THE CONTRIBUTION OF GIS AND REMOTE SENSING IN URBAN LAND USE NEGOTIATION IN DEVELOPING COUNTRIES

Faith KARANJA*and Peter LOHMANN**
University of Hannover
Institute of Photogrammetry and Engineering Surveys(IPI)
*karanja@ipi.uni-hannover.de
**lohmann@ipi.uni-hannover.de

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ABSTRACT

Most of the studies related to urban environments in developing countries focus mainly on particular aspects e.g. communication, residential, vegetated areas, etc. However, planners who are concerned about urban space management are also interested in the distribution and the change extent of the three main spatial domains namely developed, transition and reserved areas. This information facilitates subsequent land use negotiation processes. In this paper, standard classification procedures have been employed to extract this information from remotely sensed imagery such as the ones delivered by the new high resolution satellites, specifically from colour aerial photographs from 1995 and 1998 resampled to a ground resolution of 5m and Landsat TM from 1995. Postclassification analysis revealed comparable results for the 1995 datasets, whereas land use changes were evaluated by comparing the 1995 and 1998 classified images.

1. INTRODUCTION

The present status in developing countries depicts challenges for the urban planners specifically due to rapid urban extensions and development, lack of reliable information for decision making due to the heterogeneity of the data sources, and lack of tools and human resources [Paulsson,1992]. Consequently, they mainly rely on ad hoc efforts or project specific activities. This has resulted in haphazard growth patterns, irregular land allocation, environmental degradation, political and social conflicts and economic inefficiency.

Generally, the architecture of an urban environment is characterized by diverse and complex array of land uses. This can be classified into three main categories namely: developed, transition, and reserved lands. Developed land comprises of residential, commercial, industrial, infrastructure,etc, transition land can be defined as that land that has the capacity to be developed for urban purposes without causing environmenal hazards. It therefore consists of land under development and serviced vacant land. On the other hand reserved land is land set aside for a particular purpose e.g. national parks, recreational, cemetery, forest reserves, etc. This set up varies from one place to another, and depends largely on the level and type of urbanization. However, in developing countries the tendency has been to convert land within serviced areas to remunerative use. But, if the supply of social facilities is to follow demand there is an implied necessity to keep some land undeveloped to accomodate facilities as they are required [Amos, 1993]. Therefore, the significance of information giving an indication on the extent and distribution of the three urban spatial domains as an input into a land use negotiation system can not be underestimated. Moreover, this will enable clear policies on land utilization to be established by promoting participation and cooperation among the stakeholders.

In an urban context base maps are normally in the range of 1:500 to 1:2,500 scales i.e. large scale maps which is only achievable through aerial photography or terrestrial techniques. On the other hand, maps applicable to local government for planning purposes which are in the scale ranges of 1:10,000 to 1:50,000 means that satellite images can be considered for both the creation of base maps and updating purposes. For instance Spot images have been used to generate master plans (they basically define the location of development and protected areas, i.e. specifically determine land use in general considering economic, demographic and social development forcasts at scales of 1:50,000 or 1:25,000) [GDTA, 1995]. Investigations into the use of high resolution satellite data for mapping purposes are contained e.g. in Konecny [1999].

