Developing Land-Use Maps for Remediation Abandoned Coal Mines

Marisa MEI LING, Tetsuro ESAKI, Hiro IKEMI, Yasuhiro MITANI

Abstract: Facing the problem of the environmental impacts on the land due to abandoned coal mines, it is necessity to recognize the history of regional development and to find suitable methods to remediate that region. One of the methods for obtaining descriptions of land-use transition that leads to the abandonment is the analysis of changing patterns from a series of land-use maps over the last 100-years. In this paper, land-use maps series based on 1:50,000 topographical maps have been developed by applying Geographic Information System (GIS) technology. A mesh-based polygon of 100m x 100m is used as a zone area to extract the land-use values over years. In order to perform land-use maps, python were utilized to handle repetition process and time-consuming task. As a result, land-use maps can be developed effectively by implementing GIS techniques to provide the analysis of land-use transition patterns.

1. Introduction

Land degradation from old mine workings is well known in almost all countries and has become one of the outstanding environmental problems confronting the mining developments. There are many references to environmental damage from such sites; however few systematic surveys and impact assessments have been carried out, so the true scope of the problem is not exactly known. This research sets out the natural environmental situation both spatial and temporal, concerning abandoned coal mine sites in order to provide a basis for further study about how to address remediation issue on former coal mines region. The assessment of past natural environment and land utilization play an important role to explain the regional changes which leads to the abandonment.

In Japan, the magnitude of the impacts from past mining is often considerable, as environmental regulation of mining activities has in most cases only been introduced relatively recently. Chikuhou region, which has long history of coal mines industries, was selected as the area to study (**Fig.1**). Chikuhou region covers 33.30% of Fukuoka prefecture and consists of 21 administrative boundaries, has total area of 1,649.80 km^2. One of the methods for obtaining descriptions of land-use transition that leads to the abandonment in this region is the analysis of changing patterns from a series of land-use maps over the last 100-years. Since there are no records of land-use maps, thus the development of a series of land-use maps is well thought important for the study of remediation in this region. A series of land use maps of Chikuhou region over the last

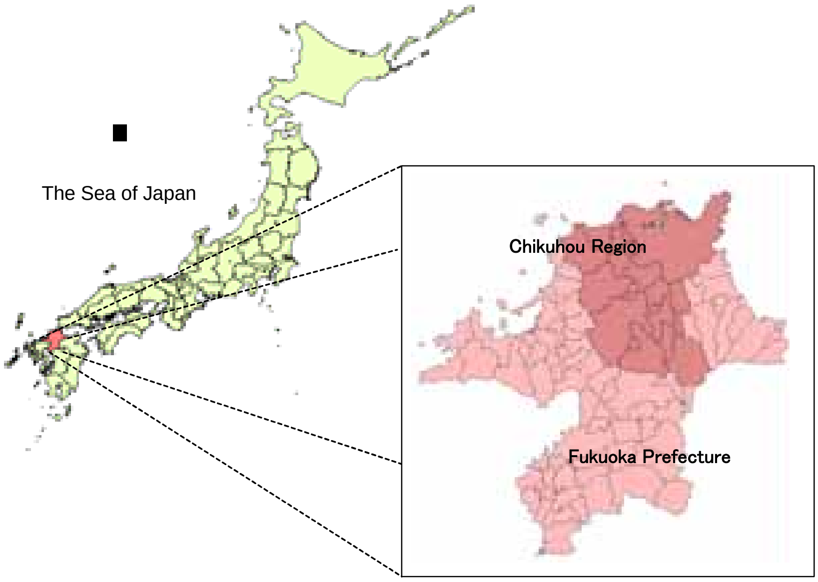

Fig.1 Study Area

100-years is developed using old topographical maps scale 1:50,000 to produce land-use datasets. Geographic Information System (GIS) technology has greatly enhanced the maps production and analyses.

2. GIS Data Source for Land-use Study in Chikuhou Region

Four series of land-use maps of the year 1900, 1950, 1976, and 1997 have been used in order to analyze pattern changes in Chikuhou region. Land-use maps of year 1900 and 1950 have been developed from old topographical maps. Land-use maps of year 1976 and 1997 have been modified from available digital data sets published by Ministry of Land, Infrastructure, and Transport (MLIT) of Japan. In this region, old topographical maps of the year 1900 and 1950 scale 1:50,000 are the only readily available data (**Fig. 2**). Eleven sheets of A2 size maps of year 1900 and year 1950 that covers Chikuhou region have been collected and scanned with 300 dpi resolution. The maps published by Geographical Survey Institute (GSI) have been repeatedly revised with relatively minor modifications in classification so that they are extremely valuable and therefore they have been used as the main data source for the production of land-use data sets. GSI, the national surveying and mapping organization of Japan, holds jurisdiction of the survey act which was established in 1949. The amended Survey Act effective on April 1st 2002 introduced a world geocentric reference system as the geodetic reference system that is "Japanese Geodetic Datum 2000 (JGD2000) instead of the former Tokyo Datum in order to adapt the coordinate system to various high-tech tools using GPS/GIS technology more easily. After the amendment, GSI has changed all the coordinates of their products based on JGD2000 and make it known to public including governmental organizations and local governments.

Topographical maps scale 1:50,000 of year 1900 and 1950 used former Japanese geodetic reference system “Tokyo Datum”, while land-use maps of year 1976 and 1997 have already adapted JGD2000 as the reference system. In order to get a concurrence analysis result from a series of land-use maps, land-use maps of the year 1900 and 1950 are developed under JGD2000 reference system. The re-projection process of old topographical maps has committed some distortion, which is traditionally related to map scale. The smaller scale will cause the more distortion. The former Japanese geodetic reference system “Tokyo Datum” was basically established in early 20th century. This coordinate system had a large shift to the world geodetic system which amounts to 400-450m. The shift is mainly due to the astronomical determination of the origin of longitude and latitude for the Tokyo Datum. The old geodetic system was also distorted internally by several meters because of different survey methods and accumulated crustal deformation for around 100 years. During georeferencing process to put the scanned map into GIS database, four geodetic coordinates of maps corner have been using as a reference. The georeferencing accuracy could be assured since root mean square error was minimized.

