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Assessing the Land Cover Change of Accra Using Landsat-TM Data

Lasse Møller-Jensen & Poul Yankson

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The objective of the current study is to produce a land cover map of Accra, Ghana, showing the recent spatial growth in order to assess the nature of this growth and the current spatial development trends. A second purpose is to test the adequacy of Landsat-TM images for urban change detection studies. Comments are made on the rationale for land cover mapping based on digital satellite images. The applied image processing method includes a texture-based classification method, pixel to vector conversion and post processing in a vector-based geographical information system.

Keywords: *Urban land cover, mapping, remote sensing, geographical information systems, Accra, Ghana*

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Most third world cities have witnessed very rapid urbanization since the middle of this century. The rapid growth of urban population has been translated into land use – the extension of urban land uses into the surrounding rural agricultural land. In most cases this process occurs so fast that it almost always overtakes the capacity of planning authorities to deal with what is happening and how to control urban growth so as to avoid the misuse of the scarce land-based resources and environmental degradation.

A major problem or factor in this respect has been a severe lack of up-to-date data or information on land use to guide planning and decision-making. Existing maps are usually old, outdated and, therefore, they cannot be used as an effective information base for planning. Various methods including windshield surveys, census data and aerial photography have traditionally been used for collecting land use and land cover information depending on the degree of details required. Most contemporary urban maps have been developed using large scale aerial photographs. Though there is much merit in this method, aerial photographs have several drawbacks: they are relatively expensive per unit of area; they are produced rather infrequently and they have to be interpreted manually, which for large metropolitan areas is a task of considerable size involving the work of a group of persons for several days or weeks. In recent years the use of satellite imagery for urban land cover studies has become quite popular. The digital form of satellite images makes it possible to apply faster automatic or semi-automatic algorithms, which employ information from all spectral bands at one time. The synoptic view of the urban area and its surrounding areas, which satellite images provide, and the repetitive coverage of the same environment within a short time are important advantages of the system. This makes it possible to gather data at short intervals thus showing changes that have occurred within that environment over the years. This is particularly useful when determining the rate and direction of physical urbanisation.

The Spatial Growth of Accra

Accra Metropolitan Area (AMA) comprises the City of Accra, the Tema Municipality and the adjoining rural Ga-district. With a population of about 1.3 million in 1984 and currently estimated to 1.7 million, AMA is the largest urban agglomeration in Ghana, and the area has experienced very rapid urbanization in the last three decades.

AMA has emerged not only as the political centre of the country but also as industrial, commercial, business, educational and cultural centre. AMA is the primate city of the country with all the problems often connected to large metropolitan areas in developing countries including congestion, urban decay and the inability of the municipal authorities to cope with pressures for the provision of services and utilities. Accra and Tema have developed separately. Accra began as a series of small coastal fishing villages encompassing the area of James Town, Ussher Town and Osu. Other coastal settlements (Labadi, Teshie and Nungua) were added later and so were the new neighbourhoods that developed to the north, west and northeast of the original area of Accra. Tema, on the other hand, was built as a new town – it was developed as an industrial satellite with deep sea port facilities for Accra. The boundary of Tema was formally determined in 1963 and has not changed since. The boundary of Accra city, however, has been revised several times in the past since its first demarcation was done in 1924. It was revised in 1943 and again in 1953 to form the the basis for the Accra Masterplan of 1958. In 1963 the present boundary was established and this still continues to serve as the area of jurisdiction of Accra. Urban development, however, has overtaken this boundary and current urbanization is taking place within the surrounding rural areas. This process of physical expansion of the built-up area is likely to accelerate in the future. At the moment there is little knowledge of how much land has been converted to urban uses and where such a conversion has taken place. The urban map of Accra is outdated having been produced on the basis of 1969 aerial photographies of the city though some efforts have been made recently to revise it. The purpose of this project, therefore, is to attempt to assess this physical growth of Accra using available Landsat-TM data.

Methodology for Urban Assesment

Two Landsat-TM satellite scenes of Accra acquired in 1985 and 1991 covering the same area were available for this study. A sub-image of size 1500×2000 pixels corresponding to 45×60 km was extracted from the original scenes. The general quality of the 1985 image is fine while the 1991 image, due to a slight cloud cover, is less clear, especially in the visible bands (1-3). The images have been geometrically corrected and co-registered pixel by pixel in order to allow the determination of changes between the images. A high accuracy is required to avoid a displacement of point and linear features (e.g. roads), which may result in the identification of false changes.

A three-step image co-registration method has been applied. The first step is to rectify one image to UTM using a number of ground control points (GCPs) and a second order polynomia. Step 2 is to rectify the second image so that it fits exactly onto the original, unrectified first image. This is also done using GCPs and a second order polynomium. By combining the polynomia used in steps 1 and 2, the second image can now be rectified to UTM as step 3.

Urban land cover classes are seldom characterized by a homogeneous spectral signature because they are composed of several cover types each having different reflectance properties. Due to this several different objects occur within an area of a particular land cover, resulting in an overall heterogenous spectral signature (Schowengerdt, 1983). To improve classification of such areas the spatial context of each pixel may be taken into account, i.e. image texture may be incorporated to improve classification accuracy (Møller-Jensen, 1990).