2. BACKGROUND

Land use information is a vital input for most urban applications which include infrastructure, demograghy, housing typology, monitoring hazard-prone areas, space management, watershed analysis, etc. However, in order to manage urban space, current information on the extent of developed, transition and reserved areas would facilitate subsequent land use negotiations, thus enhancing transparency and accountability of urban land usage. In this regard, the methodology employed in the extraction of this information from satellite imagery, is dependent on the availability of resources i.e.data sets and software and in general the cost implications on the urban planning departments budget. Consequently, methodologies range from conventional classification procedures e.g. Haara et al [1998], Gorham [1998], Sunar et al [1996], Heipke and Straub [1999] to approches incorporating GIS layers which include interative GIS querying, knowledge-based GIS models, post-classification sorting and Neural Networks and Expert systems as described in some studies e.g. [Cappellini et al. 1995, Pakzad et al, 1997, etc]. In the GIS related approaches the key to success lies in determining an image and the GIS inputs that will deliver the most optimal information for a given land use type in a given urban setting [Coulter, et al., 1999]. Moreover, multitemporal analysis facilitate changes to be detected and delineated. In this regard, change detection techniques e.g. image overlay, image differencing, image ratioing, principal component analysis and postclassification analysis exist as described in e.g. [Macleod and Congalton, 1998, and Jürgens, 1999]. However, the choice of the applied method is dependent on the specific application and minimum mapping unit i.e the degree of details being mapped. Nevertheless, studies have revealed that most changed features in urban areas are equally detectable at 1, 5 and 10m spatial resolutions [Coulter, et al., 1997]. In general, resolution requirements for purposes of detecting objects from satellite imagery are contained in [Konecny, 1999].

3. METHOD

Standard classification procedures namely unsupervised and supervised classification continue to be applied in the generation of land use classes. Unsupervised classification is based on grouping pixels into clusters, which depend on the algorithm applied. Various algorithms exist for instance, simple one pass clustering, fuzzy C means, K means and Isodata classification. They employ different criteria and therefore differ in output and computational speed. On the other hand supervised classification involves first establishing training sets which are subsequently used to assign image pixels to the training samples that best fits the corresponding data. Similarly different algorithms exist, for instance minimum distance, maximum likelihood, stepwise linear classification, and Mahalanobis distance.

In this study, a hybrid approach incorporating both unsupervised and supervised classification has been employed in which the ISODATA algorithm was used to generate 50 clusters which were then analyzed and reduced interactively through merging and deleting resulting in between 10-15 best representative classes. These were used as input in the supervised Maximum Likelihood Classification. The 10-15 classes were further assigned to the three urban spatial domains namely developed, reserved and transition which are of main interest in this study. The definition adopted here was such that developed areas are comprised of industrial, residential, parking areas and infrastructure; reserved areas consisted of farmland and green land, water bodies and forest reserves whereas, the remaining areas were classified as transition areas. Subsequent analysis was based on these three classes.

A 1995 1:25,000 topographic map was used as ground truth to test the accuracy of the 1995 datasets. The 1998 classified dataset was assessed using the 1998 colour aerial photograph as the ground truth source.

Postclassification, image overlay and image differencing change detection techniques were employed. Postclassification change detection involved computing the area covered by each of the three land use classes from the three data sources independently and a comparison made first of the two 1995 data sets and then between the 1995 and 1998 data sets from the RGB images. Image overlay based on the classification of the 1995 and 1998 RGB images involved analysing the temporal extent of the classes separately with the RGB 1995 as the background image. Specifically areas classified as developed in 1995, 1998 and in both years i.e. areas of no change are highlighted and this was repeated for the other two classes namely transition and reserved. On the other hand image differencing using the 1995 and 1998 simulated images were employed based on the intensity bands generated by transforming the RGB data sets into IHS colour space.

4. EXPERIMENT

The methodology outlined in section 3 was tested using simulated imagery from scanned colour aerial photographs at a scale of 1:37000 for the year 1995 and 1:40000 for the 1998 and Landsat TM. Simulation involved first co-registration of the three data sets to facilitate combinations and comparisons. Then the scanned colour aerial photographs from June 1995(RGB95) and May 1998(RGB98) were resampled to a spatial resolution of 5m in order to come close to the new high resolution imagery such as Ikonos, Orbview and Quickbird. The resampled RGB 95 was transformed into Intensity Hue Saturation colour space from where the Intensity was extracted and merged with the May1995 Landsat TM imagery using the principal components technique. It is therefore from these data sets that the three main urban spatial domains namely developed, transition and reserved areas were delineated.

The fast changing Expo2000 region in Hannover, Germany was used as the test area, due to problems associated in obtaining data for developing countries.

5. RESULTS

94% overall accuracy of the multispectral classification was attained for both 1995 datasets, whereas the 1998 dataset yielded 84%.

