Quantifying Urban Encroachment in Dhaka, Bangladesh from 1989–2000

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Sultana, S. and Marzen, L. J. "Quantifying Urban Encroachment in Dhaka, Bangladesh from 1989–2000." Papers and Proceedings of the Applied Geography Conference, Vol. 27, pp.231–238.

Abstract:

Even though accelerating urban growth has often been viewed as a sign of vitality for regional economies, such urban growth, unquestionably, causes tremendous changes in land use and leads to severe haphazard and unplanned growth in urban areas, which ultimately forces builders to move to outlying suburbs and exurbs. Such development has tremendous impact on the environmental characteristics of cities. Unplanned growth consumes large amounts of agricultural and vegetated lands, decreases biodiversity, produces congestion and air pollution, misallocates land resources, and may result in inefficient use of energy.

Keywords: population density | urban development | urban transportation | land use

Article:

1. INTRODUCTION

Even though accelerating urban growth has often been viewed as a sign of vitality for regional economies, such urban growth, unquestionably, causes tremendous changes in land use and leads to severe haphazard and unplanned growth in urban areas, which ultimately forces builders to move to outlying suburbs and exurbs. Such development has tremendous impact on the environmental characteristics of cities. Unplanned growth consumes large amounts of agricultural and vegetated lands, decreases biodiversity, produces congestion and air pollution, misallocates land resources, and may result in inefficient use of energy.

Dhaka, the capital of Bangladesh, has experienced significant growth in all segments of the community since the 1970s (Islam, 1995) and new infrastructural developments have arisen to provide housing, roads, schools, services, and parks for this growing population. As a result, in the past few decades, Dhaka has witnessed tremendous urban decentralization at the expense of prime agricultural lands and fragile wetlands and forests, which are often encroached upon illegally (Daily Star Report, 2003). In response to this unplanned growth, several groups including Bangladesh Paribesh Andolon (BAPA) and Bangladesh Environment Network (BEN) have been actively pressuring government and city planning officials to preserve these undeveloped areas (http://www.ben-center.org/). Despite the Dhaka planning commission's (locally known as Rajdhani Unnoyon Corportation, RAJUK) attempts to satisfy activist groups' concerns through promises to limit development in these areas, local residents and daily newspaper reports indicate that urban encroachment has been occurring and continuing at rapid rates (Daily Star Report, 2003).

While economic growth itself cannot be discouraged, the detrimental effects of the haphazard outward expansion of the Dhaka metropolitan area are certainly to be discouraged. Therefore, monitoring urban growth and change in the metropolitan area is essential for those who study metropolitan dynamics, manage city resources, and provide services in these rapidly changing environments. The primary purpose of this paper is to assess the spatial growth and urban encroachment along the outskirts of Dhaka from 1989 to 2000 using remote sensing, GIS, and change detection methods. Very specifically, this research will identify the expansion, *inter alia,* of the urban built structure. In the remainder of this paper, we begin with a brief introduction to Dhaka along with some essential existing conditions, including the city's growth and consequent environmental problems relating to the city's current structural changes. Next, the results are discussed, followed by concluding remarks with future research directions.

2. BRIEF BACKGROUND OF DHAKA'S GROWTH AND RELATED PROBLEMS

The motivation for conducting this analysis is that, since independence (1971) Bangladesh has experienced rapid rates of urbanization and the highest level of this growth has taken place in Dhaka (Islam, 1995). According to Dhaka Metropolitan Development Plan (DMDP, 1994) the boundary of the Dhaka Statistical Metropolitan Area (DSMA) is comprised of an area of 1528 sq. km with average population density of roughly 50,000 people per sq. mile (19,300 per sq. km). Thirty-five percent of the country's urban population lived in Dhaka by 2000 (Fig. 1). Prior to independence in 1971 Dhaka's population was only 557, 000. From 1971 to 1974 Dhaka grew by more than 10 percent per annum, reaching a population of slightly more than 2 million in 1974. In the period 1974 to 1990, Dhaka's population continued to grow, but the per annum growth rate fell slightly due to the remarkable urbanization pattern of spreading widely among secondary cities (Kemper, 1989). Dhaka was the 31st largest city in the world in 1985. In 1990, Dhaka's population reached approximately 6.4 million in 1990 and was expected to have 11.1 million by 2000 (Fig. 1), making it the 15th largest city (Lo, 1992). However, Dhaka's growth has exceeded the predicted rates and has assumed a place as the eighth largest city in the world since 2001 and is predicted to be the second largest city in the world by 2015 (UN, 2001). The population, which now exceeds 13 .2 million, will have continual rapid growth over the next 30 years and is expected to be 22.8 million in 2030 (UN, 2001).