One additional texture band for each image has been generated by computing the local variance for every pixel in the image using a fixed-size moving window. The major problem of a fixed-size window is the boundary effects occuring when the window is located on a boundary between two land cover classes. The resulting errors have been minimized by using only a part of the window in such cases (CHIPS, 1993)

A classification scheme was defined which include 7 urban and non-urban land cover classes. These classes are listed below. A 30x30m pixel resolution is inadequate for the identification of individual buildings (Welch, 1982). The definition of 7 relatively general classes reflects both the small-scale nature of the data source and the focus of this study on areas converted from non-urban to urban use (class 1) rather than the production of a detailed land cover map of urban areas.

1. Areas converted to urban use between 1985 and 1991.
2. Built up 1985 – high density (no vegetation).
3. Built up 1985 – medium density (little or no vegetation).
4. Built up 1985 – medium/low density (moderately vegetated).
5. Vegetated areas. 6. Exposed surfaces.
7. Sea / other water bodies.
8. Unclassified.

To achieve the objectives of this study, a supervised classification using the maximum-likelihood algorithm has been applied. This is based on training areas determined according to the classification scheme defined above. Band 3, 4, 5, 7 and texture band from the two images, in total 10 bands were used in classifying the images. Typical training areas were located in the field and subsequently identified in the images. Image statistics (i.e. mean and standard deviation for each band, covariance/correlation between bands etc.) were computed for each training area. Class separability was estimated by computing the Jeffries-Matusita distances (Niblack, 1985) and by inspecting the within-class image histograms. The classification process was done with and without texture bands to evaluate the effects of incorporating texture. All image processing was done with the CHIPS software (CHIPS, 1993). The output of the process is a digital image in which each pixel is assigned a value (1-8) corresponding to the class label of the ground area it represents.

Outcome of Land Cover Mapping

The initial result was characterized by a number of isolated, single pixels which are mainly the results of mixed pixel effects. An attempt was made to remove some of these pixels by applying a clean-up filter using a 3x3 window. This filter changes the class label of a pixel if the local neighbourhood is considerably dominated by another class. This may, however, increase inaccuracies in some small areas due to boundary effects. The pixel-based land cover map, having a large number of small segments, is rather difficult to reproduce without loss of details if colours are not available. Vector-based geographical information systems (GIS) are more suited for actual map production because they normally contain a number of functions for manipulating shades, lines, characters etc. To take advantage of this, the current land cover class image was converted from pixels to vector polygons using the PC-ArcInfo software (ESRI, 1991). An additional advantage of the vector-GIS is that a database can be connected to the map providing additional information about each polygon for interactive data analyses. The ArcInfo GIS includes a function for eliminating small polygons by removing the longest borderline to any of the neighboring polygons. This function was used to remove areas smaller than 0.25 km2 from the land cover map. The final result, therefore, must be seen as a synthesizing land cover map aimed at highlighting general trends.

The resulting land cover map is shown in fig.1. Some major areas of transition (marked with letters A-C in fig.1) are:

(A) Along the western flank of Accra: the McCarthy Hill area and the Malam-Gbawe area. These are zones of active residential development.

(B) On the north-western flank a strong sector development is occurring outside the Accra City boundary. These areas include New Achimota, Dome, Christian village and Taifa.