Figures 1, 2, and 3 show the simulated images from the colour aerial photographs RGB 95, Intensity-Landsat TM 95 and RGB 98 respectively. An example of an area that has been converted from reserved in both the 1995 datasets has been highlighted in the 1998 image.

Similarly, figures 4,5 and 6 show the classification results from the simulated images namely RGB 95, Intensity-TM95 and RGB 98 respectively. The three main spatial domains, i.e. developed, transition and reserved are depicted. Two examples of areas classified as reserved in the 1995 images and converted to developed in 1998 have been highlighted.

Figures 7.1 and 7.2 show the comparison between the 1995 data sets i.e. the difference image and area coverages respectively. The results are quite comparable. The extent in temporal variation and distribution in developed, reserved and transition areas based on the classification results from the RGB data sets (1995 and 1998) with the 1995 as the background are depicted in the image overlays namely 8.1a, 8.1b, and 8.1c respectively whereas figure 8.2 shows the corresponding statistical area coverages. Changes based on intensity from the RGB data sets are highlighted in figure 9 where 9b is a filtered version of 9a. Further, problems encountered in the delineation of the three classes and change detection are depicted in figure 10. The changes highlighted in the classes is characteristic of the extensive developments taking place in preparation for the EXPO2000 which will be held from June to October 2000 in Hanover, Germany.

