Estimation on Sustainable Carbon Stock with using GIS - Case Study in Kitakyushu city, Japan

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This paper took Kitakyushu city in Japan as a case study to estimate sustainable carbon stock using Geographical Information System (GIS) data revealing historical change of land use and carbon density in Japan forest. Firstly, in order to examine land use change for each ward, land use types were divided into 10 classes (paddy, agri-land, forest, wasteland, land for building, trunk transportation land, river and lakes, seawater, grass and other land) according to national classification standard of land use and purpose of this study. Secondly, forest and urban area per person, carbon stock per capita and GDP per capita were calculated using carbon stock and economic and social indicators from 1976 to 2006. Based on forest area and carbon density, this approach resulted in estimated total carbon stocks of 985,543t C in 1976 and 921,920t C in 2006 respectively, indicating the contribution of carbon emission into the atmosphere over 30 years. The total area of forest was decreased by 6 % in 2006 compared to 1976. Correlation results showed that in 2006, carbon stock per capita was getting increased compared to that in 1997 because shrinkage rate of population is higher than the decreasing rate of forest area.

Research results indicated that land use change has grown more and more diversified and unbalanced. Land use change and carbon stock in Kitakyushu were revealed for decision makers toward low carbon society. The study was anticipated to better understand land use system, and develop land use management strategies that could better balance urban expansion, forest area and carbon stock.

Key Words : *Kitakyushu, Carbon Stock, Land use change, urban and forest area*

1. INTRODUCTION

Carbon presents in different natural stocks in the environment. These are oceans, fossil fuel deposits, the terrestrial system and atmosphere. A major part of the globe's terrestrial carbon, is sequestered in the standing forests, forest under-storey plants, leaf and forest soils. Carbon sequestration is the extraction of the atmospheric carbon dioxide and its storage in terrestrial ecosystems for a very long period of time. Forests offer some potential to be managed as a carbon sink[1)].

Carbon sink in forest and urban areas can be combined to see the whole picture of carbon stock in our society. Many studies suggest that at global level the storage of carbon in harvested wood product is likely to be increasing thus, being important for mitigating the accumulatin of green-house gas (GHG) concentration in the atmosphere.

More recently, industrialization has encouraged the concentration of human populations within urban areas (urbanization) and the depopulation of rural areas, accompanied by the intensification of agriculture in the most productive lands and the abandonment of marginal lands. All of these causes and their consequences are observable simultaneously around the world today[2)]. Land use change can cause a change in land cover and an associated change in carbon stocks[3)4)]. Based on trend of land use change, estimation of carbon stock in the region is crucial to understanding the regional, city level carbon budget and climate change. Forests are one of the most important carbon sinks on earth. However, because of the complex structure and variable geography, estimation of forest carbon stock is still a challenge[5)6)7)].

GIS data can be used to monitor land use change for estimation of carbon stock, for better assessment of damage from natural or anthropogenic events and for effective environmental management support.

The first objective of this study was to examine the process of historical change on land use from 1976 to 2006 in Kitakyushu city using GIS data. The second one was to identify the socio economic aspects of the changed process. The third one was to estimate the current land use change and carbon stock.

2. MATERIALS AND METHODS

(1) Study area

Kitakyushu (32 52`N, 130 49`E) is a city located in Fukuoka Prefecture, Kyushu, Japan. Kitakyushu is the second largest city in Fukuoka with a population of around 1 million. Its total area is 486.81 km^2 and population density is 2,019.34/km^2. Kitakyushu has seven wards: Kokurakita ward (39.27 km^2), Kokuraminami ward (170.25 km^2), Moji ward (73.37 km^2), Tobata ward (16.66 km^2), Yahatahigashi ward (36.36 km^2), Yahatanishi ward (83.04 km^2) and Wakamatsu ward (67.86 km^2).

(2) Data source and research method

The data in this study spanned 30 years that were divided into the year nodes of 1976, 1987, 1991, 1997 and 2006. To instigate land use change in Kitakyushu city in Japan from 1976 to 2006, GIS format land use data from National Land Information Division, National and Regional Policy Bureau, Japan was used. Firstly, using Arc View software, five national land use maps of Japan were taken for extracting the map of study area using administrative map of Kitakyushu. Secondly, land use map of Japan and administrative map of Kitakyushu were joined to obtain the land use mesh data of Kitakyushu in 100m x 100m resolution in each year.

As a statistical data, carbon density for all forests including planted and natural forests in Japan, Gross Domestic Products (GDP), population and road infrastructure data were used from 1976 to 2006 in Kitakyushu as shown in **Fig. 1**.