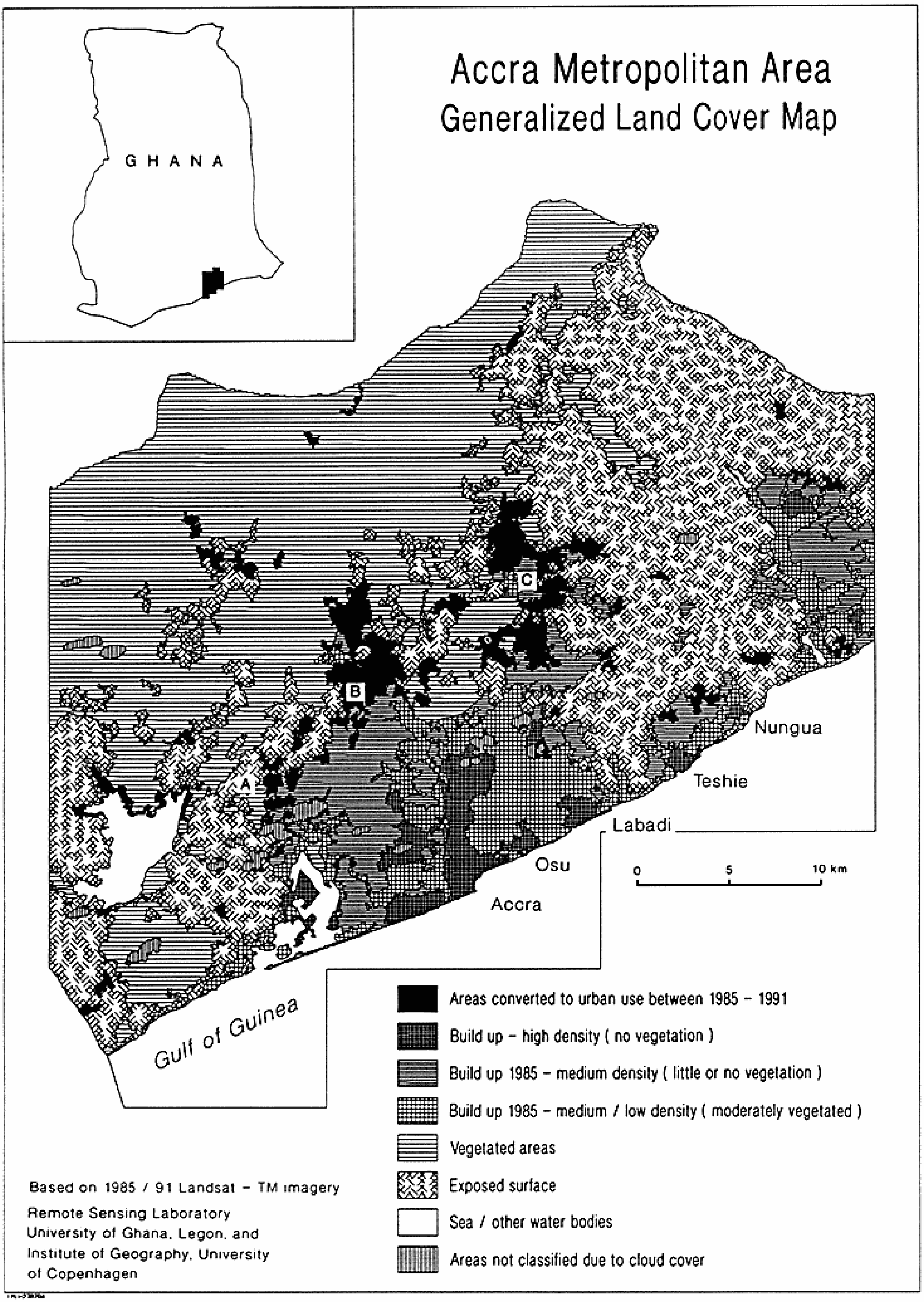
(C) In East Madina a number of residential development satellites are emerging – e.g. Ashaley Botwe New Town, which has been subdivided for residential development.

Most of these areas started to develop in a rather haphazard manner from the middle of the 1970s. The growth map shows that these developments must have been intensified and consolidated from the middle of the 1980s.

Intervening "rural" spaces between the outermost satellite cities and the built up urbanized areas are occupied by various forms of agribusinesses such as poultry farms, ranches, large-scale vegetable farms, open parks or nature reserves. The area between Tema and Accra has been designated a natural preserve for sea-shore birds, golf courses and vegetable gardens, all catering for the interest of city dwellers.

Concluding Remarcs

Satellite image processing in an urban context is faced with some specific problems as a consequence of the heterogeneous nature of the built-up urban areas. This paper has demonstrated how a generalized land cover map may be produced using a relatively simple approach. A few remarks concerning accuracy and suitability of the methods used should be made:


GHANA
Accra Metropolitan Area
Generalized Land Cover Map
A
B
C
Nungua
Teshie
Labadi
Osu
Accra
Gulf of Guinea
0
5
10 km
Areas converted to urban use between 1985 - 1991
Build up - high density (no vegetation)
Build up 1985 - medium density (little or no vegetation)
Build up 1985 - medium / low density (moderately vegetated)
Vegetated areas
Exposed surface
Sea / other water bodies
Areas not classified due to cloud cover
Based on 1985 / 91 Landsat - TM imagery
Remote Sensing Laboratory
University of Ghana, Legon, and
Institute of Geography, University
of Copenhagen

The results of the image classification reflect to a large extent the reality on the ground, i.e. the trend of urban development described above. A large number of newly urbanized areas have been correctly identified. Some areas, which are not urbanized yet but are exposed surfaces, have been misclassified as "areas of urbanization 1985-1991" due to problems of class separability.

The use of texture resulted in some areas – such as those in close vicinity of water bodies – being incorrectly classified as "Areas converted to urban use between 1985 and 1991". A comparison of classification with and without texture bands suggests that better results were achieved without the use of texture in these specific areas. Other factors may, however, have influenced the result. In larger, texturally more homogeneous areas, accuracy was improved, as the textural information reduces incorrect classification of pixels with spectral values that differ significantly from the average of their class.

The current work is carried out on an Intel-based personal computer and requires a relatively powerful CPU and a large disk capacity. Nevertheless, once the computer and software are in place a new up-to-date map may be produced at the cost of acquiring a satellite image. The manual work involves handling and rectification of satellite data, identification of training areas and GIS-supported post processing. Compared with traditional methods for map production, the magnitude of this work is limited, and the possibilities of a continuous monitoring of the urban spatial development have increased.

Fig 1. Accra Metropolitan Area, Generalized Land cover map. (A) McCarthy Hill and Malam-Gbawe area. (B) New Achimota, Dome and Taifa. (C) East Madina.

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