(76) A GIS-BASED ESTIMATION OF ENVIRONMENTAL VARIATION FROM LONG-TERM LAND-USE CHANGE IN KITAKYUSHU AREA

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We obtained old topographic maps of four regions of Kitakyushu around the year of 1900, and then converted and summarized them into one 100m×100m mesh digital map. Using the land use data of Kitakyushu from 1976 to 2016 downloaded from MLIT, we standardized these land use maps including the digital map in 1900 by using ArcGIS software. The long-term land-use changes and urbanization during the past 110 years in Kitakyushu area were analyzed. From the deviation between the land uses in 1900 and 2016, we estimated the variation of CO_2 absorption in Kitakyushu area. The present method allows us to evaluate quantitatively the impact of the long-term land-use change on the green carbon in Kitakyushu area.

Key word: GIS, land use, urbanization, CO_2, environmental variation.

1. INTRODUCTION

With the urbanization in rural regions, the declines of forests, beaches, and croplands, and the reclamation of water areas has drastically changed environmental conditions. The land-use change is one of the most important factors for the global environmental change and inducing the carbon cycle imbalance. Also, the urban area becomes a large source of greenhouse gases through the consumption of fossil fuels and energy.[1)] It is very important to analyze the carbon absorption and emission in combination with the land use change.

A software created based on GIS, (i.e., ArcGIS) can speedily and conveniently combine the geographic information and attribute one. Therefore, digital maps and the ArcGIS software have widely been used for the analysis on the industry and environment.

In this study, we used ArcGIS to combine the geographic and attributive information of the land use map in Kitakyushu area to visually show the evolution of land use and its impact on the environment within the long-term temporal and spatial change.

2. PREPARATION OF DATA

(1) Conversion of old topographic maps

According to the homepage of *"Minster of Land, Infrastructure and Transport"* there was no digital land use maps before 1976, so that the long-term analysis of land uses was impossible. For this reason, a total of 23 old topographic maps including 4 regions in Kitakyushu around 1900 were collected and processed numerically. Due to some differences in the year of issue, the old topographic maps of 1903 and 1905 were defined as Kitakyushu old topographic maps of 1900 (**Fig.1**).

Since the scanned topographic maps are not available to some necessary elements, such as a digital coordinate system and unified legends. Therefore, adding digital properties to scanned maps is inevitable. In this research, the processing of scanned old topographic maps mainly involves the following three steps:

a) Correction of coordinates

Because the subsequent analysis is based on digital maps, the scanned maps need to be assigned a digital coordinate system. We used the "Georeference tool" that comes with ArcGIS to redefine the coordinates of each map.

b) Reference of legends

Although old maps in 1900 were accompanied by legends, there is a certain difference between the original representation and the latest one. Hence, we referred "The variation of map legends" published by the Japan Map Center to identify the land use type in the old topographic map.

c) Conversion to mesh files

We manually outlined the scanned map into a polygon file in ArcGIS. Then the polygon file needs to be converted into a 100m mesh file. Due to the boundary of the polygon file is irregular, two or more land use types exist in one mesh (**Fig.2**). Occupancy area was selected as a standard for normalization, by which filling grids' land use type with the largest areas one (**Fig.2**).

After the above three processes, the converted 100m×100m mesh land use map in 1900 is shown in **Fig.3**. The land use type was respectively classified into five types, i.e., forest, city, and water area including sea and river, cropland, and beach.

