Study of change in Urban Landuse

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Abstract
Land use and land cover change are the result of complex interaction between socio-economic factors and other driving forces. The driving forces in land use change include population growth, technological capacity, economical development, political structures, culture and the environment. Land use and land cover change modelling has becoming an extremely common tool to understand and explore land use change. This report primarily aims to predict the change in urban land use for future scenarios. Next, it evaluates satellite imageries along with analysis techniques for feasibility in urban change detection. A post classification comparison is done to find out the land use change in Kathmandu valley from 1988 to 2001. Based on the land use maps urban land use was found to change from 11% to 19% during the study period. Adeos AVNIR 1997 image and maximum likelihood classification was found to be the best among the tested. Urban prediction was established on a rule-based model along with weightage tables to fit the local conditions. The predictions were done on the vector data of 1992 and overlaid upon the classified urban of 1997 to determine the accuracy of predictions.

***Keywords**: Classification, Land use change, Urban Area prediction, Urban Land use, Urban fringe growth, Urban planning, Satellite imagery assessment, Analysis technique assessment.*

1. Introduction

Land use maps were created in the Survey Department in 1984 from aerial photographs; since then the maps have neither been updated nor re-printed. Technologically, Remote Sensing and GIS provided the best alternative for creating such maps from satellite imagery. At this juncture, the training by AIT, GAC and sponsored by JAXA, was very welcome because it provided the department with the opportunity to learn and explore different methods of analysis for creation of land use maps.

From AIT's point of view, the creation of land use maps was mere manual work requiring very little analytical techniques and adding very little to the produced land use maps. Value added work was suggested and with the joint consent of AIT and SD, the present study "Change in Urban Landuse" was undertaken. This was also within SD's objectives as urban extraction or delineation had always been problematic for topographical base map updating. A model to predict future land use would be helpful for planners. Evaluation of satellite imagery for delineation of landuse units would be extremely helpful to the department for future evaluation of alternatives.

1.2 Study Area

The study area is Kathmandu valley comprising of the Metropolis Kathmandu, the Sub – metropolis Lalitpur, and the municipalities Madhyapur Thimi, Bhaktapur and Kirtipur. For the purposes of study in urban change, the area provides a good mix of rural, urban, vegetated, cultivated, flat-land, steep land, terrace farming and bare-land. In the national topographic database (NTDB), the area covers two Topo sheets of scale 1:25000, 2785 06A and 2785 06B.

1.3 Objectives of the study

- Update land use maps
- Evaluation of satellite imagery and image analysis techniques
- Predict future urban growth scenarios

1.4 Methodology

Images of the study area were geo-corrected and enhanced. Supervised and unsupervised classifications were done on these images to obtain land use maps of chosen land use classes. Fieldwork aided ground truthing and provided input for supervised classification and accuracy assessment. Further analysis, such as PCA and NDVI were done to evaluate their feasibility in extracting urban land class and to perform a comparative analysis. Analysis was also done for assessing viability of urban extraction from imagery of different sensors. Upon extraction of urban extents for the available images of various periods, urban growth was charted mathematically and factors/variables affecting urban growth identified. After evaluation of the primary predictor model, snapshots of predicted urban were created for various baseline years like 2005, 2010 etc. An alternative method of urban prediction was proposed.

2 Satellite images

The satellite images used were TM 1988, Adeos AVNIR 1997 and ETM+ 2001. Similar corrections, classifications and analytical techniques were applied on all of them. Bands 1,2,3 & 4 were taken for all of them to obtain similarity in results.

2.1 Land use classes

The land use classes for the present study was chosen according to Level 1 of the European Corine Land-cover Nomenclature. The classes are Artificial, Agriculture, Forest and Wetland. Due to low separibility in the spectral bands, mixed land characteristics, relatively low spectral and spatial resolutions Level1 was adopted for the study.

2.2 Geo-correction & Image enhancement

Images collected from satellite sensors must be corrected geometrically before they can be used with other images that have been geometrically corrected. In our study geometric correction was done to the subset images with easily identifiable GCP tie points on both the satellite image and the vector data of the study area. Image enhancement is the process of making an image more interpretable for a particular application. Enhancement can make important features of raw, remotely sensed data more interpretable to the human eye.

3. Image Analysis

3.1 Maximum Likelihood Classification

Classification is the process of sorting pixels into a finite number of individual classes, or categories of data, based on their data file values. If a pixel satisfies a certain set of criteria, the pixel is assigned to the class that corresponds to those criteria. [Erdas Imagine Tour Guide].

<u>Discussion</u>: The result of this classification was satisfactory for all the images.

3.2 Principal Component Analysis (PCA)

Principal Component Analysis (PCA) is often used as a method of data compression. It allows redundant data to be compacted into fewer bands—that is, the dimensionality of the data is reduced. The bands of PCA data are non-correlated and independent, and are often more interpretable than the source data (Jensen 1996; Faust 1989; cited in Erdas Imagine Field Guide).

