

LAND USE PHENOMENA ANALYSIS USING SPATIAL DATA BASE

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Abstract

Remotely sensed image data represented by Landsat data are very useful in the evaluation of land use phenomena in regional urban areas. This paper focusses on the development of a land use phenomena analysis system through integrating spatial data mapping with multi-temporal Landsat image data, geographical data and social census data processing using a hybrid system which is composed of personal, mini and main frame computer systems of the institute. The application is used toward urban information management problems for land use design and environmental planning.

1. Introduction

In the past, information concerning a city have been processed planimetrically in the form of an analogue map. However, due to the technological development of satellite remote sensing and geographical information processing, digitization and automation of spatial information is being developed. The purpose of this study is to develop a land information management system in order to integrate land cover information which is converted to the raster type data through remotely sensed image data processing with census information and conventional map information which has been converted to the vector type data through a computer mapping process to illustrate spatial information of a city.

In regard to the former, a registration method of land cover information and land cover change detection derived from remotely sensed data which is based upon its spatial resolution level was developed. In regard to the latter, a digitization method on various subjects from conventional maps using a simple digitizer was developed.

Further, toward automation of the land information management in a city, the above two different types of data are reasonably integrated as a spatial urban structural model. In this case, the system design is performed by dividing the spatial information into the three phases i.e., spatial data management, mapping, and analysis.

In this study, the efficacy of this system was evaluated by selecting a city of regional area size (Hiroshima city area) as

an experimental research area, then studying the analysis of land use phenomena caused by the impact of urban development trend in the city mentioned above.

2. Hybrid System for Land Use Phenomena Analysis

In the field of image processing, the processing is usually performed with a relatively large scale computer ranging from a main frame to mini computer. Due to the increasing number of personal computer users, personal computer image processing systems have been widely discussed lately due to the availability of improved hardware at a reasonable cost.

In the remote sensing field, a personal computer can be of practical use when the problems of memory size capacity and processing speed are solved. The above three computer systems are organically linked together into the hybrid system in order to implement land use phenomena analysis by complementing each system.

LUPAS (Land Use Phenomena Analysis System) is a system originally developed by the Remote Sensing Laboratory of the Hiroshima Institute of Technology with the main purposes of remote sensing, environmental planning and land use planning. LUPAS was developed according to the following original design technique.

2.1 Realization of Simple Operational System by Adopting the Interactive Menu Process

LUPAS software has a stepwise structure with three modules. Due to this structure, users may retrieve a prepared function and may perform image processing interactively. LUPAS can provide various functions including a representation system for land information which performs displaying out analyzed images on a CRT, supporting system for planning management which implements the land use phenomena analysis and spatial data base management system which implements data handling and data base generating in relation to the above two systems as shown in Figure 1.

2.2 Integration of Image Processing and Geographical Information System

LUPAS is able to perform remotely sensed image data mapping and to analyze land use phenomena through combining the above functions and data sources for geographical information system including topography, population and so on.

With this system, superimposing vector and raster type data is made possible by integrating techniques of the geographical information system and the remote sensing system. This function is the vital point of thought design of LUPAS and is designed to process information concerning a city into a Spatial Data Base.