With its unplanned rapid growth, Dhaka has become a showcase for almost every urban problem imaginable (Bangladesh Environment Network, 2003), most of which are related to the high density of population. Hence, Dhaka has been considered as one of the most congested and polluted cities in the world. The city's current planning is dedicated primarily to coping with population pressures and infrastructural needs (Sultana, 2000). These pressures have resulted in the expansion of the outskirts of the city with an improper balance between residential and commercial locations and public transportation management. As a result, unrestrained use of private vehicles also increased dramatically (Table 1). This, combined with an inadequate infrastructure for cars (e.g. narrow roads), ultimately created more congestion throughout the metropolis from early morning to late evening. Moving towards a dependence on automobiles, the recent trend of mode of transportation in Dhaka is disturbing to many planners and activist groups. With the current congestion, it is becoming difficult to get anywhere by car, but also neighborhood character of the city is being damaged. Airborne pollution from vehicle emissions is so severe that streets are inhospitable to pedestrians and to businesses that require foot-traffic to draw customers. Motor vehicle emissions currently account for 60 to 70 percent of all air pollution in Dhaka (Ipe, 1995).

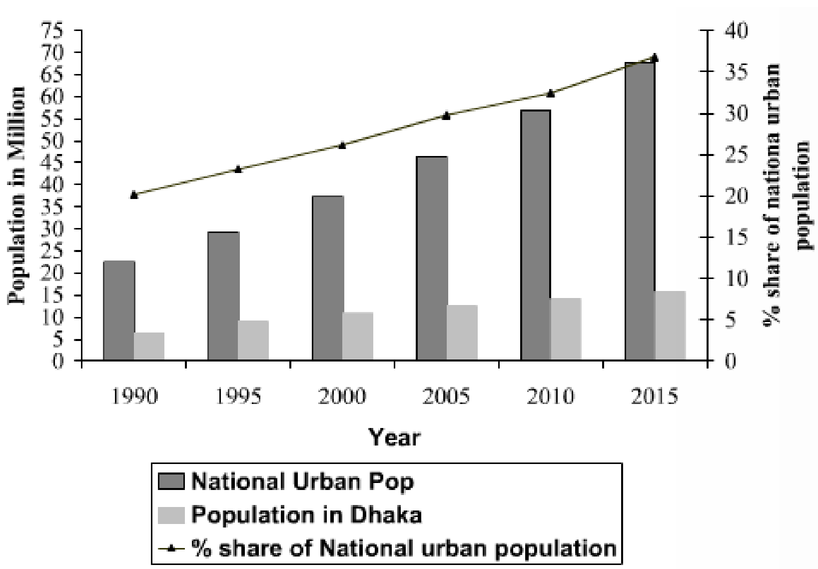


Figure 1. Projected Population in Dhaka, 1999-2015

Table 1. Growth of Private Cars vs. Public Transportation in Dhaka: 1966-1997

Year	Private Car	Bus/Mini Bus
1966	12,958	3,739
1970	19,929	5,879
1975	15,048	5,223
1980	28,799	6,457
1985	24,163	17,297
1990	31,847	20,753
1995	39,454	23,314
1997	49,054	24,882

Source: Bangladesh Statistical Yearbook, 1998

3. DATA AND METHODOLOGY

Planners all over the world recognize the value of spatially explicit information and have embraced GIS (geographical information systems) technologies as an important means to understanding the relationships between people and locations (Kolin et al., 1998). It has been found that satellite imagery is a cost-efficient source of continually updated spatial data which can be integrated in a GIS with demographic data in order to analyze the growth of the city quickly and accurately (Ryznar and Wagner, 2001). The combination of these technologies allows researchers to accomplish work (image processing, socio-economic data integration, and modeling) which in the past was too difficult or time-consuming to be carried out, especially in many parts of the developing world like Bangladesh. This project integrates satellite imagery data and change detection methods in a GTS environment to explicate the patterns of urban spatial growth in Dhaka. Population density data are also analyzed in the assessment of urban growth using Landscan Data from 2002 (ORNL, 2002).

Two cloud-free Landsat TM images were obtained to examine the growth of urban built-up areas from 1989 to 2000. To avoid cloud interference and summer flooding associated with the monsoon climate, the anniversary images were obtained during the drier winter period (Landsat 5 TM image from February 13, 1989 and a Landsat 7 ETM+ image from February 28, 2000). A post-classification change detection matrix procedure was used to identify the spatial diffusion of urban built-up areas over the 11 year period. The images were processed by the USGS Eros Data Center in Sioux Falls which included geometric, atmospheric, and radiometric correction. Landsat 7 ETM+ data use a definitive ephemeris for geometrically correcting ETM+ data and substantially improves the positional accuracy of the satellite imagery data product over Landsat TM (USGS, 2004). Change detection analysis requires that all images be accurately registered to each other. Therefore the more accurate 2000 Landsat ETM+ scene was used to register the 1989 Landsat TM scene. To aid in the delimitation of Dhaka City, the Oak Ridge National Laboratory 2002 Landscan Global Ambient Population data were used along with a 4-3-2 False Color Composite (FCC) of the Landsat ETM+ scene from 2000. Both images were subset based on this delimited boundary.