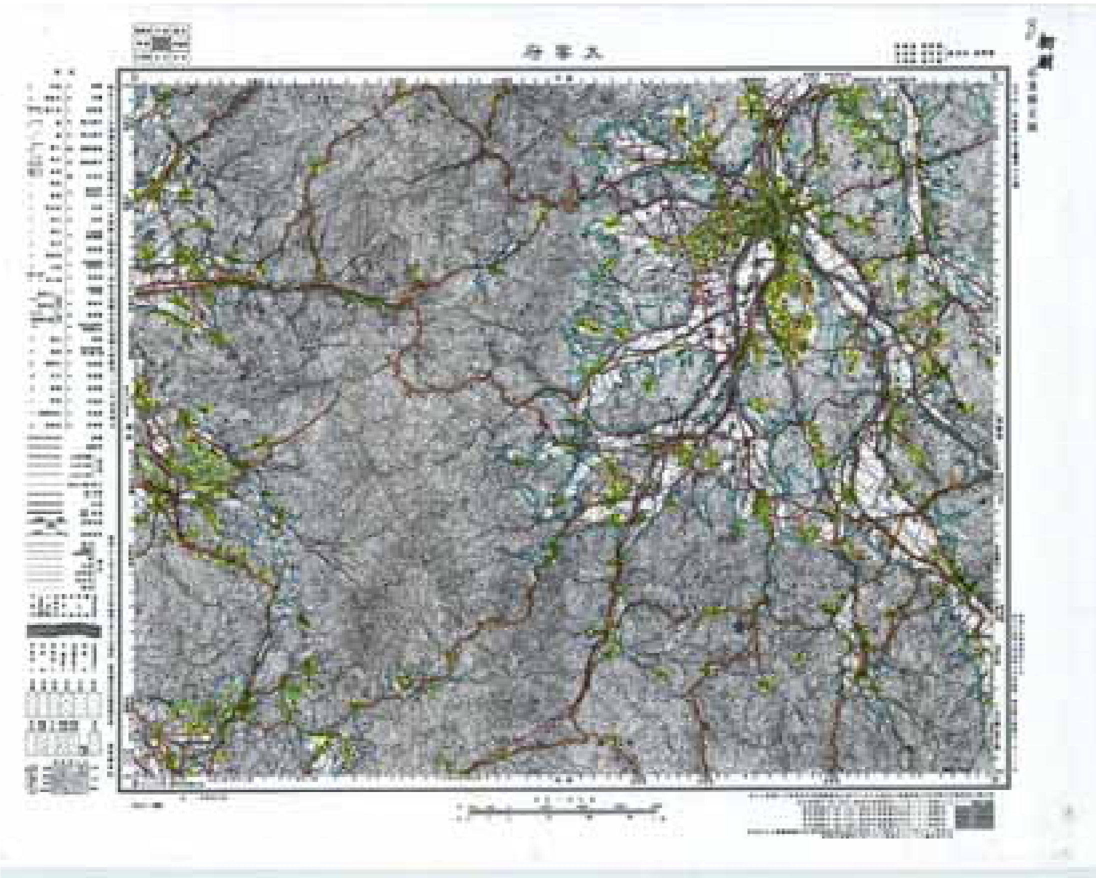

Fig. 2 Topographical Maps scale 1:50,000 of the year 1900

The scale of data also reflects resolution and its relative accuracy on a map: the larger scale will cause the more accurate and detail the data set. Resolution is defined as the size of the smallest features that can be mapped or sampled at a given scale. The resolution of a map is directly related to its scale. A map scale decreases, resolution diminishes and feature boundaries must be smoothed, simplified, or not shown at all. There will be a minimum polygon size and line length that can be represented at a given scale. Since the resolution of objects that can be represented at a 1:50,000 scale is limited, the maps were marked by color in order to distinguish the colonies boundary before digitizing process. Theoretically, the determination of colonies boundary need the accumulation of surveying and mapping experiences, spatial information about the related location such as aerial photograph, and an appropriate interpretation techniques. The positional accuracy of a map is a function of the scale at which a map was created. Typically, maps can be accurate to roughly one line width or 0.5 mm, so the 1:50,000 map could be only positional accurate down to 25 meters and in turn the maximum tolerable error will be 6.25 % or 0.0625 ha within one hectare area.

Another data source available is a digital elevation model of year 1997 published by MLIT. The data visualization represents the topographical surface of Chikuhou region and shows the interaction with physical landforms of land-use data placed upon it (**Fig.3**). Chikuhou region mostly covered by plain area along the river, 5% of the region in the southern part was surrounded by mountains with elevation varies from 300 to 1134 meter above sea level.