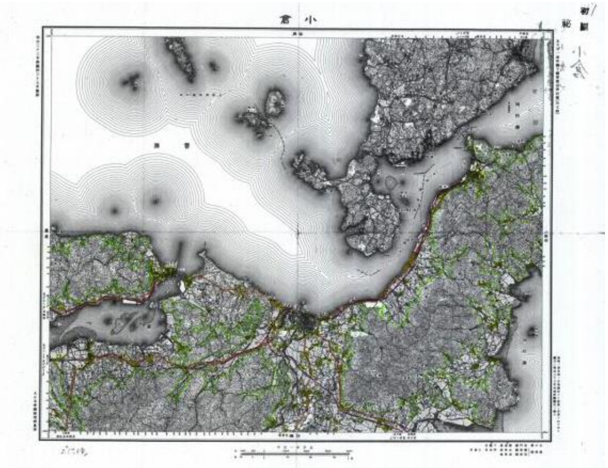


Fig.1 Old topographic map of Kitakyushu in 1900

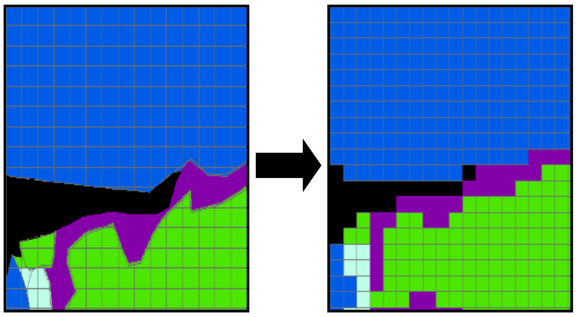


Fig.2 Procession from Polygon files into mesh files

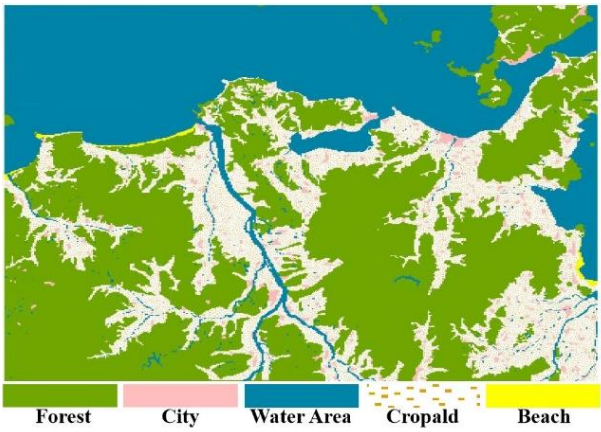
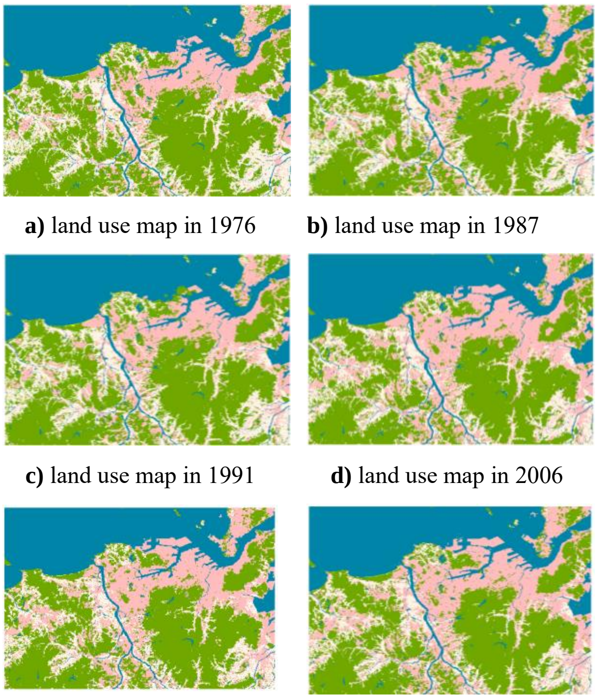


Fig.3 Digital map of Kitakyushu in 1900

(2) Collection and correction of other land uses

From the official website of *Minster of Land, Infrastructure and Transport*, we obtained the seven 100m×100m mesh maps in 1976, 1987, 1991, 1997, 2006, 2009 and 2016. The types of land use on the official website are more detailed, however they do not match the classification in 1900. In order to achieve the analysis afterwards, the official classification was condensed and summarized into the same five categories as in 1900.

The standardized land use maps are shown in the **Fig.4**. It can be clearly found from the figures that the proportion of city areas, (i.e., pink areas) in the whole map increases monotonically.



a) land use map in 1976 **b)** land use map in 1987
c) land use map in 1991 **d)** land use map in 2006
e) land use map in 2009 **f)** land use map in 2016

Fig.4 Unified land use maps from 1976 to 2016

3. CALCULATION AND ANALYSIS BASED ON LAND-USE CHANGE

(1) Urbanization

Through the transfer matrix made by ArcGIS, the urbanization areas from the four land-use types: forest, water area, cropland, and beach between 1900 and 2016 were extracted, as shown in **Fig.5**. The bottom-layer map shows the land-use distribution in 1900, where the light green, light blue, orange, and shaded yellow represent the urbanized areas converted from forest, water, cropland, and beach, respectively. It can be clearly seen from the figure that a large number of croplands have been changed to cities in the past 100 years, with the northeast region being the most concentrated.

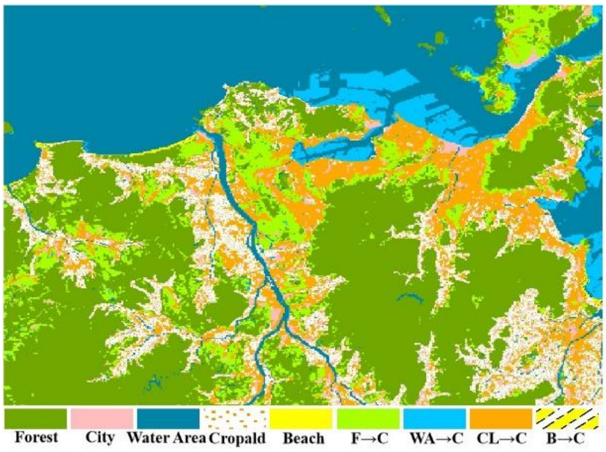


Fig.5: Urbanization from 1900 to 2016

In addition, we calculated the temporal variations of the land uses from 1900 to 2016, as shown in **Fig.6**. In 1900, the cropland and forest are accounted for 22.83% and 44.09% per the total area, respectively, whereas in 2016, their areas are dropped to 13.02% and 34.02%, i.e., both of these land uses almost drop 10%. The area of the city has risen from 2.06% in 1900 to 24.94% in 2016. From the figure, it can be found that there is a tendency of mutual compensation between the ascending segment for the city and the descending one for the cropland from 1976 to 2016. This also shows that the cropland may be a main part in the urbanization over 100 years.

