Updating urban land use data in Geographic Information System using Landsat images

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Abstract

In developing a Geographic Information System, the major problem is to update large volume of data in an efficient way. On the other hand remotely sensed Landsat TM data are rich in geographic information and can potentially be acquired on regular basis. Therefore, the integration of these two technologies can be conceived as a vital component of a relevant techonology for GIS application in the future.
In this paper a new approach for updating GIS data using Landsat TM data is described. The methodology is based on combining GIS and image processing techniques. The results indicate that it should be cautious in updating large scale land use map by Landsat TM and the classification accuracy can be improved only under certain conditions. Moreover, it leads to a concept of "multi-stage" investigation with regard to the method of updating GIS data.

Introduction

GIS are popularly applied in agencies for planning and management in Japan. The need for up-to-date land use map covering a specific region in due time is increased. To meet this requirement for a given time constraint is difficutlt. It can be facilitated, if the existing land use map in GIS data base and the new Landsat land cover can be utilized together, to produce a new land use map. But, the problems associated with an attempt to conjoin the two technologies, GIS and Remote Sensing, as well as the applicability of such a procedure is relatively unknown. The trends in GIS technology with respect to input and output devices, memory devices, and also the softwares development are well described. ARC/INFO (ESRI, USA) is referred to as one of the representative vector based GIS softwares of advanced computer technology. On the other hand, the trends in Remote Sensing technology are also evident in terms of both popular image processing systems and the image processing techniques. ERDAS (ERDAS CO., USA) Image and GIS processing software is one of commercially available raster based systems and can be interfaced with ARC/INFO. Both these two systems are utilized in this study.

Even though the trends in each individual field, i.e. GIS and Remote Sensing can be referenced to the corresponding literatures, the studies on integration of the two technologies are still desirable. A series of problems will affect the results in such an attempt. By keeping usual accuracies in rectification and classification, the study stresses the problems relating to land use and land cover, reliability and the map scales. The discussions are based on the results from a case study in an urban area.

Data and study area

Land use data from 1978 and Landsat TM from 1984 are used to procduce the new land use map 1984. The reliability is studied by comparing the results with the land use data maps of scale 1:2500 which are compiled by a photo-interpretation of about 1:10000 scale aerophotos. The reference map for checking the results is one year older than the scanning date of Landsat TM. The changes during this one year are therefore observed visually on the monitor by using aerial photopraphs of two benchmark years (1977, 1984).

The study area covers an area of about 4300 ha. in North Eastern part of Yokohama City. It is the capital of Kanagawa Prefecture and has second largest population after Tokyo in Japan. The study area is Kohoku-ku, a Ward in Yokohama City where the New-Town plan is in progress. Urban land use changes are active there due to the constructions in this project. The Landsat subcene for the case study area is comprised of about 300 pixels in rows and columns of 30m resolution.

Land use categories

The problems relating to land use and land cover begin with the difficulty in selection of categories for analysis. GIS land use map covering the study area is encoded in 34 categories conformed to the classification scheme of the City-Administration. By an analysis of Landsat TM for all 34 categories it was found that many areas of different categories in builtup areas are too small for selection of significant training areas. The categories should therefore be combined in a relevant way.

Table 1: Landsat TM false colour by land use type

	Land use / Color pattern	Builtup area	Agri-culture	Forests	Vacant land	City parks
1	Red			○		○
2	Light red		○			
3	Reddish gray		○		○	
4	Gray	○				
5	Dark gray	○				
6	Dark gray-Black	○				
7	White-Light blue	○	○		○	○
8	Light blue-Blue	○	○		○	
9	Yellowish blue				○	

For this purpose, land use map 1983 is compared visually with the Landsat TM false colour image of 1984 (Bands 2,3 and 4). The results are summarized in Table 1. It illustrates several land cover types within the areas of a given land use category. But, it also indicates that the separation of builtup area into two categories may be possible. The land uses for this study is thereafter defined in eight categories as in Table 2.

Table 2: Land use categories for analysis

	Land use category	Process
1	Residential areas	for classification
2	Nonresidential builtup areas	
3	Agriculture	
4	Forests	
5	Vacant Land	
6	City Parks	Overlay land use map
7	Roads	
8	River and water bodies	

The changes in categories 6 through 8 for urban areas are considered to be minimum. Therefore, these areas are excluded from the analysis by masking. The results referred to in the remainder part are based on categories 1 through 5.