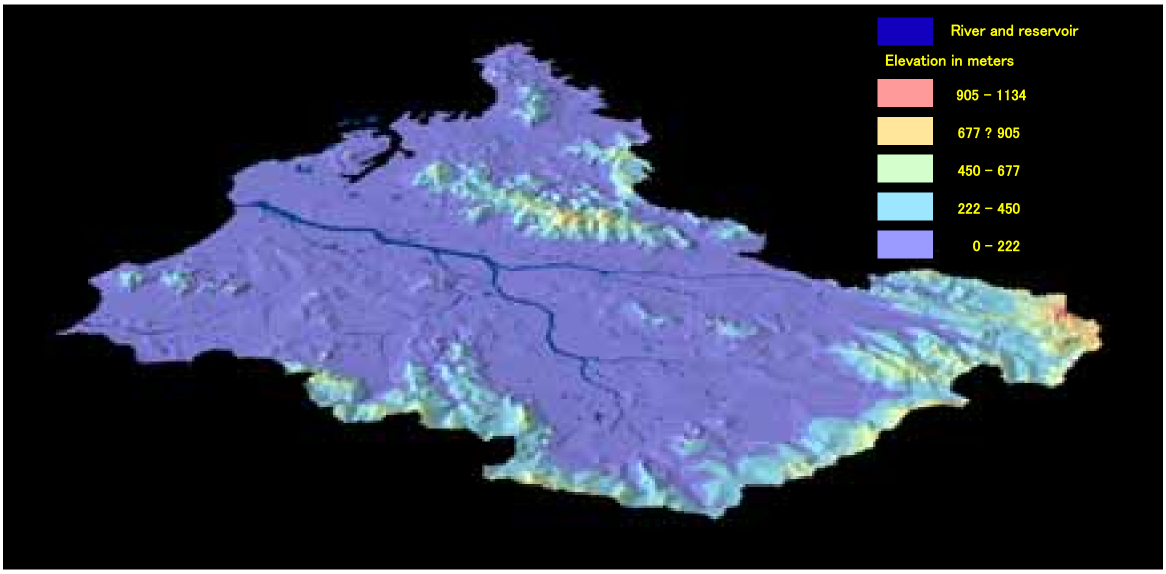

Fig.3. 3D view of digital elevation model of Chikuhou region

3. GIS Methodology of Making Land Use Maps

Fig.4 shows the flow chart of making land-use maps in GIS. The process of developing land-use maps begins with the conversion paper maps into digital data format which is carried out through scanning process. Rectified maps are obtained once georeferencing digital data completed. Georeferencing is a process of assigning coordinates to known points on the scanned-map which can also be easily distinguished in referenced data layer. During georeferencing, four geodetic coordinates of maps corner have been using as references. The rectified maps, which are now in raster format, are digitally extracted by firstly converting it into vector format through onscreen digitizing. An aggregate classification was used to represent the major types of land-use, and a different code is assigned to each class on the attribute table. This operation results polygons of land-use. During digitizing, it is important to make sure that each different polygon perfectly intersect with each other and is assigned appropriate codes.