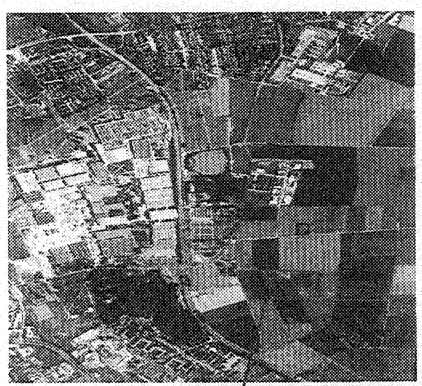


Fig. 1: Imagery from RGB 95

Fig. 2: Imagery from Intensity-TM 95 data merge

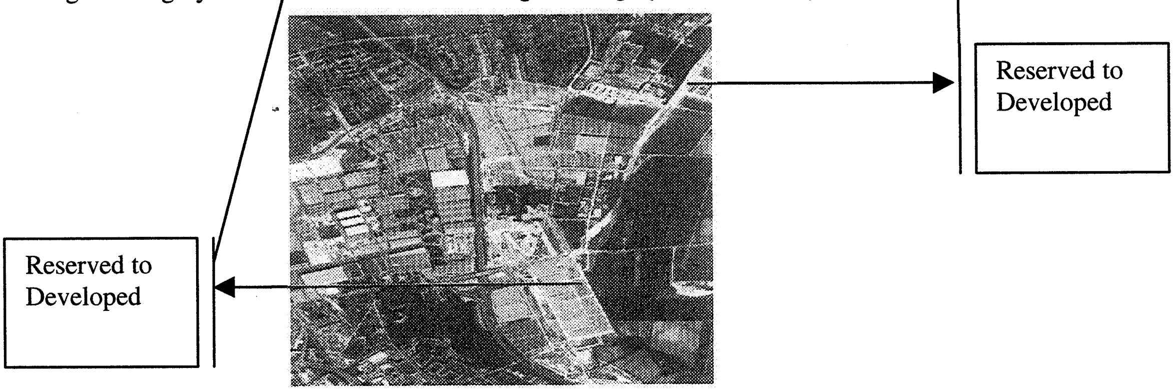


Fig. 3: Imagery from RGB 98

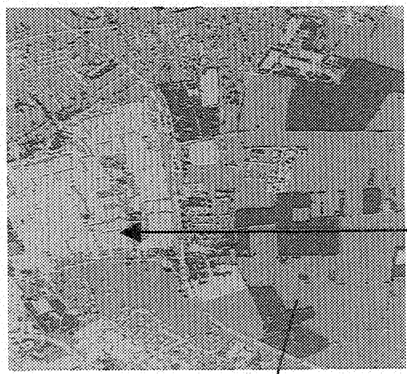


Fig. 4: Classification results from RGB95

Fig. 5: Classification results from the Intensity-TM95

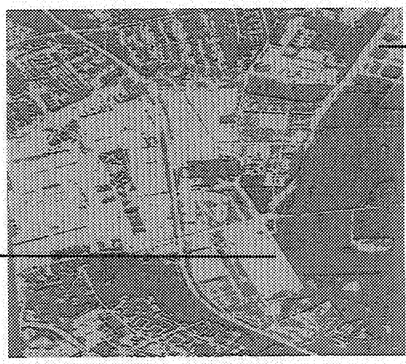


Fig: 6: Classification results from RGB 98

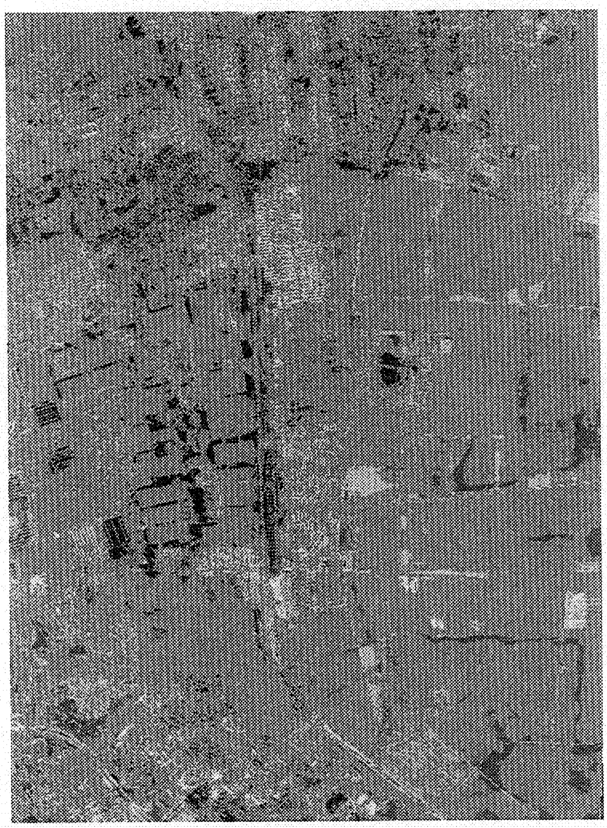


Fig. 7.1. RGB-TM 95 image difference

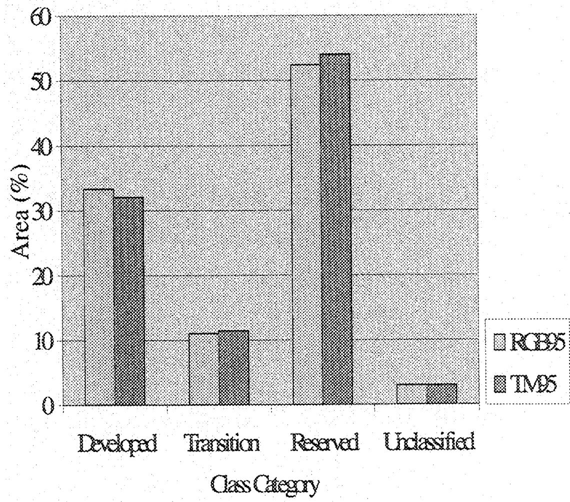
