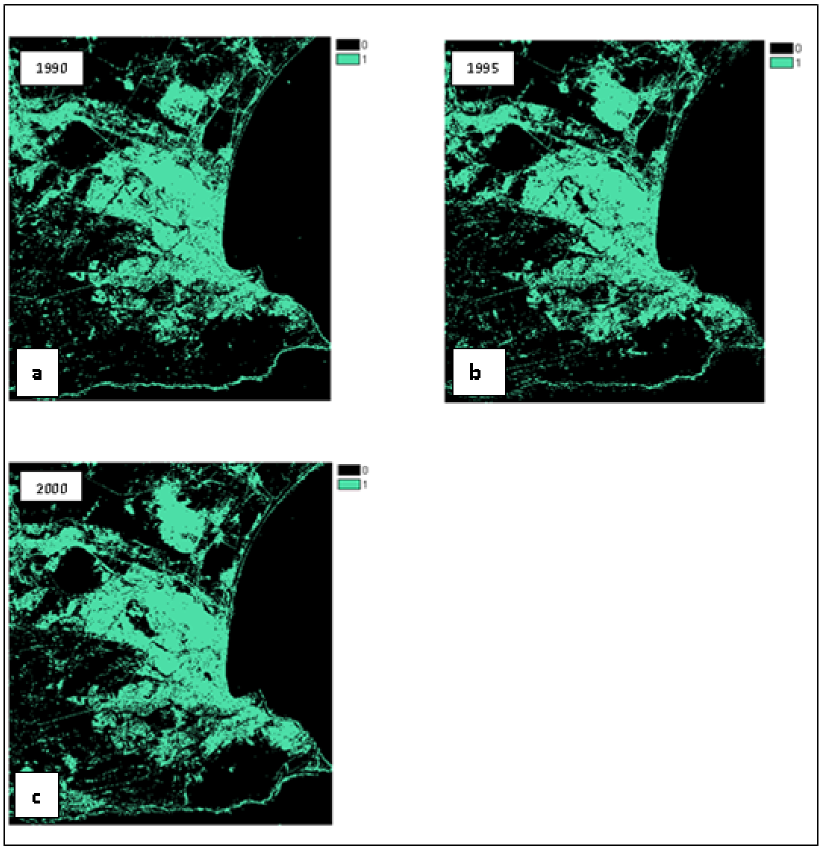


Figure 4 (a-c). The built-up areas in Port Elizabeth (1- Built-up area; 0- other land cover types).

There was no significant change in the area covered by water and sand dune/sea wave classes over the the 10 year period (Figure 5). The area coverd by water in Port Elizabeth was 24458.67ha, 24678.09ha and 24554.07ha for 1990, 1995, and 2000 respectively. This constituted an increase by 219.42ha (0.89%) in the 1990-1995 period and a decrease of 124.02ha (0.5%) in the 1995-2000 period. An examination of the imagery and their respective classes showed no significant change in water bodies. There was however similarity in spectral characteristics between sand dune and sea waves during the time of imagery acqusition in 1995. Change in rainfall patterns and vegetation recruitment can lead to an increase or decrease in sand dune volume and size, the presence of sea waves can partly be used to account for fluctuations in area covered by Sand dune and sea wave class of 262.55ha, 247.68ha, 244.94ha for 1990,1995, and 2000.

Built-up area land cover class increased by 752.4ha (2.89%) between 1990 and 1995 and 2929.95ha (9.8%) between 1995 and 2000. Between 1990 and 2000, built-up area land cover class increased by 3682.35ha and was the most significant positive change of all the landcover types studied. The Vegetation and open area class had the most significant decline during the same period (Figure 5). The area covered by this cover class declined by 1782.81ha (3.52%) between 1990 and 1995 and 2594.61ha (5.3%) between 1995 and 2000. Within the 10yr study period, the area declined by 4377.42ha (8.64%) and constituted the most significant land cover loss (Figure 5). The Vegetation and open area land cover class was also the most affected by the by the positive increase in built-up areas.