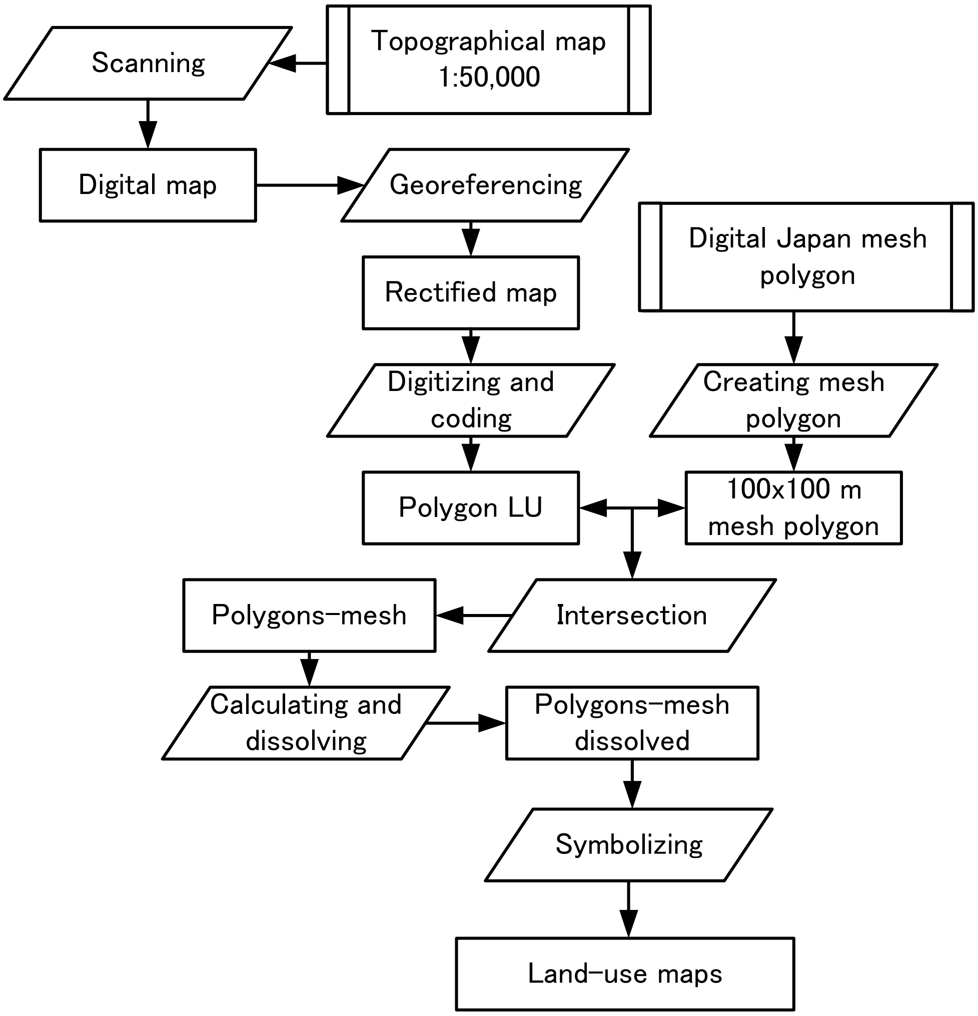

Fig.4 Flow chart of making land-use maps from topographical maps

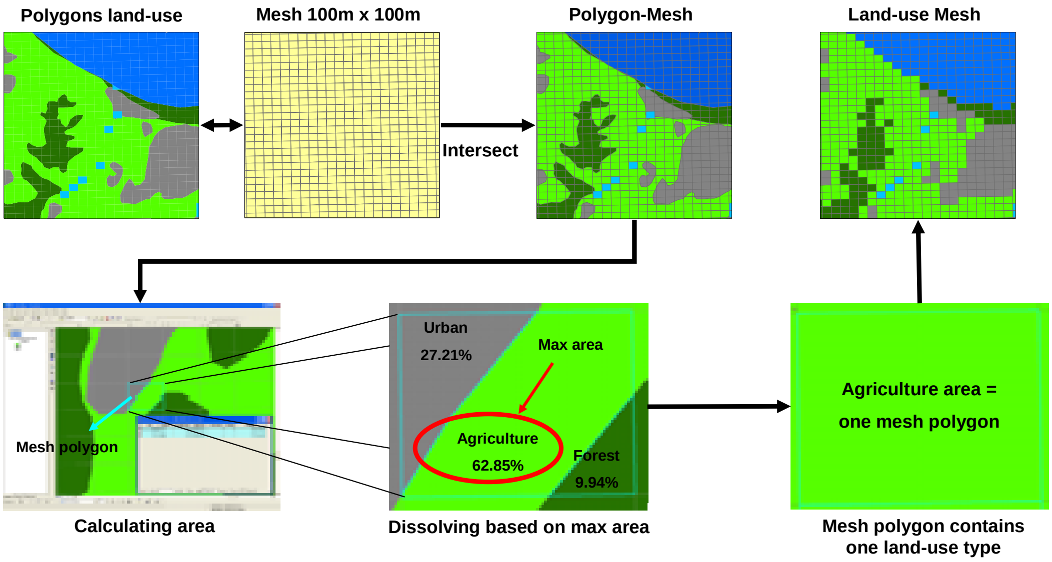

Fig. 5 Illustration of intersecting and dissolving area within GIS

A mesh-polygon of about 100m x 100m zones, which is defined in 1993 by the Japanese government, has been generated automatically using the script. A script is a set of instructions in plain text usually stored in a file that is interpreted or compiled at run time. In addition, GIS operations built under python scripts have supported multiple and iterative geoprocessing tasks. The next process is intersecting polygons of land-use and 100m x 100m mesh polygons. As a result, a polygon-mesh is gained and through the calculating area and dissolving operations, another dissolved polygon-mesh based on maximum area is produced. **Fig.5** illustrates the intersecting and dissolving process within GIS. Land-use map as a final result is completed by symbolizing polygon-mesh based on land-use codes.

By applying a mesh-polygon approach, reading attribute value at mesh-polygon will be done easier. When working with a table to join data from others layers, regular mesh-polygons based on x,y location is found to be useful in modification process.

4. Land-use maps series over 100 years of the Chikuhou region

GIS methodology has been successfully implemented to yield a series of land-use maps of Chikuhou region. **Fig.6** shows land-use maps of year 1900, 1950, 1976, and 1997. With the assumption that river area and shape have not changed over the period, the series of land-use maps are analyzed in order to explain the trend of development that is apparent in this region. Historically, during the period of 1900–1950 the demand for the food supply has caused the extension of rice field, during the period of 1950–1976 mining industries had reached the peak, and urban settlements had grown enormously during the period of 1950-1997.

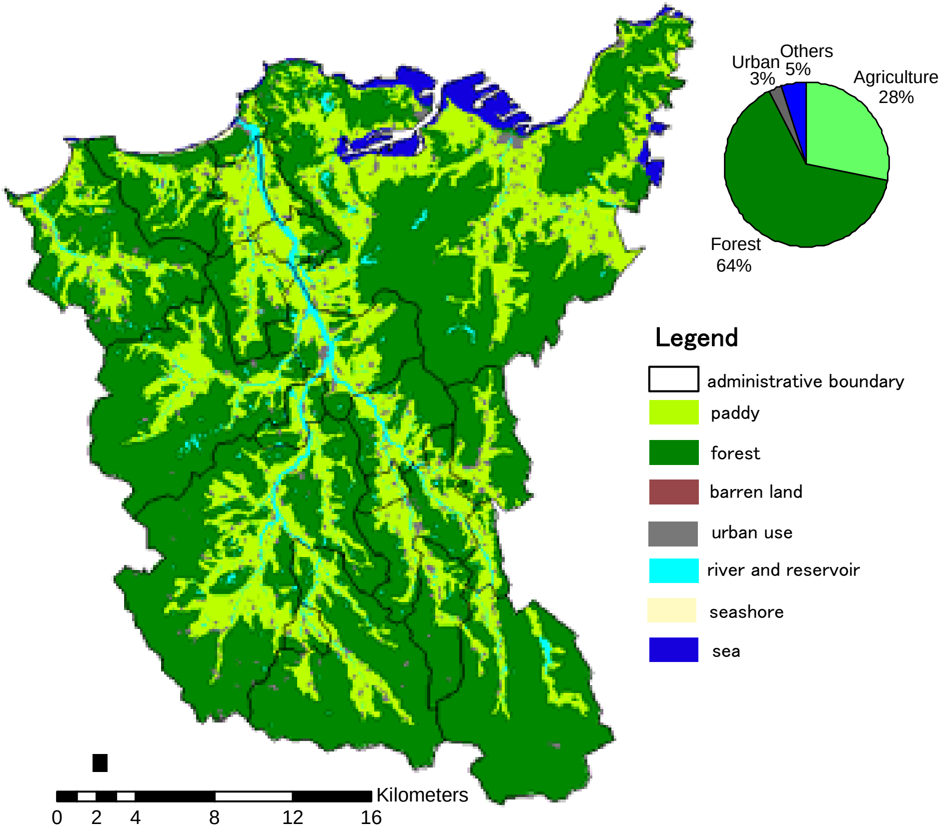

Fig. 6a Land-use Chikuhou 1900.