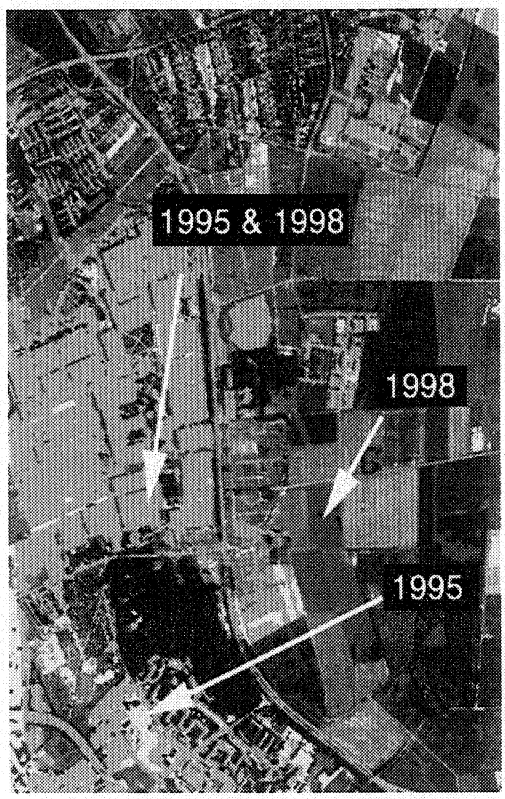
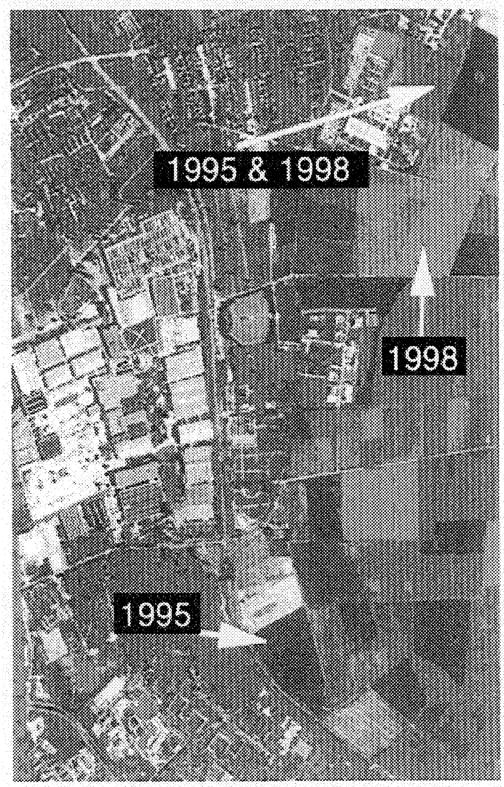


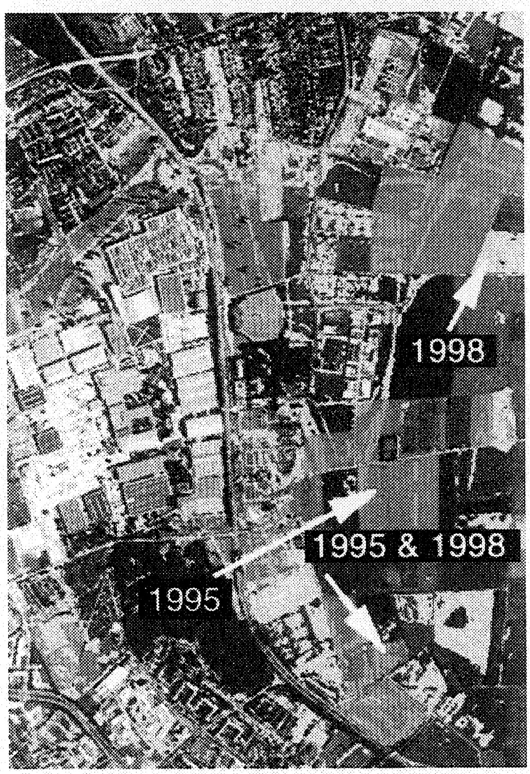
Fig. 7.2. Area(%) comparisons from RGB-TM95



Yellow: only in 1995; orange: in 1995and 1998; Red: only in 1998.
Fig. 8.1a. Temporal variations in developed areas



Red. Only in 1995: Dark green: in 1995 and 1998; Green: only in 1998.
Fig. 8.1b. Temporal variations in reserved areas



Red: only in 1995; Orange: in 1995 and 1998
Yellow: only in 1998
Fig. 8.1c. Temporal variations in transitional areas.