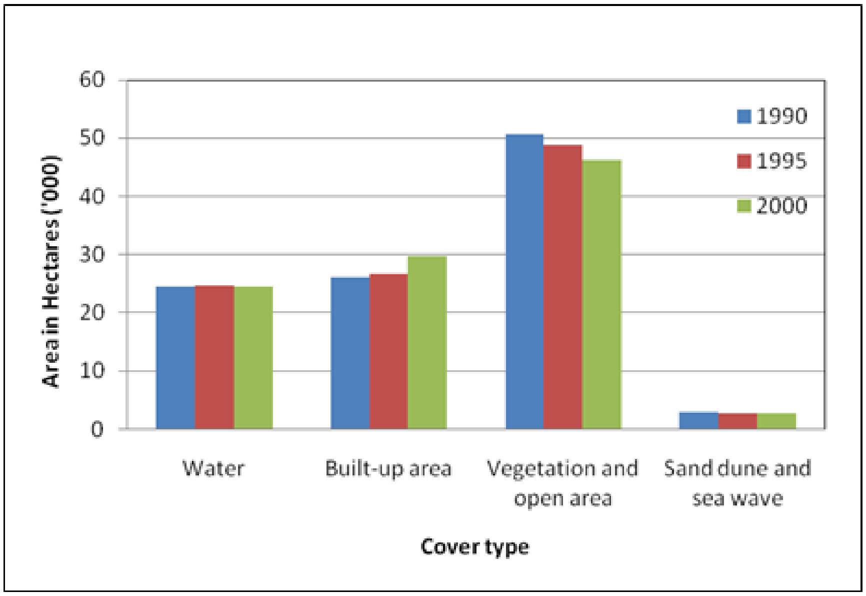


Figure 5. The area of land cover changes from 1990 to 2000.

The results in this study are consistent with existing literature on urban growth. According to Christopher (2001), the beginning of unrestricted rural-urban movement in 1986 and the formal end of the "Group Areas Act" in 1991 saw a dramatic increase in urban population. According to Christopher (2001), there was a 27% increase of black South Africans in urban areas while Kok & Collinson (2006) note that there was a 4.3% average urban population increase between 1996 and 2001. According to Gelderblom (2003), this trend was in response to the restrictive laws during apartheid regime that restricted urban growth. Since the end of apartheid, the growth of urban areas has mainly been influenced by government initiated development policies aimed at undoing the effects the apartheid city (Donaldson & Van Der Merwe, 2000). An example is government housing initiative under Reconstruction Development Program (RDP) to provide houses to low income urban dwellers (Abbot & Douglas, 2003). However, not all low income urban dwellers in Port Elizabeth were accommodated in the RDP initiative; this led to a significant amount of informal settlements in the city. The RDP initiative, informal settlements and other physical infrastructure development led to a significant increase in built-up area in Port Elizabeth during the study period.

CONCLUSION

The use of multi-temporal imagery and landcover classification techniques in the city of Port Elizabeth showed a significant change in built-up areas between 1990 and 2000. While this study did not differantiate built-up cover types in Port Elizabeth, it can be assumed that the rapid rise in the city's population and therefore growth in residential areas as well as increase of other cover types like transport infrustructure, retail, and industrial were the major causes of expansion in built-up area. There was a lower growth in built-up areas between 1990 and 1995, this period concided with the later phase of negotiations for South Africa's democratisation that included formal end to aparthied laws that restricted movement to urban areas. The period after South Africa's democratisation in 1994 was characterised by higher growth in built-up areas attributed to the new gvernment's policies to provide basic services particularly housing. Urban green spaces have long been known to play a critical role in sustainable urban growth, urban environmental quality and general quality of life. The rapid loss of Green spaces and open area land cover class, to built-up area land cover class should therefore be of particular concern to managers and policy makers in the city. This study shows that remote sensing applications offer viable options in planning and monitoring urban growth and therefore can be used to generate data and information for informed decision making in support of for sustainable urban growth.

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