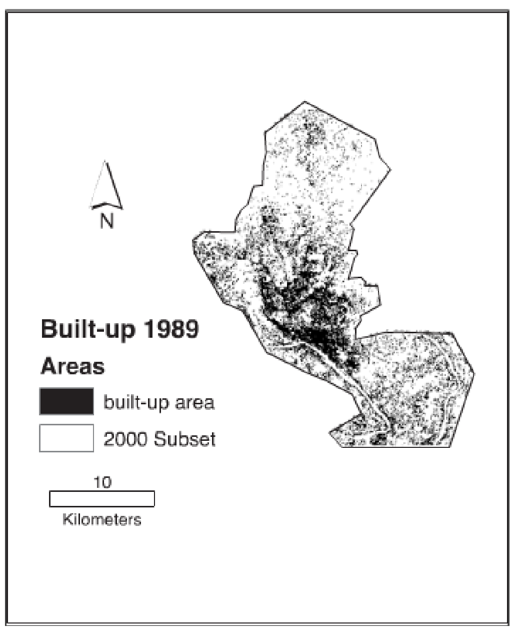
One of the difficulties faced in this study was the definition of what is considered urban. Therefore it is assumed that urban areas are those areas that are built-up, including residential, industrial, commercial, and institutional land that is easily identifiable using Landsat imagery. It is noted that residential settlement, along the periphery of Dhaka may be difficult to identify as these settlements are not as easily identifiable as built-up land. To differentiate between built up areas and those areas that were not built-up (including wetlands, forested areas, agricultural land, and grasslands), an unsupervised ISODATA classification procedure was applied. Initially 30 classes were used to identify urban and non-urban areas. It was immediately evident that some wetlands and sparsely vegetated areas were spectrally similar to some low-density residential urban areas which caused substantial classification errors as determined in a comparison with the Landsat FCC images. Therefore a cluster busting procedure (Jensen, 1996) was employed to differentiate between these areas. After the cluster busting procedure, the images were recoded into urban areas and non-urban areas. Due to a lack of ancillary data available for ground truth, a quantified accuracy assessment was not possible at this time. Through a visual comparison of the FCC composites, the Landsat Pan 15m image, and with the 2002 Landscan data, it was determined that the classifications and change detection procedure provides a reasonable estimate of change.

Along with built-up structures, human activity also plays a role in the urban encroachment of Dhaka into the surrounding non-urban areas. A 2002 ambient population dataset was obtained to provide information about population density. The Landscan Global Population dataset provides an estimate of population density at approximately 1 km^2 spatial resolution. These data are produced for the purposes of estimating ambient populations at risk from natural disasters. These data integrate diurnal movement and travel habits in order to estimate population densities for areas where people work and travel rather than where people sleep, as is the case with traditional census data. Best available census counts are assigned to cells based on probability coefficients related to road proximity, slope, land cover, and nighttime lights. Ideally, a comparison of 2002 Landscan data with previous Landscan data would allow changes in density to be traced over time, but these data are only available back to 2000 and the methods employed to provide the estimates have improved with each subsequent release. Given this, it is recommended that different years of the data are not used for change detection studies (ORNL, 2002). Therefore only the 2002 data were used to assess population density in the classified urban areas.

4. RESULTS AND DISCUSSION

4.1. URBAN CHANGE DETECTION

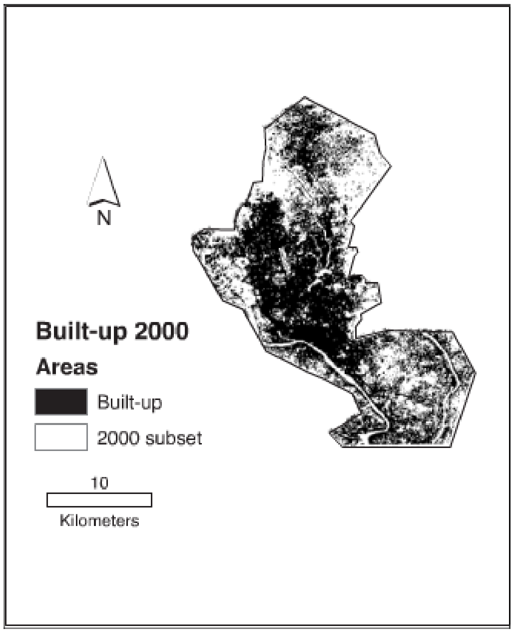
Figures 2 and 3 show the results of the classification procedures and extent of estimated change that occurred between 1989 and 2000. A comparison between Figures 2 and 3 graphically shows the outward urban expansion. The Urban expansion was mainly concentrated in the northern (e.g.,Tongi, Gazipur) part of the city and inner city (Uttora) with some in the southern part of the city. Significant growth also can be visible in Savar area, the eastern part of the city.