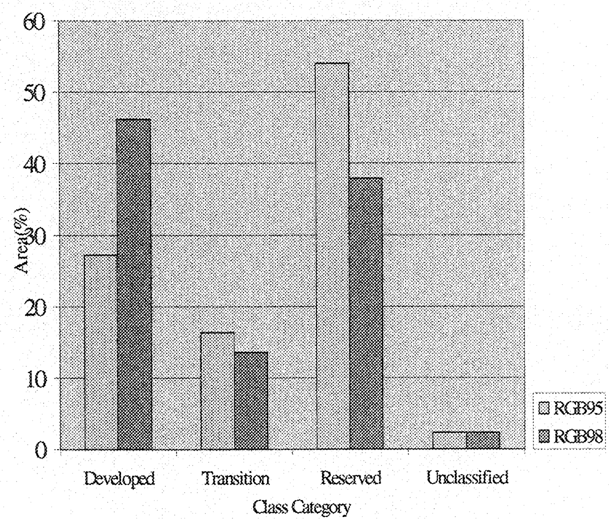
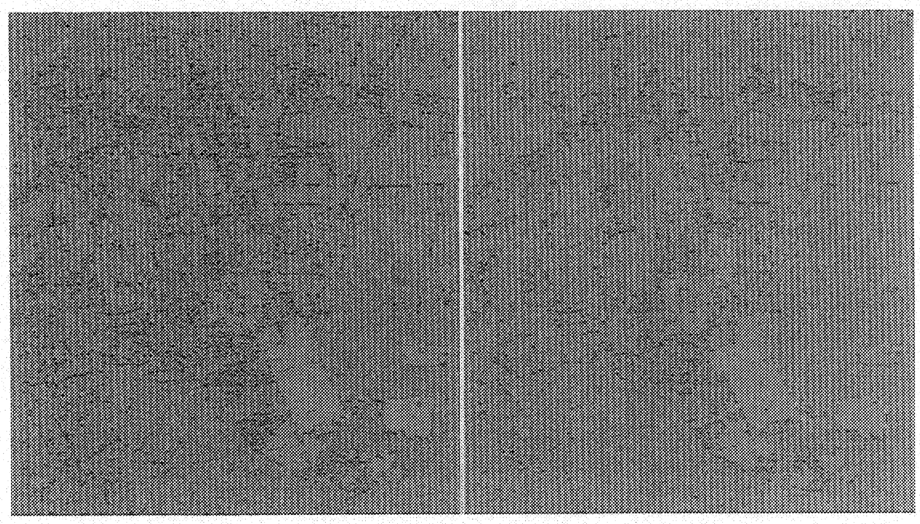


Fig.8.2.Area(%) comparisons from RGB95-98



Red: changed areas Blue: no change
Fig. 9. Differences in intensities a) before filtering b) after filtering