Table 1 C density for all forests and planted and natural forests in Japan[8)]

Period	C density (Mg C/ha)		
	Mean	Planted	Natural
1976-80	41.9	38.3	44.4
1981-85	47.2	45.4	48.6
1986-90	50.4	51.1	49.8
1991-95	53.6	58.5	49.8

Following the study purpose, land use types were divided into 10 classes (Paddy, Agri-Land, Forest, Wasteland, Land for Building, Trunk Transportation Land, Grass, River and Lakes, Seawater and other land) in each ward in Kitakyushu. Land use figure of five different years were obtained.

Research method included three aspects: processing GIS data in each ward in each year; correlation between land use change and socio economic data using both GIS and statistical data and estimation of carbon stock based on forest area in the Kitakyushu city. In order to calculate the carbon stock in each ward in each year, the following equation is used[9)]:

$$A_c \times C_{dc} = \Delta C_c \quad (1)$$

Where, A_c : area lost/ gain per class c
C_{dc} : carbon density for respective class c
C_c : change in carbon stock for respective class c

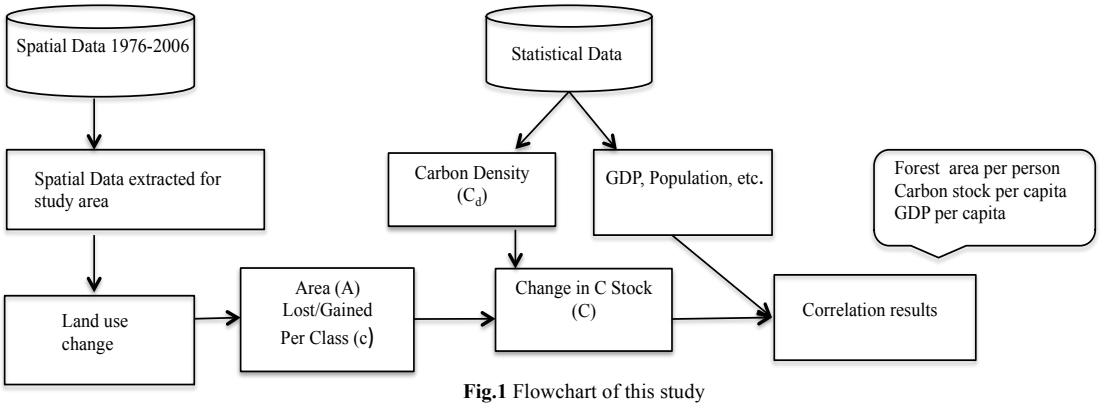

Fig.1 Flowchart of this study

3. RESULTS AND DISCUSSION

(1) Land use change from 1976 to 2006

The land use maps of the Kitakyushu in 1976, 1987, 1991, 1997 and 2006 obtained by GIS data are showed in **Fig.2**. In 1976, forest occupied the largest proportion of land (about 50%), followed by padddy (about15%) and urban (about 10%). In 1987, these shares were 40%, 9% and 25%, respectively, and in 1991, they were 35%, 8% and 25%. In 2006, the urban area was increased to 30% but forest and paddy were decreased to 30% and 5% as shown in **Table 1**.

Spatially, the larger percent of urban land increased in Yahatanichi and Kokuraminami wards among the wards in Kitakyushu but in Tobata and Yahatahigashi wards urban area has less percent increase between 1976 and 2006.

It can be seen that there is significant change in the land use, with urban land greately expanding while paddy farm land decreasing. Between 1976 and 1987, about 494 hectares of paddy land were converted to urban use. 119 hectares of paddy land between 1987 and 1991 and 955 hectares between 1991 and 2006 were used for urban purpose.

During the period 1976 and 2006, 2,173 hectares of water area were changed into urban use purpose in Kitakyushu. In order to mitigate the negative effects of city development on natural resources, the environment and quality of life in the city, efforts have been made to increase the area of vegetation by laying out wooded parks in the suburban areas, planting trees along the roads and increasing the green spaces in residential zones.

As a result, 323 hectares of grass land were increased for urban relaxation and golf course between 1976 and 2006.