An approach to the determination of land use changes

Given the land use map of base year (1978) and the Landsat TM of current year (1984) which is classified in accordance with the land use categories, changes can be computed. These changes however, will include the actual land use changes during the years from (1978) to (1984) as well as the errors caused by various sources. This consideration is depicted in Figure 1 referring to an area of land use map category - vacant land.

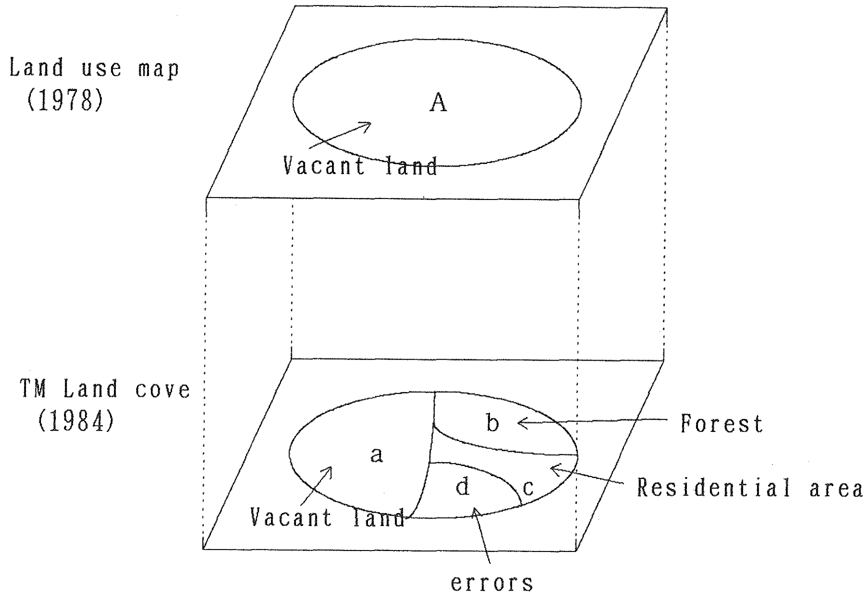

Fig. 1 Comparison between land use and land cover

If, A : Land use area of a given category (e.g. vacant land) on map (1978),
a : Land use area of the same category (vacant land) on land cover(1984),
b : Area of such category (e.g. Forest) which correctly represents the actual land cover (grass, etc.) but, it is assigned to the other category of land use (e.g. vacant land),
c : Actual land use changes during the years from (1978) to (1984), and
d : Remaining errors

then, the changes (A-a) detected by Landsat TM are:

$$A - a = b + c + d$$

Assuming that areas (b) of category forest in vacant land for example, can be computed, the land use changes with the remaining errors can be determined:

$$c + e = A - a - d$$

Landsat TM of 1984 is rectified by an estimated accuracy of half a pixel, and classified by Maximum-Likelihood method in five categories mentioned before. The classification accuracy as it was observed on the confussion matrix is about 60-72 %. Changes are then computed by an overlay of this land cover with the land use map 1978. These changes are checked by land use map 1978 and 1983 as well as aerial photographs of 1977 and 1984.

The overall agreement of the computed changes with the actual land use changes is 69.2%. Better result can be expected by higher accuracy of the classification.

By an in-depth study of the errors it was found that some of the built-up areas in 1978 become forest in 1984 and these are computed as land use changes in the above concept. Analog "changes" are also computed in the areas of vacant land and agricultural land. They are defined as "errors" in error-analysis. These areas are displayed on the land use map in background and compared with the corresponding areas on aerial photographs of 1977 and 1984. The above land cover forest could be verified as green areas (grass or trees) on photos, and no changes are significant during the two dates. Futher land covers (e.g. vacant land) in other land use areas (e,g, residential areas) are also found out but, it shows the actual changes too. In cases where changes may not have occourred, the areas (b) of certain land covers can be modified to the corresponding land use. The conditions which could be found through the test are given in Table 3. By applying these, the results can be improved by nearly 12%.