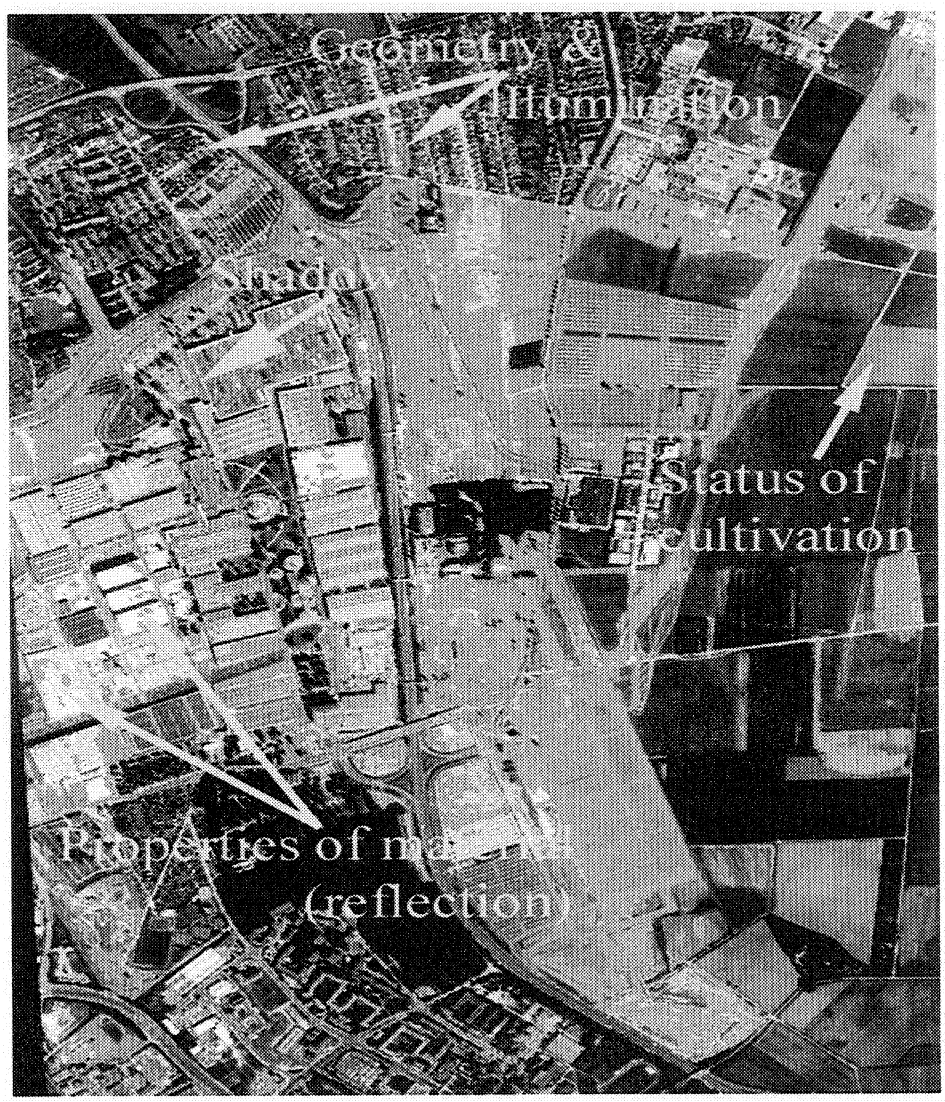


Fig. 10. Image Overlay highlighting changed areas and associated problems
Red: Changed areas between 1995 and 1998

6. DISCUSSION

The results presented here show in general the status and the changes in the extent of areas defined as developed, transition and reserved. The definitions adopted are aimed at encompassing all the aspects of an urban environment so as to facilitate a better diagnostic of the urban dynamics. The current status and temporal changes associated with the three urban spatial domains serve as important inputs in subsequent land use negotiation. The success of automatic extraction of this information from remotely sensed data relies on how well these three domains can be spectrally distinguished and delineated. However, radiometric and geometric problems due to differences in illumination and perspective result in variance inconsistencies whereby similar features exhibit different spectral differences and vice versa. Also cultivation status and shadowing further complicate automatic features delineation procedures These problems encountered are highlighted in figure 10. In this regard support of GIS information and interactive aggregation procedures can not be underestimated to compliment automatic classification procedures.

7. CONCLUSION

Financial constraints associated with data have always been a bottleneck for urban planners especially in developing countries, who require up-to-date information to facilitate land use negotiations. This study has demonstrated that remote sensing data such as those delivered from the new high resolution satellites can be used successfully to provide information on the extent and distribution of the three main urban spatial domains. Moreover, integration of multispectral data with high resolution enhances the classification accuracy. However, the success of this method relies on clear definition of these classes to avoid misclassification, especially between transition and reserved areas. Consequently, prior knowledge about the area under investigation and GIS information e.g. locational oriented planning information, that define the preset land use type would be highly advantageous. Also the architecture of an urban environment in developing countries is different from that in developed countries and therefore the definitions necessitate tailoring depending on the region of application.

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