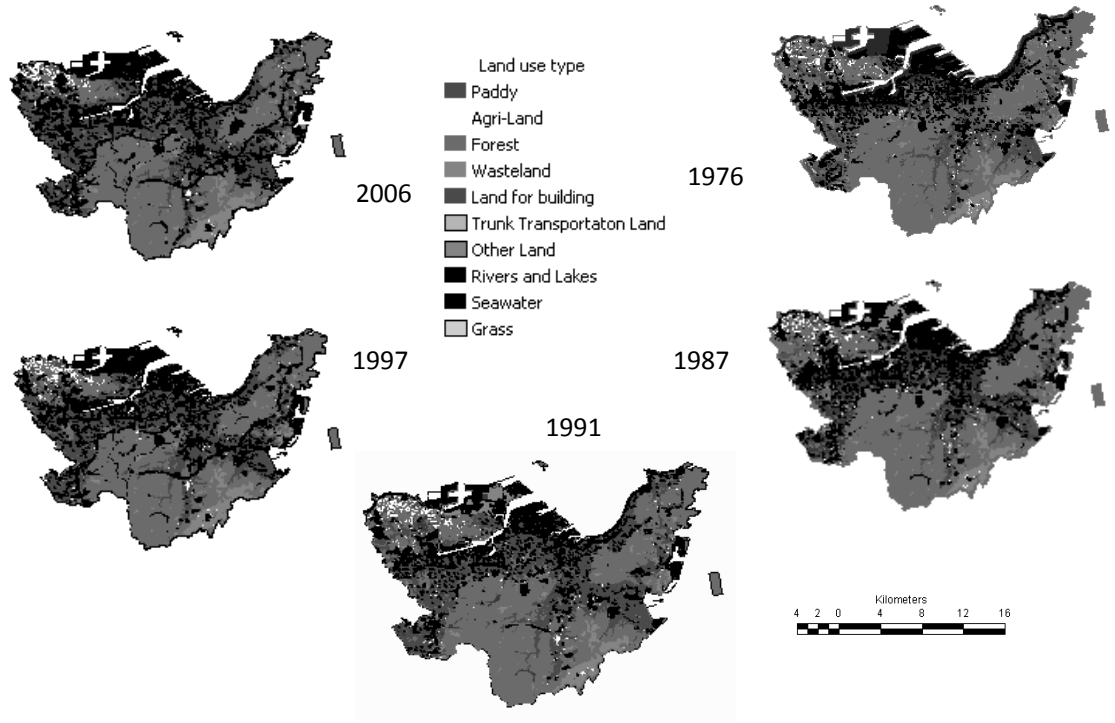

Fig. 2 Land use maps of Kitakyushu for 1976, 1987, 1991, 1997 and 2006

Table 2 Land use change of Kitakyushu between 1976 and 2006 (Hectares)

Year	Paddy	Agri- Land	Forest	Wasteland	Urban	Water	Grass	Other Land
1976	4295	619	18387	2207	3354	3113	0	5010
1987	3802	625	18385	2537	10658	3225	0	3424
1991	3683	766	18057	2584	10803	3093	28	3784
1997	3177	802	17583	2155	13133	1252	269	4276
2006	2728	691	17200	2290	14259	946	323	4277

(2) Urban area growth and socioeconomic background in 1976-2006

In view of the insufficiency of GIS data for providing continuous information of land use and socioeconomic change. the trend of urban area based on GIS data from 1976 to 2006 and the socioeconomic gackground based on statistical data from 1990 to 2009 are decribed as shown in **Fig.3**. Generally, the increase of urban area in Kitakyushu went through a rapid expansion stage between 1976 and 1987, followed by slow growth in the period 1978-1991 and medium growth after 1991[10].

In the 1990s, Kitakyushu's economy rapidly developed. With the rapid development of economy, urban industrial structure was significantly changed[11]. In term of road infrastructure, the length of road was increased with a rapid growth until 2009. In 1991, about 3.8 meters per person was changed into about 4.3 meters per person.

According to the **Fig.3**, the trend of population was decreased with slow rate from 1.021 million in 1991 to 1.019 million in 1995 but from 1995 up to 2009, it was changed to 0.982 million with dramatic rate in Kitakyushu. Like other cities in Japan, Kitakyushu has been facing a decline birthrate and an older population that means there are more retired people and relatively less working people and working people are increasingly called upon to support the retirees with their labor. Currently, about 70 percent of the population in Kitakyushu is of working age. According to projection of National Institute of Population and Social Security Research, if current trends continues, the figure will drop to 60 percent by 2025.