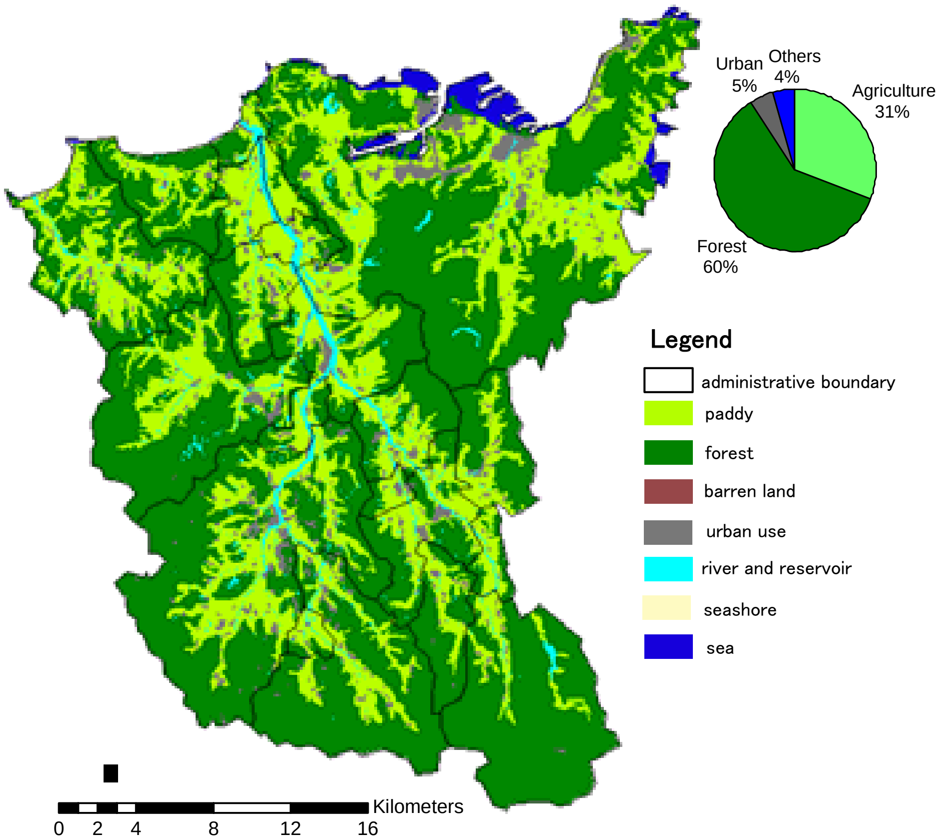

Fig. 6b Land-use Chikuhou 1950.