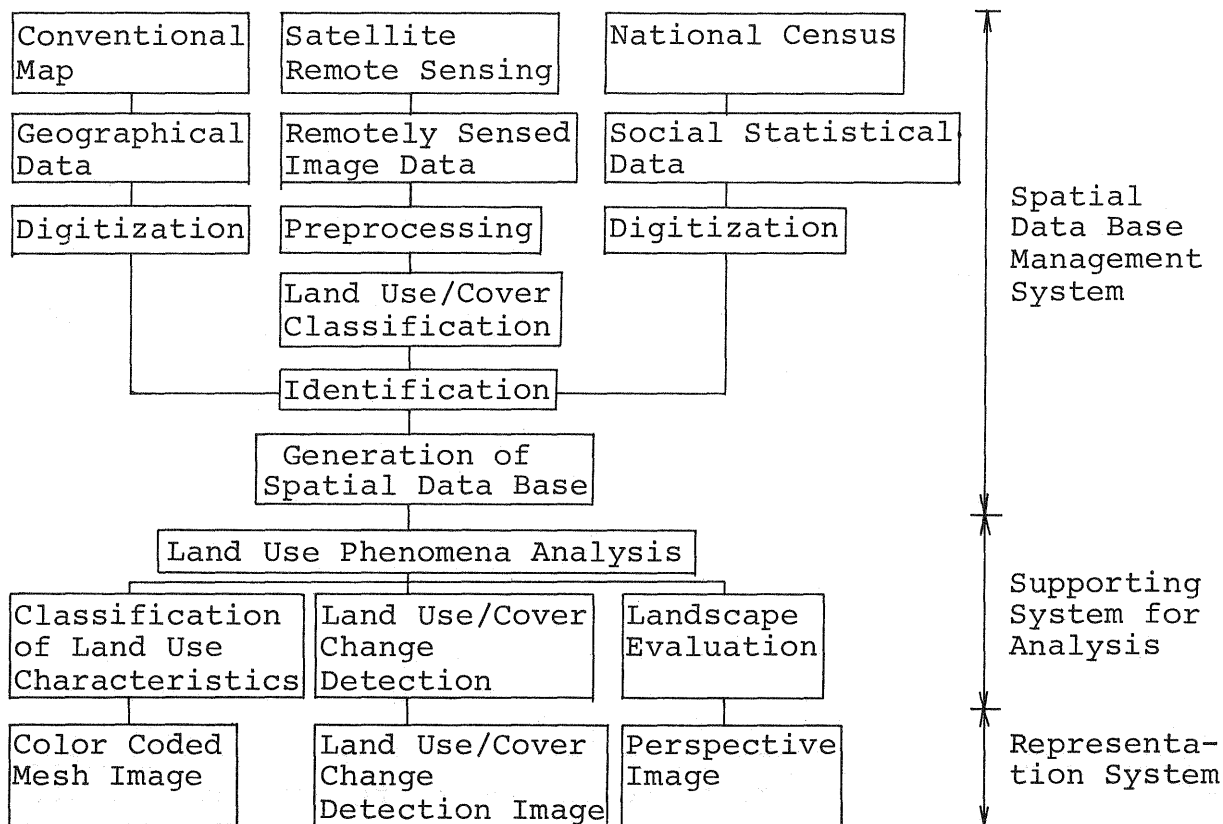


Figure 1 : Concept of Land Use Phenomena Analysis Using Spatial Data Base

2.3 System Configuration

LUPAS hardware consists of a main frame, a mini and a personal computer to which an image processor can be connected and a color monitor which is capable of displaying out on a CRT with 16.8 million colors for effective operation of image data handling. Further, I/O peripheral devices including MT, disk and digitizer can be connected to these computers. Also dispersive processing can be performed with these three computer systems.

Social statistical data and Landsat data processed by the mini and main frame computer systems are transferred to disk files. Software of these processes implements pre-processing of both data using FORTRAN77. One of a personal computer consists of interactive program using BASIC language.

3. Land Use Phenomena Analysis

In general, for the diverse evaluation of land use condition, the following two kinds of methods are available. One is to convert the characteristics of land use to absolute values by a numerical rating evaluation system. The other method is to relatively grasp the quality difference in land use characteristics by a categorizing evaluation system. The latter method is adopted in this study for the land use phenomena analysis by means of multi variate analysis.

Satellite remote sensing was introduced for this analysis. Specifically, conventional social statistical data including populations, and ratios of densely built up areas, residential areas and vegetation areas are combined and assembled. These three ratios can be acquired from Landsat data. Through the above procedure, Land Use Phenomena Analysis in regional area size was performed.

Both social statistical data and Landsat data assume the same form of mesh type data. The former is filed as a representative value by dividing it into the mesh unit based upon longitude and latitude. As for the items of attribute, total population and industrial population are to be set. The latter is filed as land cover classification data by dividing it into a pixel unit. As for the classification item, densely built up areas, residential areas, vegetation areas and water areas are to be set and Hiroshima city was selected as a study area.

4. Procedure of Land Use Phenomena Analysis

The analyzing procedure consists of three phases; data production, principal component analysis and the classification of regional land use characteristics.