Discussion: While visual interpretation provided a fair overview of the urban areas, it was considered to be inadequate for any form of extraction of information either automated or otherwise.

3.3 NDVI

Healthy green vegetation has low response in the red band and a high response in the near-infrared band of a satellite image. Subtracting the red band from the near infrared band should produce higher values for vegetated areas than for areas dominated by concrete, soil or water. This difference can then be divided by the sum of the band responses to normalize the value so that it may be less sensitive to particular lighting conditions. $NDVI = (NIR - R) / (NIR + R)$

Where NIR is the reflectance in the near-infrared band and R is the reflectance in red visible band.

Discussion: Classification of NDVI gave a nice picture of the urban and forests for some of the images, but it failed to fit to the general trend of growth.

3.4 IHS Merge (Pan sharpening)

IHS Merge was applied to the ETM 2001 image and the resulting image provided good visual perception for the urban areas.

Discussion: The IHS Merged image provided visually good distinction between urban areas (blue), agriculture (red), vegetation (green) and bare soil (brown) but there was no verification of numerical values to corroborate the visual impact. The classification results were unsatisfactory.

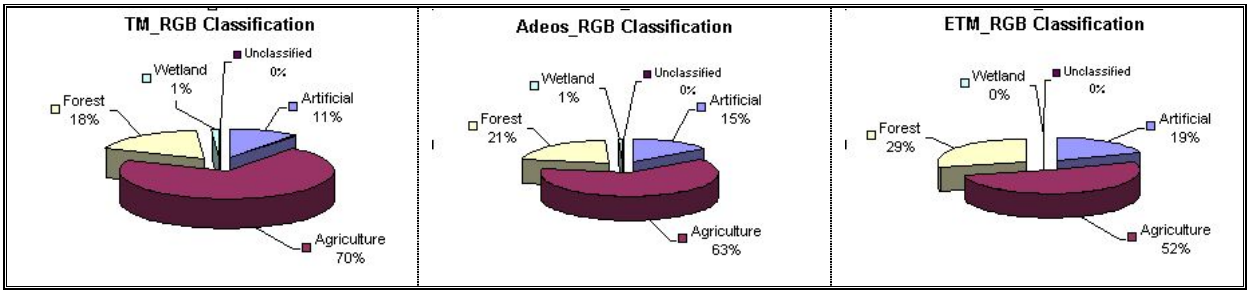
3.5 Normalisation

Sensor look angle and local topographic effects affect pixel albedo (the ratio of the radiation reflected from an object, to the total amount incident upon it, for a particular portion of the spectrum). For airborne sensors, this look angle effect can be large across a scene. It is less pronounced for satellite sensors. This calculation shifts each (pixel) spectrum to the same overall average brightness. Correctly applied, this normalization algorithm helps remove albedo variations and topographic effects. [Erdas Imagine Field Guide]

Discussion: This resulted in certain areas being highlighted in the visual inspection, but the result of the classification was very bad since 50 – 75 % of the pixels remained unclassified.

3.6 Classification accuracy

For the accuracy assessment of the maximum likelihood classification 256 random points were generated and the classification reference values assigned from the ortho-photo and IKONOS image of Kathmandu. The accuracy obtained from maximum likelihood classification for TM 1998 was 92.5%, so it was the best among the 13 analyses for the three images.



Comparison of Landuse units from Classification

Discussion: The land use maps have been derived from classification of satellite imagery of various periods. *Agriculture*: It has shown a decrease of 10.04% in the first period and 18.24% in the second period. The first period is of 11 years and the second is of 5 years only. Overall, the agriculture land use decreased from 70.7% to 52% over the whole study period.

Artificial: Urbanisation has shown a rapid increase at the cost of agricultural lands and has increased from 10.7% to 19.2% over the whole period. Phase-wise, it has increased at a rate of 36.45% in the first phase and 31.51% in the second phase.

Forest: It has increased from 17.7% in 1988 to 28.7%. The increase percentages for the two stages are 18.08% and 37.32% respectively.

4. Urban Prediction

Although urban growth is perceived as necessary for a sustainable economy, uncontrolled or sprawling urban growth causes various problems. Not only does urban sprawl rapidly consume precious rural land resources at the urban fringe, but it also results in landscape alteration, environmental pollution, traffic congestion, infrastructure pressure, rising taxes and neighbourhood conflicts. [Allen, Lu]

Urban growth prediction is a complex science. Successful dynamic model is yet to be built because urban growth commonly shows irregular spatio-temporal patterns, has many indefinable and un-quantifiable variables, and is governed by internal forces and external market pressures.

There exist a number of urban growth models. One method is the Rule-based method developed by Allen and Lu, which is considered to be highly suitable for a spatio-temporal urban growth model for this study.