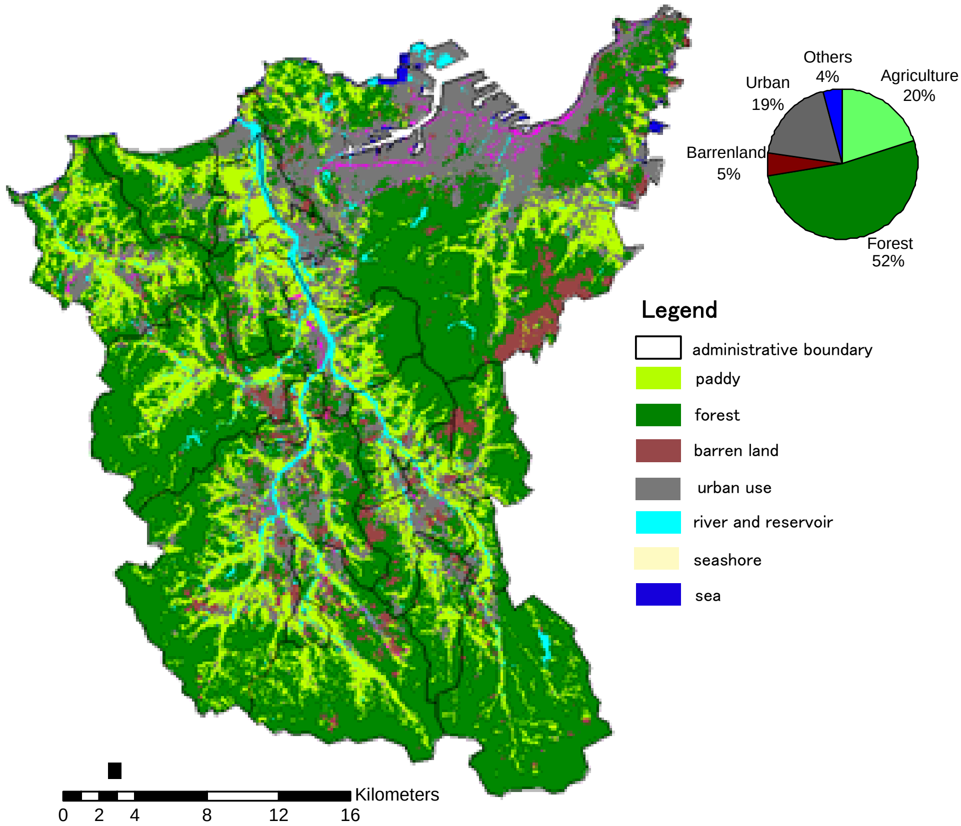

Fig. 6c Land-use Chikuhou 1976

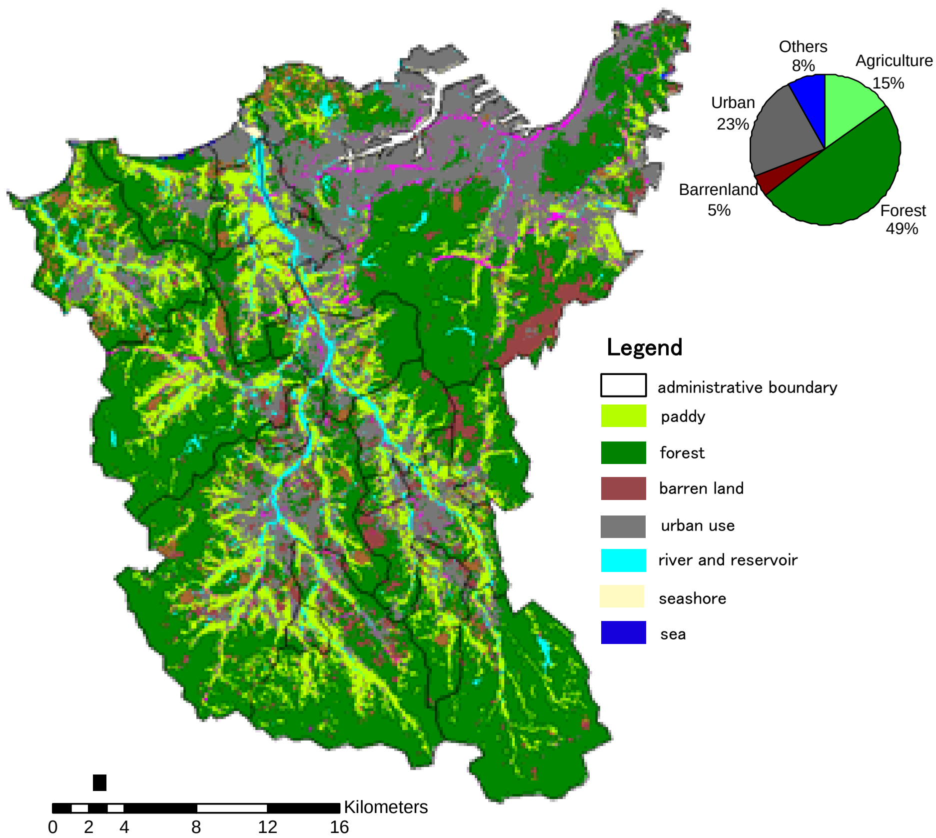

Fig. 6d Land-use Chikuhou 1997.

Since year 1900, the significant agricultural development has been found mostly in the plain area along the river. Agricultural land occupies 15% of the region at present, indicating a major decrease from 28% in the beginning of the century. Urban area occupied only 3% of the region in the beginning of the century, but has increased 23% up to the present. Urban settlement has significantly expanded in the northeastern part of the region, while it also expanded in the area of underground coal mines excavation. The mountain area surrounded the southern boundaries of the Chikuhou region has not shown any significant changes from the original land-use since the beginning of the century. The mountain area mostly covered by forest that has an extreme elevation up to 1134 meter above sea level. Forest area, which is covered more than half of the region, has not changed very much since the year 1900. It has decreased notably during 1950 and 1976 in the northern part of the region, where agricultural and mining development has progressed.

In order to calculate changes from one land-use type to the other at a different date, the amount of mesh polygons from each land-use type is summed, then those features for which the land-use codes are not equal-that is, the category at the first date is different than that at the second date. With the assumption of one mesh polygon of about 100m x 100m is equal to one hectare, the changes area is calculated from the difference between mesh polygon values. **Table 1** describes urban development during the period 1900-1997. Urban expanded to agriculture is 30.73% from total agricultural area and urban expanded to forest is 13.37% from total forest area. The illustration of the percentage of pattern changes can be seen in **Fig.7**. Barren land occurrence during the period of 1950-1997 is shown in **Table 2** and illustrated in **Fig.8**. Barren land has expanded accordingly to 3.66%, 7.70%, and 1.93% from total area of agricultural, forest and urban. From digital geological map of Chikuhou region shown in **Fig.9**, some barren land area in the northeastern part has recognized as limestone material. Yet the barren land appearance in some part inside the former underground coal mine excavation has been an indication of land abandonment due to past mining activities.

Table 1. Urban development period 1900-1997

Period	Agriculture to urban use (ha)	Forest to urban use (ha)
1900-1997	18047	14414

Table 2. Barren Land (BL) Occurrence during period of 1950-1997

	Agriculture to BL (ha)	Forest to BL (ha)	Urban use to BL (ha)
1950-1997	2016	7855	769

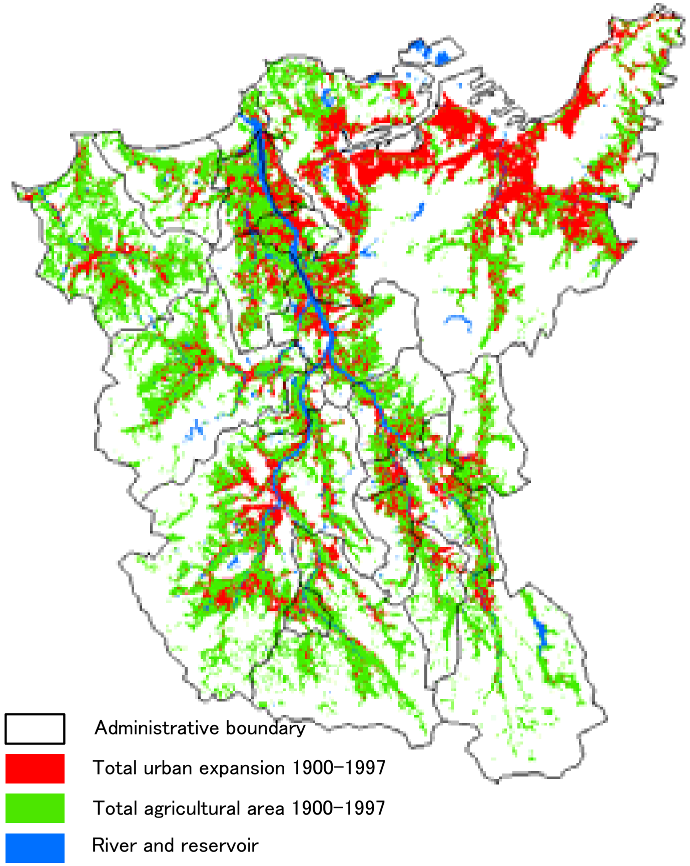

Fig.7a Urban expands agricultural area.