A shrinking population is likely to cause the economy shrinkage. The economy of Kitakyushu is regarded as a mature economy. According to Investopedia, a mature economy is the situation where the country's population has stabilized or is in deline, and the pace of economic growth has also slowed. A mature economy is characterized by a decrease in spending on infrastructure, and a relative increase in sonsumer spending. For GDP in Kitakyushu, the trend of GDP from 1997 to 2002 declined dramatically but from 2002 to 2004, it had stable trend of GDP. During the period between 2004 and 2009, high fluctuation was occurred in economic progress[12]. In the **Fig.3-4**, the same number of the minimum values on the axises are not used to show clear trends in each change in the study.

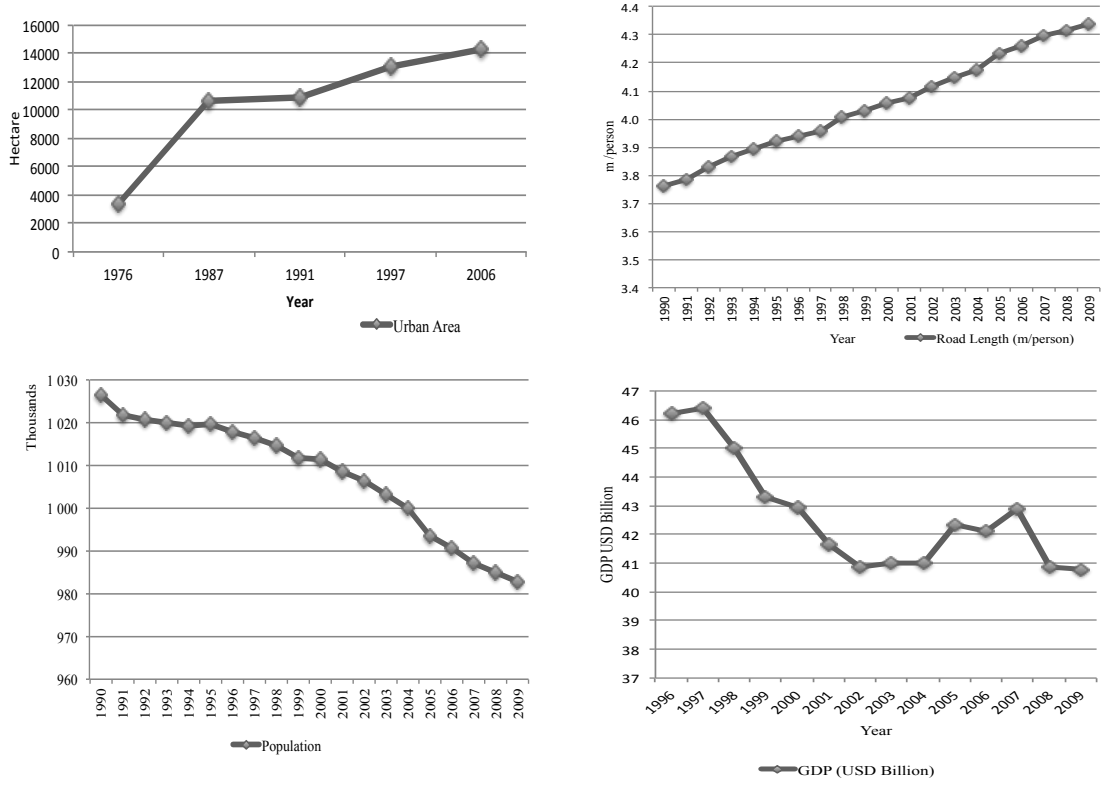

Fig.3 Comparison of urban area growth, population, GDP and road infrastructure trends

(3) Relationship of urban area, forest area and carbon stock in 1976-2006

In 1976, urban area per person was 31.5 m^2 but it was increased to 106.3 m^2 in 1991. In 2006, urban area per person was found at 143.9 m^2. While the population was shrinking, urban area per person went up dramatically. In 1970s, the rate of economic growth developed very rapidly. The economic development also brought up increases in investment of housing construction, industrial estates and other urban use which led to the expanding of urban space at an accelerated rate.

In Kitakyushu, forest area was decreased from 18,387 hectares in 1976 to 17,200 hectares in 2006 due to many kinds of reasons such as larger increase of land for urban use purpose. The largest area of forest (over 800 hectares) was lost in the Kokuraminami ward compared to other wards between 1976 and 2006. The forest area in Yahatanishi ward was lost from 2,632 hectares in 1976 to 2,133 hectares in 2006. But some wards such as Tobata ward and kokurakita ward had made progress in increasing forest area. In Kitakyushu, forest area per person was 172.8 m^2 in 1976 but 176.7 m^2 in 1991 and 173.6 m^2 in 2006. The trend of forest area per person went down from 1976 to 1991 but the trend went down from 1991 until 2006 because population shrinkage rate is higher than the reduction rate of forest area during the period of 1991-2006.