4.1 Rules guiding urbanization

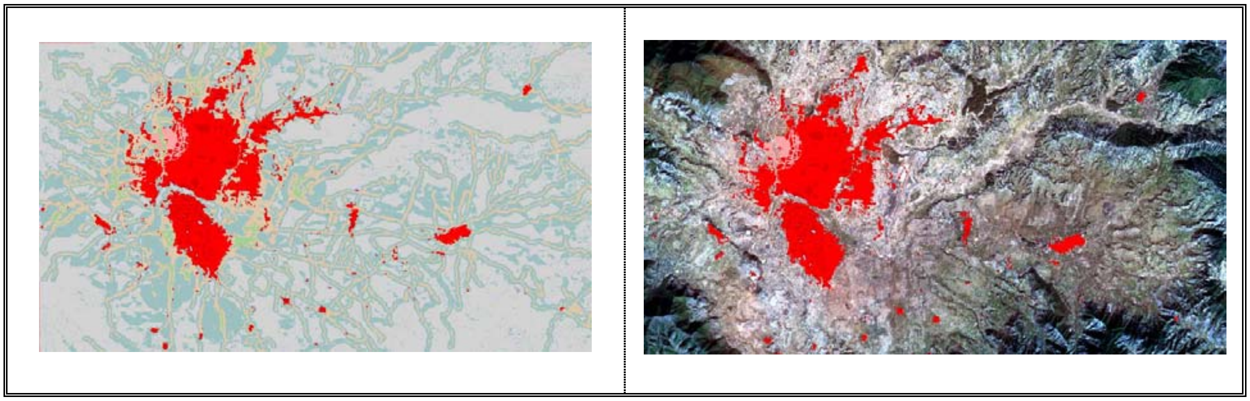
Physical suitability: Rules that reflect the onsite relationship between land properties and urban development. (Land properties, Landscape)

Access Oriented: Rules that manifest the effects of infrastructure and other factors towards urban transition. (Infrastructure, Facilities, Utilities, Services)

Market oriented: Rules for identifying factors that stimulate faster growth in comparison to other areas. (Population, Employment, Housing, Land prices)

Urban-to-Urban: This rule determines that urbanisation is a unidirectional process, existing urban will remain urban and thus an exclusion mask can be created. Further use of the existing urban is to determine the increased affinity towards urbanisation and its use as a superposing variable.

Policy: This rule guarantees that some land will be protected from urbanisation while some land will be forced towards urbanisation. (Constraints, Forced)



High growth probability and final prediction

For this study, the rule-based model predicts the urban growth on the basis of probabilities of growth of various regions through weighting, assigning suitability scores and creation of exclusion and urban gravity masks and the subsequent mapping of chronologically ordered growth through reclassification of high probability areas.

Results and discussions

From the results of the urban prediction, the rule-based model was verified and found to give reliable results. For creating the exclusion mask, buffer zones for road, rivers, open spaces, high-tension lines (utilities), etc. based on actual figures were used. Protected spaces like forests, and hydro were excluded because they are secluded from urbanisation. Based on rules, appropriate layers were used to create the exclusion mask. The remaining area was used for the urban gravity.

High probability areas were derived from the urban gravity and these were evaluated with urban areas derived from classification. The accuracy obtained was 85%. The accuracy was evaluated for the predicted area for vector of 1992 against the urban extents of 1997.

5. Conclusion

This study was undertaken with mainly two objectives. (A). One of the objectives of the Survey Department was to learn to update the landuse maps it had produced more than 20 years back. (B). Study of change in urban land use was undertaken to utilise the land use maps obtained, for further applications. The study addressed it's objectives. It started with the identification and selection of the land use classes for the study and the basis for it, followed by classifications of images and the results of the analysis of sensors and techniques. Urban extents were mapped, prediction model defined and the results analysed. A model for urban prediction was also proposed. These derived urban areas were then tested on the existing ones and the results were found to be satisfactory.

Thirteen image analysis techniques were evaluated for each of the three satellite images, Landsat TM 1988, Adeos 1997 and Landsat ETM+ 2001. Accuracy assessments were done and the overall accuracy, kappa statistics, producer' accuracy and user's accuracy were analysed. The maximum overall accuracy obtained was 92% for the Landsat TM 1988. The classified images were then studied from urban extraction point of view. Each classification technique and each image were then placed on a table with values based on their usefulness towards urban extraction. The results showed that Adeos with a spatial resolution of 18m was the best alternative among the three images and maximum likelihood classification was the best analysis technique among the thirteen tested.

Urban growth was based upon a rule-based model, which projected most of the factors of the rules to a format that could be integrated into a GIS. From the five rules, namely, Physical suitability, Access oriented, Market oriented, Urban-to-urban and Policy, an exclusion mask and a gravity layer was created to calculate the high probability of growth in certain areas. From the probability map, the values were reclassified to rescale the value to appropriate time scale and ranges. This gave the predicted urban for various periods. The 1997 predicted urban area from 1992 vector data was tested against the urban extents derived from Adeos 1997. The accuracy of prediction was found to be 85%. However, the weightage table need to be recalibrated for more accurate projection of existing conditions or factors, and for further prediction.

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