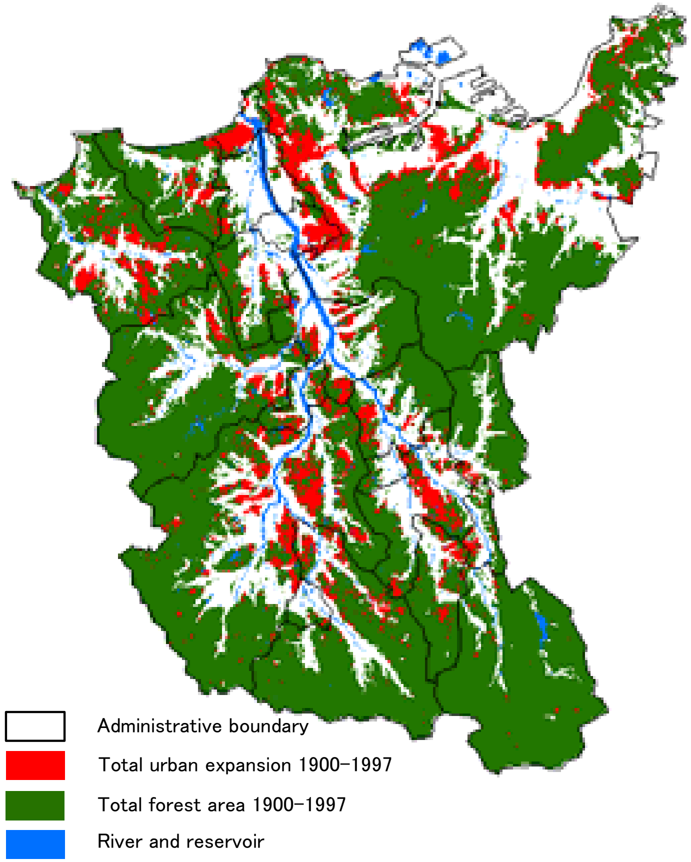

Fig.7b Urban expands forest area.

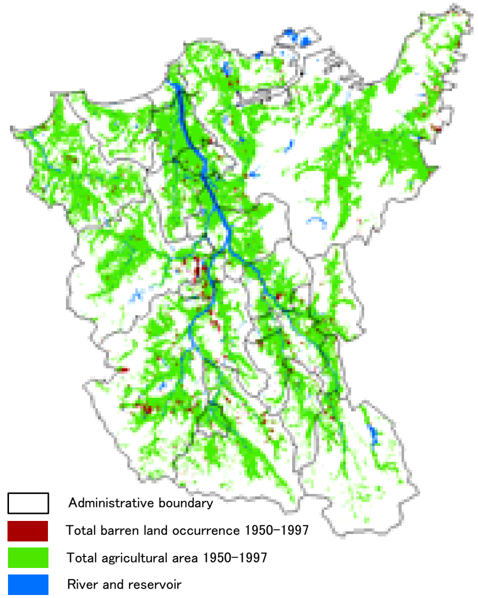

Fig.8a Barren land expands agricultural area.

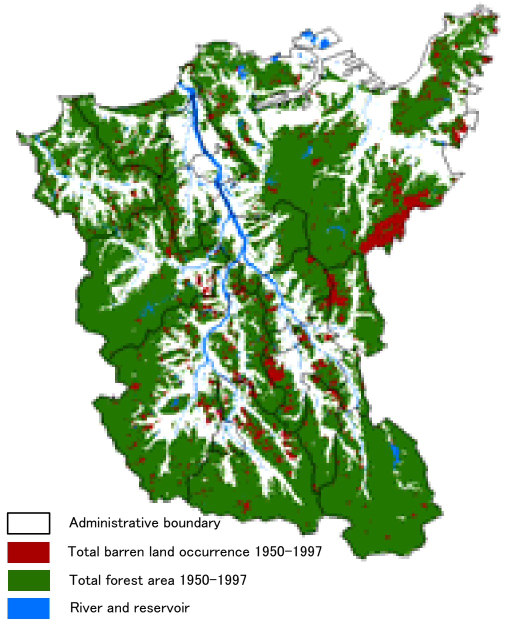

Fig.8b Barren land expands forest area.

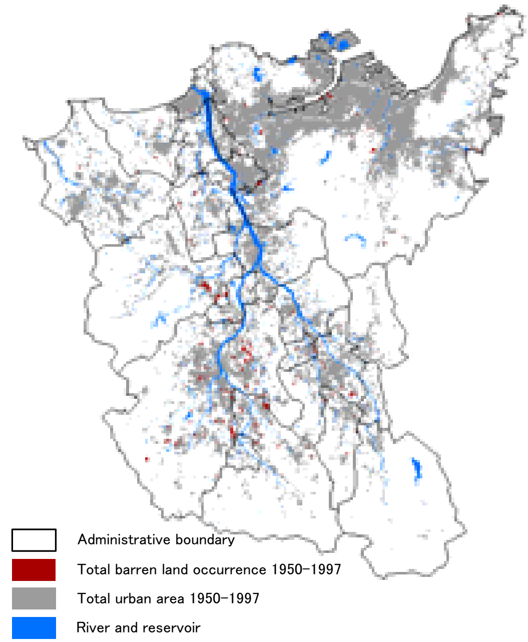

Fig. 8c Barren land expands urban area.