4.1 Data Generation for Analysis

With regard to the social statistical data, mesh type data is produced by the identification of an evaluation parameter concerning population acquired by 1/2 standard areal mesh (500m mesh) referring to Standard Areal Mesh established by the Statistics Bureau of the Prime Minister's Office. With regard to Landsat data, the land cover classification image is produced by extracting geometrically corrected study area. Landsat data consists of each image which is identified as 1/2 standard areal mesh data. These two different type data were assembled and filed.

With regard to the social statistical data, each attribute value is filed after a study area being analyzed is divided according to the directions of longitude and latitude into the assigned mesh size. For this procedure, the spatial data base is so designed that processing of input, correction and updating can be performed interactively.

With regard to Landsat data, the classified image of land cover is divided into the assigned mesh size. In this case, occupying areal ratio of each classified category per mesh is filed as attribute value.

In generating data set for the land use phenomena analysis, the intensive clustering of variables is made possible through the integration of more than two classified variables in this system. Thus the explanation variable is filed using each attribute value acquired by the above mesh data.

4.2 Principal Component Analysis

The characteristics of certain variables (averages, standard deviations and coefficients of correlation) composed of social statistical mesh data and Landsat mesh data are considered. Then each principal component using its eigen value and factor loading is interpreted. The relationships among these variables are then synthetically analyzed. Then the social, economic and land use structural characteristics of each region is analyzed by using the principal component score of each mesh data. Based upon this result, classification of land use phenomena in the study area is performed.

The input data file for use as the principal component analysis was produced by combining the social statistical data and Landsat data. In this case, selection of an assigned explanation variable is performed interactively and then the analysis processing is performed. The results of statistical analysis are printed out, and based upon the results, the criteria for classification of regional land use phenomena is established. In this case eight classified regions are categorized according to the combination of the plus and minus signs.

4.3 Classification of Land Use Phenomena

As an evaluation unit for classification of land use phenomena, the grid system based upon a mesh analysis method (referring to the Standard Areal Mesh) is used. Following classification by principal component score, each mesh referring to the criteria of regional classification is zoned into the grid. A color coded mesh image which represents characteristics of land use phenomena is displayed out on a CRT of this system. In this case, interactive feed back processing is adopted so that prompt visual investigation of the classification criteria and its validity can be possible by means of the color coded mesh image.

5. Case Study in Hiroshima City

As a study area of land use phenomena analysis, a rectangular area of 23.0 kms from east to west, and 18.4 kms from north to south was set. This area corresponds to a map size of a scale of 1:50,000 around the city center of Hiroshima. Also the study area was set based upon 1/2 standard areal mesh which consists of 1,600 meshes in total divided by 40 columns x 40 lines in the direction of latitude and longitude, respectively.

For the parameters of evaluation of land use phenomena in the study area, data set was prepared by setting two factors : a factor of population (total population, population of primary, secondary and tertiary industries) and a factor of land use/cover (ratios of densely built up areas, residential areas and vegetation areas).

With regard to the factor of population, Standard Areal Mesh of Hiroshima which has already been published was transferred to a disk file. With regard to the factor of land use/cover

acquired by Landsat MSS data was used. MSS data was geometrically corrected to the accuracy of registration of less than one pixel so that it can correspond to the study area, then the identification was performed for the 1/2 standard areal mesh by setting categories of densely built up areas, residential areas, vegetation areas and water areas. Based upon the above analysis data, data set was produced by combining the seven variables, and characteristics of land use phenomena of each mesh in the study area was considered using principal component analysis.

Coefficients of correlation of the total and tertiary industries populations take the highest correlation of 0.98. Also the total and secondary industries populations take the high value of 0.93. In regard to secondary and tertiary industries, populations take the relatively high value of 0.86. Vegetation area has no correlation to the other factors. Tables 1 and 2 show the results of applying principal component analysis. As for the result of Table 1, those taking the eigen value of more than 1.0 are PC1 and PC2 from which 74.5% information is intensively explained. Also 87.1% information is accumulated when PC3 is included.