Source: Classification of Landsat 5 image for February 13, 1989

Figure 2. Built-Up Areas in Dhaka, 1989

Table 2 shows the land allocations for each year in 1989 and 2000, and Table 3 provides an estimate of the amount of land that remained the same land cover and the amount of land that changed land cover allocations. For the purposes of this paper, which seeks to provide an estimate of the areas that have been encroached upon by urban expansion, the change from non-urban to urban is the measure that provides this estimate. Approximately 12,361 hectares are estimated to have changed to urban built-up between 1989 and 2000 which accounted for 33 percent of the 2000 subset. The 1,785 hectares of change from vegetation to urban were probably mostly a result of classification error. Approximately 23,141 hectares remained unchanged from 1989 to 2000.



Source: Classification of LandSat 7 + ETM image foe February 28, 2000

Figure 3. Built-Up Areas in Dhaka, 2000

Table 2. Urban Land Cover for 1989 and 2000

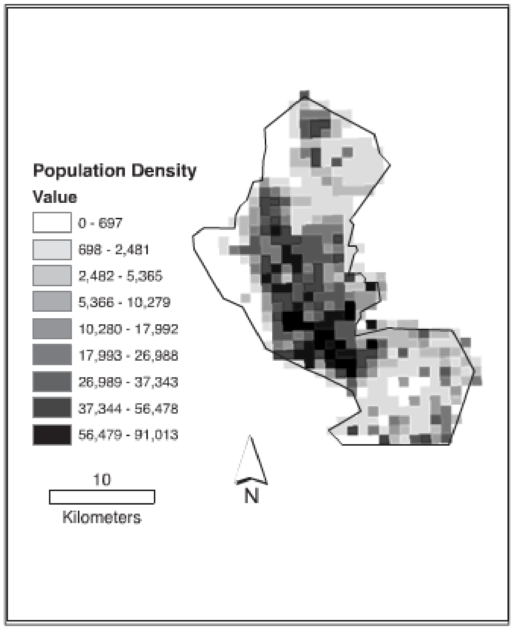
Classes	1989	percent of total area	2000	percent of total area
Urban	9,026	24	19,602	53
Non-urban	28,261	76	17,685	47
Total	37,287	100	37,287	100

Table 3. Urban Land Cover Change for 1989 and 2000

Classes change or unchanged	Area in hectors	percent change
Unchanged in urban area	7,241	19
Urban to non-urban area	1,785	5
Non-urban to Urban area	12,361	33
Unchanged in non-urban area	15,900	43
Total	37,287	100

4.2. MAPPING URBAN DENSITY

Analysis of the Landscan population data indicates that there is a mean population density of 12,600 people per sq. km in our subset. However, this number is an underestimation as it included areas that were classified as non-urban. To account for population density in only urban areas, the Landscan data were masked using the 2000 classified imagery. The results showed that the mean population density for urban areas in 2002 is 18,600 people per sq. km. The maximum population density in Dhaka is 91,000 people per sq. km and these high densities occur in the South Central part of Dhaka. Ln the northern cluster of growth, population densities reach a maximum of around 30,000 people per km^2. Figure 4 provides a map of the spatial distribution of population density for 2002 within the subset area.



Source: Oak Ridge National Laboratory, 2002

Figure 4. Ambient Population Density in Dhaka for 2002

5. CONCLUSION AND FUTURE DIRECTIONS

Despite RAJUK's efforts and governmental promises to limit urban expansion in Dhaka, our remote sensing, GIS and change detection analysis indicate that urban encroachment has occurred throughout the last decade and likely will continue in valuable wetlands, forests, and productive croplands. While our findings are not error-free due to lack of ground truth and remote sensing limitations, this error can be further reduced as socioeconomic data are incorporated into the classification procedure. Based on our primary findings, we want to expand this research to explore the relationship between the quality of urban life and natural environmental changes in Dhaka, in order to suggest ameliorative solutions for the future. The results can be used to begin to develop sustainability models aimed at reducing outward urban expansion. The open space retained today should be conserved and used wisely in the future in order to sustain a growing population. This is why planning within an ecological framework will become the basis and challenge of future urban management issues. To ensure this framework, a policy should be strictly focused on a well-planned strategy that considers both urban development and environmental issues, and a sense of balanced community should be encouraged.

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