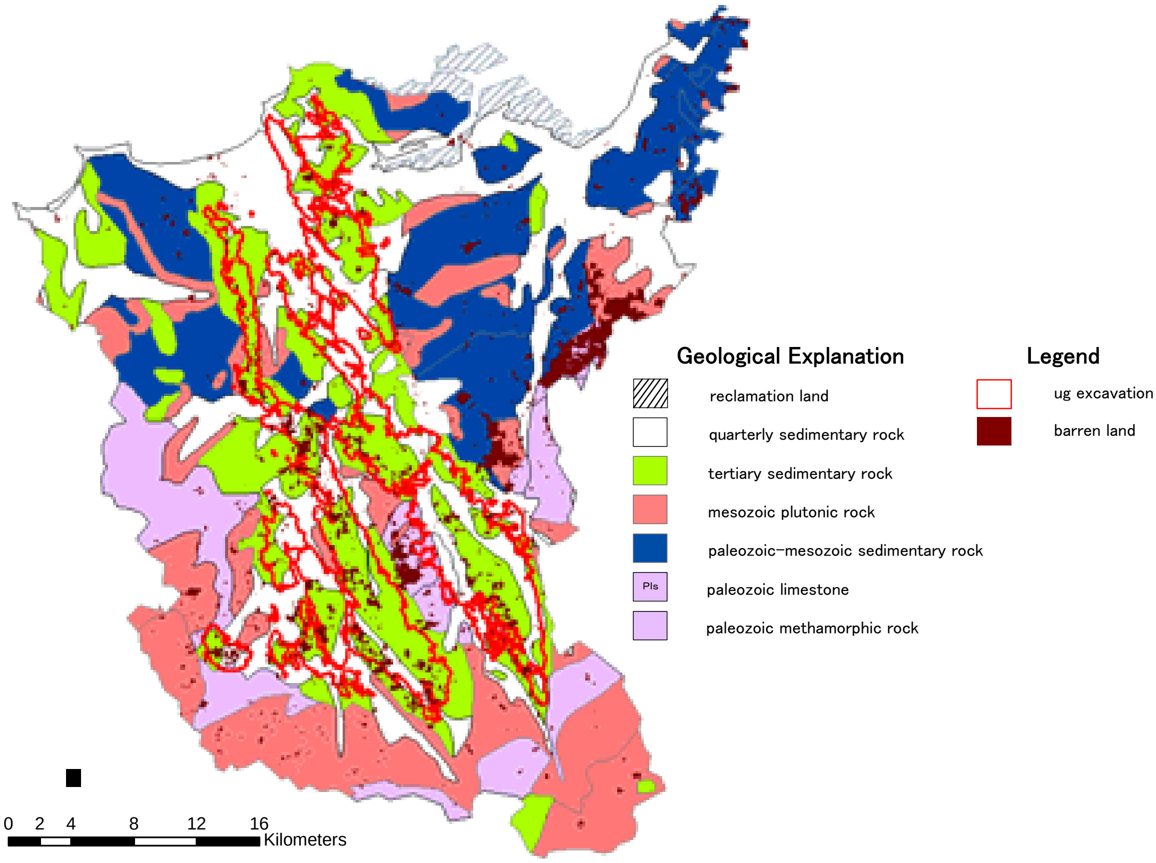

Fig.9 Geological explanation of Chikuhou region

5. Conclusions and Discussions

A series of land-use maps over the last 100-years has been developed, based on 1:50,000 old topographical maps. By applying GIS technology, the process of making land-use map which could not be handled in the past, has been made possible to be carried out in the present time. The method is considered to be valuable and applicable because it allows a fast calculation of land-use areas through the intersection with mesh polygons of about 100m x 100m. Moreover, it provides organized steps as a guideline in producing a series of land-use maps. This research has also been successful in outlining how the land-use data sets have been sufficiently used for analysis regional area and explaining what has been happening in the region during the past 100 years. Through the development of land-use maps series, the history of regional development can be recognized and understood and in turn, will be a basic for the remediation plans. Barren land area illustrated in **Fig.9**, particularly those which located inside the former underground mine excavation, can be considered as remediation sites for land-use planning in the future. Further research has to be carried out in order to find the best method to determine the appropriate land-use boundary from old topographical maps.

References

Genske, D. 2003. Urban Land: Degradation, Investigation, Remediation. Springer, Germany.

Esaki,T et al. 2003. Land Degradation through Developments and Its Remediation. Macro Review Special Issue: The Review of Japan Macro-Engineers Society Vol. 16, No.1, 2003 (Serial No.25): 21-26.

Weinberg, A. 2000. Urban Recycling and the Search for Sustainable Community Development. Princeton University Press, USA.

Tomlinson, R. 2003. Thinking About GIS: Geographical Information System Planning for Managers. ESRI Press. Redlands, California.

Himiyama, Y. 1998. Land use/cover changes in Japan: from the past to the future. Hydrological Processes 12, 1995-2001. Hokkaido University of Education, Asahikawa 070-8621, Japan.

Balkau, F. 1999. Abandoned Mine Sites. Problems, Issues and Operations. Paper on the Berlin II Roundtable on Mining and the Environment. Germany.

Decker, D. 2001. GIS Data Sources. John Wiley & Sons. USA.

Mitchell, A. 1999. The ESRI Guide to GIS Analysis Volume 1: Geographic Patterns & Relationships. ESRI Press, California, USA.

Geographical Survey Institute (GSI) Government of Japan. 2004. The New Geodetic Reference System of Japan: Its adoption and application to our products. Bulletin of the Geographical Survey Institute, Vol.50 March 2004.

Fukuoka Prefecture News 2006. Bulletin

Ministry of Land Infrastructure and Transport Japan: http://nlftp.mlit.go.jp/ksj/

AUTHOR INFORMATION

Name: Marisa MEI LING

Title: Doctoral Student

Organization: Institute of Environmental Systems, Kyushu University

Address: 744 Motooka, Nishi-ku, Fukuoka-shi, JAPAN 819-0395

Telephone: +81-92-802-3398

Fax number: +81-92-802-3396

E-mail address: marisa@ies.kyushu-u.ac.jp