Table 2 shows the factor loading of each component. Interpretation of each component is summarized out of these results. Factors showing variables of high factor loading in PC1 are total population, tertiary industry one, secondary one and residential area ratios, while vegetation area ratio has a minus signed factor loading. According to this, it can be interpreted that PC1 shows the difference of accumulation of population. In PC2 densely built up area and residential area ratios take minus signs, while vegetation area ratio takes a relatively high value. PC2 shows the difference of degree of vegetation naturalness. PC3 shows accumulations of agricultural activities and/or the difference in expansion of housing land in agricultural areas.

The criterion of classification of land use phenomena is decided according to the plus and minus signs of each principal components as shown in Table 3 through which the classification of each mesh is performed. The result will be displayed out on a CRT as the color coded mesh image of classification which is shown in Plate 1. Category 1 (blue) is the area of high PC1 score in which accumulation of population is extremely high in the study area. PC3 score forms plus signed area or highly developed housing land area. Category 2 (red) in which only PC1 takes the plus value shows extremely high accumulation of population. It mainly consists of densely built up areas which are concentrated in the city center. Category 3 (purple) in which only PC 2 takes the plus value is mainly occupied by forest with a high degree of vegetation naturalness. Category 4 (green) in which PC2 and PC3 take a plus value is suited for agricultural activity with low accumulation of population and a high degree of vegetation naturalness. Category 5 (light blue) in which all PCs take a minus value is the area of scarce accumulation of population with its land use still undeveloped. Category 6 (yellow) which has a certain accumulation of population consists of a residential area adjacent to forest

Table 1 : Eigen Values of Principal Components

Component	Eigen value	Contribution	Accumulated Contribution
1	3.873	55.3	55.3
2	1.344	19.2	74.5
3	0.884	12.6	87.1
4	0.501	7.2	94.3
5	0.250	3.6	97.9
6	0.138	2.0	99.9
7	0.010	0.1	100.0

Table 2 : Factor Loading

	PC1	PC2	PC3
Total population	0.910	0.370	-0.158
Primary industries	0.360	0.303	0.875
Secondary industries	0.859	0.402	-0.120
Tertiary industries	0.894	0.318	-0.219
Densely built up areas ratio	0.610	-0.565	-0.015
Residential areas ratio	0.733	-0.547	0.025
Vegetation areas ratio	-0.685	0.482	-0.173

Table 3 : Criterion of Land Use Phenomena Classification

Land Use Category	PC1	PC2	PC3
1	+	-	+
2	+	-	-
3	-	+	-
4	-	+	+
5	-	-	-
6	+	+	-
7	-	-	+
8	+	+	+

and one with a certain amount of vegetation area in the densely built up area. Category 7 (orange) consists of a residential area developed through expansion of suburban housing land. Category 8 (gray) which has a certain accumulation of population is the agricultural area in the suburbs with well-developed housing land.