Table 3: Conditions for modification of land covers

Land Use 1978	Land Cover 1984	Modified Land Cover 1984
Builtup area	Agriculture	Builtup area
	Forest	
Vacant land	Forest	Vacant land
Agriculture	Forest	Agriculture

Vector-raster conversion errors

The errors in vector-raster conversion are investigated for each category by vector-raster-vector conversion approach using the land use map 1978. These are about 1% (except roads). Futher, the same areas are compared with the land use map 1983 and changes are computed. These changes are again observed in both vector and raster format. The resulting discrepancies ranges from 3 to 15% among land use classes. It implies that the changes are more sensitive to the vector-raster conversion errors. A considerably high percentage of errors in the latter case might be mainly caused by the mixed pixels.

The errors discussed here are examined on a map scale of 1:2500. But, the grid cell size of 30m will be 0.3mm on a map of scale 1:100000. It is already closed to the usual accuracy in mapping. Thus, the above errors may no more be significant at this and the smaller map scales.

Discussion

The fact that a regular updating period for a land use map is relatively long (e.g., five years) and the land use changes in urban areas occourred rapidly during these years, explain the need for updated geographic information in shorter time intervals. In case where a GIS data base exists, an approach with the integration of GIS and Landsat TM seems to be appropriate to fullfil this need in a given time constraint.

According to the results in this study a higher accuracy in land use change detection can be assumed by higher accuracy of classification, and further reduction of errors can be expected by known conditions for modification of the specific land cover types to the corresponding land use category. One major cause for the remaining errors may be explained by the mixed pixels problem. The techniques for improvement of such problem were already dicussed in the previous studies. So, the possibilities for improvement of the accuracy can be viewed optimistically, without neglecting thereby the limitations due to the resolution of Landsat TM. Concomitantly, a methodology for integration of GIS with Landsat TM is considered to be desirable and thus, multi-stage investigation approach is discussed in the following.

A map scale of 1:30,000 **is** used to describe the overall environmental conditions in the whole territory of Yokohama City. The land use base maps for detail studies within a selected area (e.g. A Ward : Kohoku-ku) are of 1;2,500 scales. An appropriate methodology for integration of Landsat TM to such a multi stage GIS-application is illustrated in Figure 2.

Rectified Landsat TM subscene covering the whole city area will be classified in compliance with the land use classification scheme. Land use changed areas with reasonable accuracy can be determined as discussed on the previous pages. These changes will be listed by administrative units at city's districts (Ku) and subdistricts (Cho) levels, as shown in Table 4. A hard copy map at scale 1:30,000 showing the overall changes in land use within the City can also be made available. Documents numerical, graphical or both, will provide additional information regarding land resources for use by the decision makers.

Table 4 : Land use changes by administrative units

No.	City's District (Ku)	Subdistrict	Land Use changes [%]	Areas (ha)
1	Nishi-Ku	Total	6.0	632.9
2	Naka-Ku	Total	2.1	1860.0
3	Kohoku-ku	Kitayamada	63.8	119.6
		Chigasaki	59.6	172.7
		Ushikubo	57.7	185.4
		⋮	⋮	⋮
		Total	20.8	4354.9
⋮	⋮	⋮	⋮	⋮