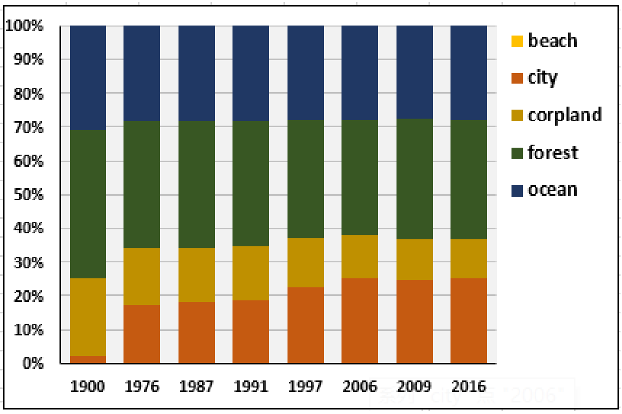


Fig.6: Land-use change from 1900 to 2016

(2) Estimation of CO2 absorption

In recent decades, the decline of natural resources through various human activities has become more serious. In particular, the activities such as uncontrolled destruction of forests, consumption of fossil fuels, change of land uses, and disappeared wetlands have caused the concentration of CO_2 in the atmosphere to increase so as to accelerate the climate change.

For this reason, the present study attempts to evaluate the temporal variation of CO_2 absorption over 100 years based on the GIS analysis of land-use change. The relation for the CO_2 absorption E_i is given by

$$E_i = T_i \times \delta_i , \qquad (1)$$

where i represents the i-th land-use type, Ti the CO_2 coefficient for the absorption, δ_i the area of the i-th land-use type.

The estimated results for the CO_2 absorption in 1900 and 2016 are summarized in **Table 1**[2) 3)]. Since the land-use category in 2016 is richer compared to that in 1900, the forest is divided into two parts. We can find from the table that the CO_2 absorption for each category in 2016 was smaller than that in 1900. In particular, the absorption of the cropland and forest was reduced by about 62% and 13% for 100 years.

Since the table cannot visually show the variation of CO_2 absorption by the land-use change, we used the ArcGIS to visualize the change of the CO_2 absorption of each mesh for different land types. The result is shown in **Fig.7**, where the blue-colored part indicates that the CO_2 absorption in 2016 is greater than that in 1900 whereas the red-colored part indicates the decreased area.

Table 1 CO_2 absorption estimation

Year	Land use	T_i (t/ha/year)	δ_i (ha)	E_i (t/year)
2016	Wetland	0.5156	2,052	34,220
	Woodland	0.6036	54,940	
	Cropland	0.0070	19,072	133.50
	Beach	0.0050	84	0.42
	Water Area	0.2380	44,855	10,675
1900	Forest	0.5596	71,066	39,769
	Cropland	0.0070	49,647	347.53
	Beach	0.0050	361	1.81
	Water Area	0.2380	49,647	11,816

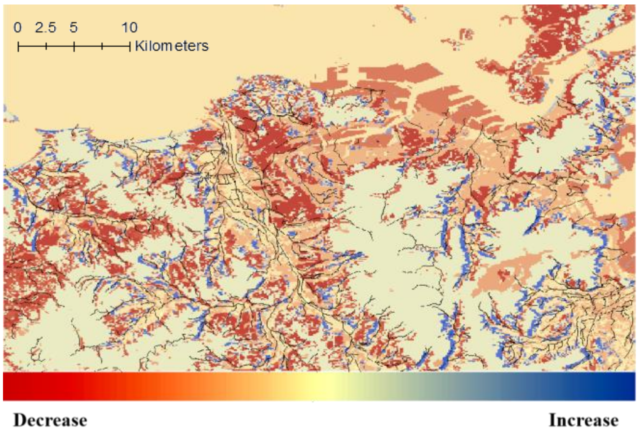


Fig.7 Change of CO_2 absorption between 1900 and 2016

4. CONCLUSION

In this study, we digitized the old map in 1900, and analyzed the influence of the land-use change based on the digital maps from 1976 to 2016. We found that the urbanization has continued to expand in 116 years, for which the intensity of urbanization increased sharply from 1987 to 2006, however it eased slightly after 2006. Moreover, the decline of the cropland was found to be most obvious among the five land use type from the year of 1976 to 2016.In the end, we estimated the local amount of CO_2 absorption by using the empirical relation.

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