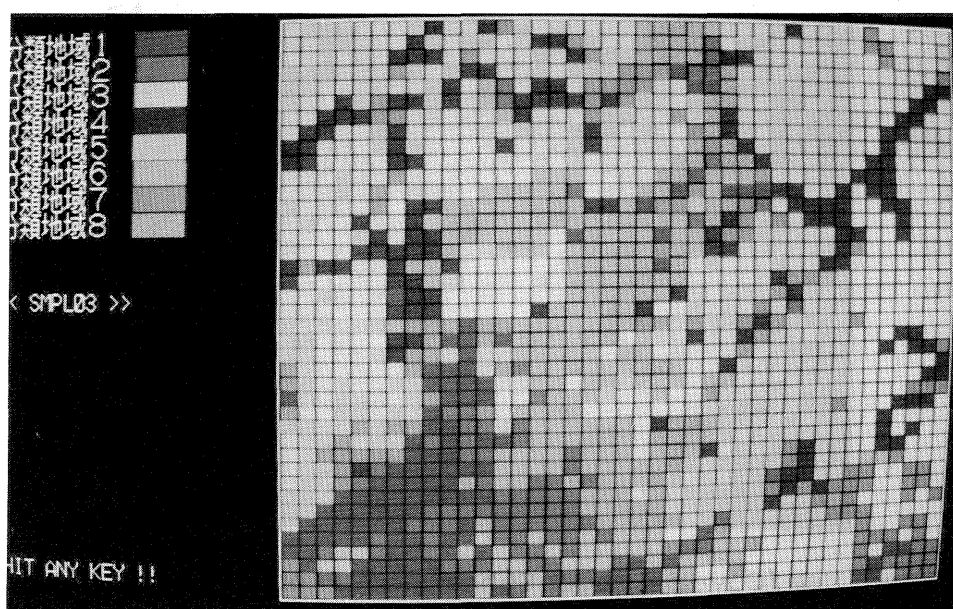
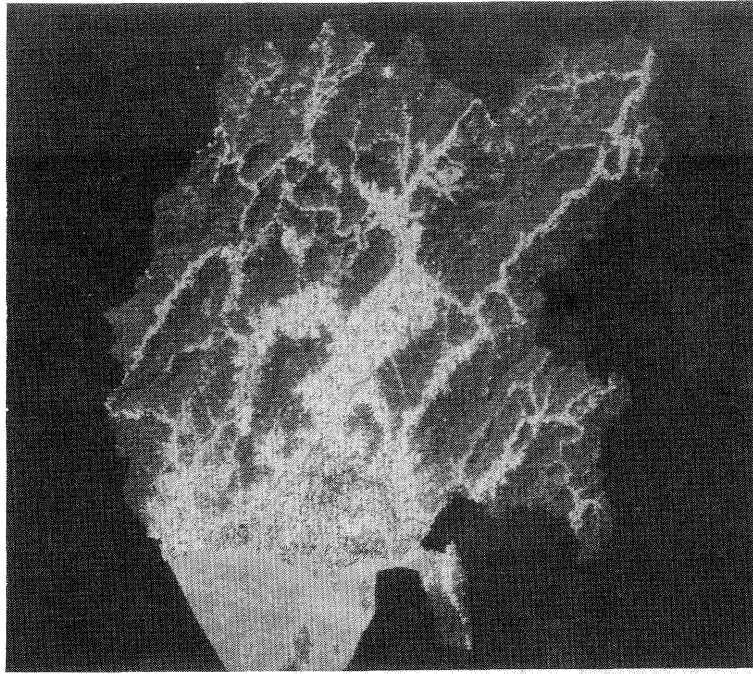


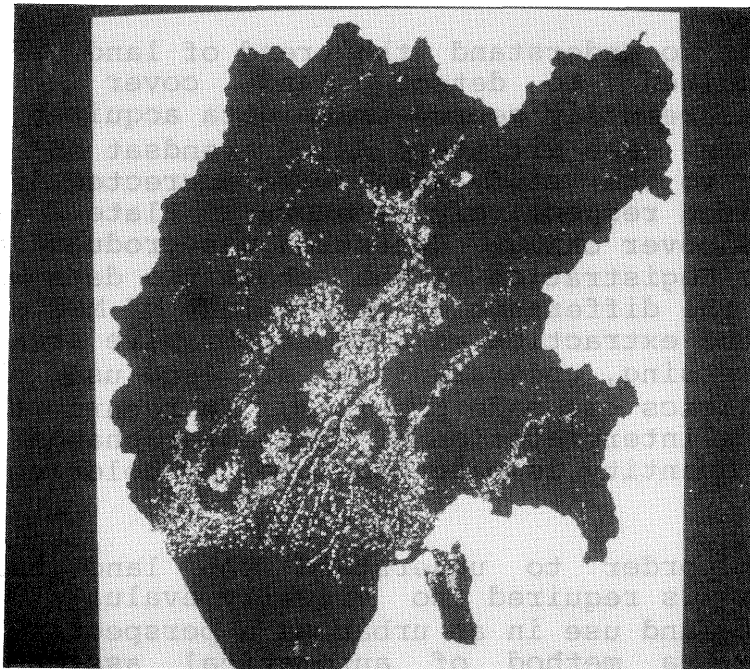
Plate 1 : Color Coded Mesh Image of Land Use Phenomena Classification (Hiroshima)

Next, in order to understand the trend of land use phenomena, it is required to detect land cover changes using multi-temporal remotely sensed image data acquired on different dates. In this case different dated Landsat MSS and TM data corresponding to the study area were corrected geometrically and categorized respectively as shown in Plate 2 (a), then the image of land cover change detection was produced as shown in Plate 2 (b). Registration of the above two data was performed according to the difference in resolutions of MSS and TM data. Also due to the extraction as an administrative area of the city by mask processing, understanding of land use phenomena in terms of politics is made possible. In regard to the change detection, the interpretation of land cover change in terms of quality and quantity is made possible by color coding of this method.