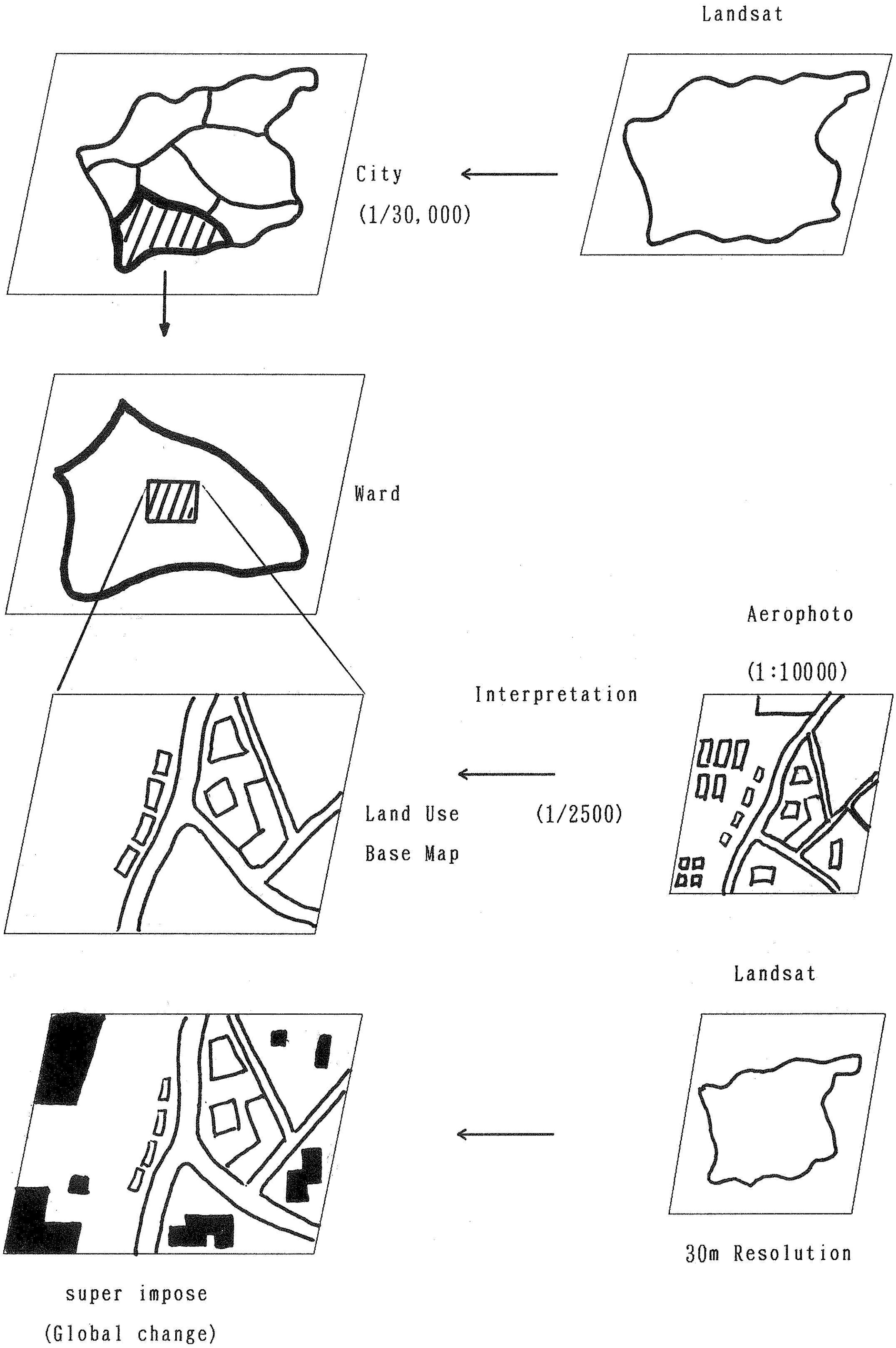

Fig. 2 Multi-stage investigation scheme

The changes detected by Landsat TM will give guide to select the priority cases in macroscopic terms. It can be for example, allocated where such changes as new buildings in former agricultural land, etc, occourred in a given city's district or subdistrict (Ku or Cho). The aerial photographs are then required only for those selected areas. By interpretation of these aerial imageries the land use in GIS data base can be updated interactively on the graphic display. Regarding the method of presentation of the results, a variety of overlay and display functions are available.

GIS capabilities nowadays will no doubt facilitate the decision making in resources planing and management. The major problem at present seems to be updating these data bases. An application of Landsat TM to this issue is viewed optimistically and described how such an integration approach can be implemented. The adequacy of the approach may be judged by the given time constraint and the user's need.

Concluding remarks

The trends in development of computer technology show a continuous enhancements of GIS capabilities in terms of input, output, memory devices and the softwares for a variety of overlays, interactive edting etc.. Image processing systems with integrated GIS functions are also developed. In such a given technological condition the application of Landsat TM should not be limitted to merely producing Landsat images. Complex and numerous problems are associated with an integration attempt of GIS vector data and the raster images. Above all, the problems of land use and land cover, the problems involved in vector-raster conversion and the mixed pixels seems to be of great importance.

The results in this study indicate that an application of Landsat TM for updating land use in GIS data base will be characterized by the errors in detection of changes. The identification of detail land use classes also will be limitted by the resolution of Landsat TM. The effects due to these problems on updating GIS data base may however, depend on the map scale required. Given a proper classification scheme, a clear definition of map contents with respect to land use types and map features the application of Landsat TM may have much less limitation for small scale mapping.

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