Finally, in order to understand the land use phenomena diversely, it is required to visually evaluate the present conditions of land use in an urban as a perspective image. For this purpose, a method of automatic assembly of three dimensional perspective image is developed by combining the Landsat mapping system and digital terrain modeling system. Plate 3 shows a perspective image of Hiroshima City which was generated from Landsat TM data. Through this method, visual understanding of landscape of a city from any view point at any time can be achieved. Also in this case, image processing is performed by combining vector data of roads extracted from a map by digitizer and raster data of Landsat image.



(a) Land Use/Cover Image Generated From Landsat TM data



(b) Land Use/Cover Change Detection Image Using Landsat MSS and TM Data (1979→1984)

Plate 2 : Land Use/Cover Change Detection Image Using Landsat Data (Hiroshima)

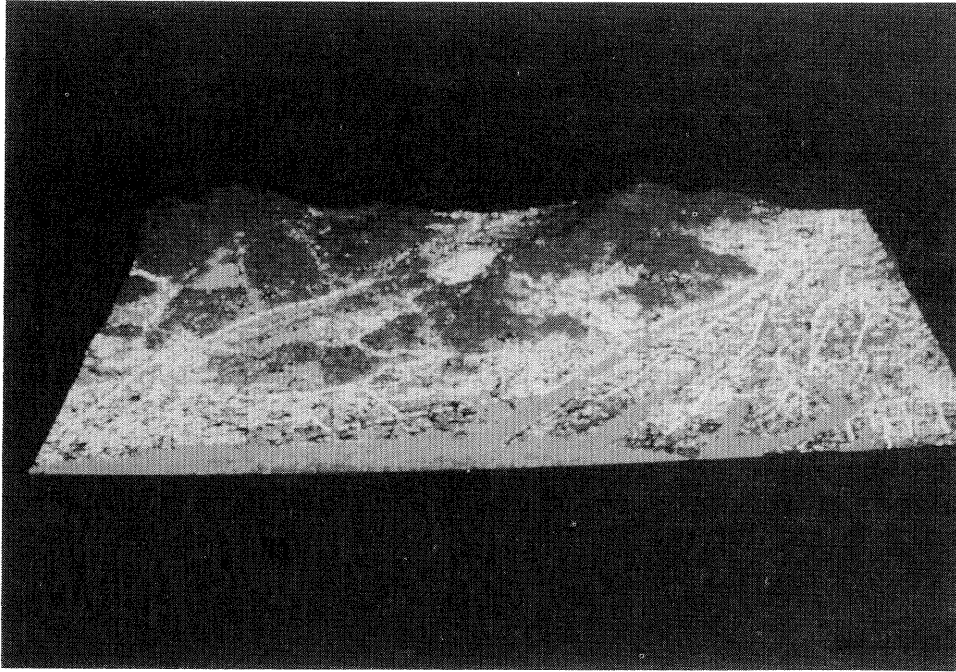


Plate 3 : Perspective Image Generated From Landsat TM Data
(Hiroshima, 1984)

6. Conclusion

LUPAS developed through this study consists of a hybrid system, an integration of personal, mini and main frame computer systems for spatial data base generation and of land use phenomena analysis system. Spatial data base consists of social and geographical data represented as vector type data and remotely sensed image data as raster type data. Land use phenomena analysis is performed by means of principal component analysis with the spatial data base.

LUPAS is considered to be effective in acquiring basic materials and supporting a policy framing with respect to land use planning in a city. Effective and expansive integration of a remote sensing system and a geographical information system which is to be applied separately can lead to a new field of application hereafter.

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