In terms of relationship of urban area and forest area per person, the trend of urban area per person grew with very rapid upward from 1976 to 2006 while having population shrinkage. It means the rate of urban area development per person was much higher than that of population decline. But forest area per person grew at very slow rate from 1976 to 2006. The trend of forest area and urban area per person was reflected by the population.

Based on combining mean carbon density for Japan forest, carbon stock in each ward could be obtained in Kitakyushu. In the past 30 years, forest C stocks in Kitakyushu was decreased from 985,543 Mg C in 1976 to 967,855 Mg C in 1991 and 921,920 Mg C in 2006. In term of carbon stock per capita, 0.926 Mg C in 1976 was changed into 0.947 Mg C in 1991 and 0.931 Mg C in 2006 as shown in **Fig.4**. Carbon stock per person in 1976 is almost the same with that in 2006 because it has been effected by the trend of forest area and population. In 2006, Kokuraminami ward is the highest one among the wards, in terms of carbon stock per capita (2.01 Mg C/ person) and forest area per persib (375 m^2/ person). Compared to other wards, Tobata ward is the lowert one because of carbon stock per capita (0.05 Mg C/ person) and forest area per person (9 m^2/person).

(4) Sustainable carbon stock

Under the terms of the Kyoto Portocol, Japan has agreed to reduce its GHG emission by 6 percent rel

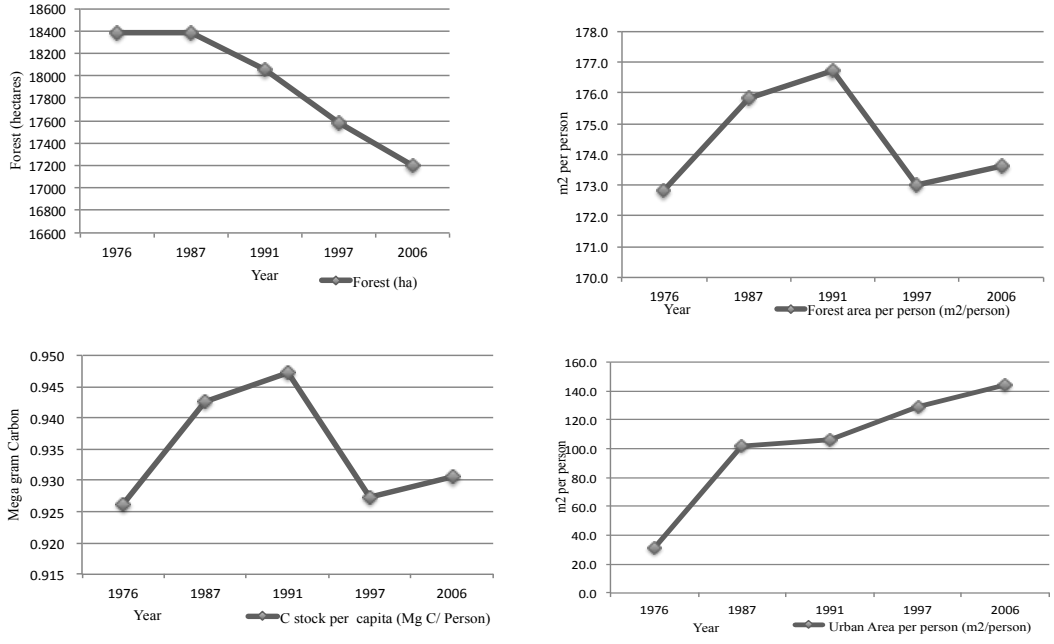

Fig.4 Relationship of urban area, forest area and carbon stock per person during 1976-2006

ative to 1990 levels[13]. Consequently, the sources of carbon stock should be deveoped and maintained through sustainable forest management[14]. Under the Japan commitment 6% reduction of GHG under Kyoto Protocol, 3.8% will be achieved by carbon sink. Japanese government develop the policy to promote sound forest management and efficient utilization of timber resources[15]. Scientific evidence indicates that carbon in wood harvested from forest is stored in products for a period of time[16]. Carbon dioxide is removed from the atmosphere by increasing carbon stock in both forests and wood products in urban areas by displacing more energy intensive materials such as steel[17].

The strategic management of carbon stock in forest area and urban area is likely to lead to sustainable carbon stock in the region in the long term.

5. CONCLUSION

This paper investigated the trend of land use change and carbon stock in Kitakyushu associated with socioeconomic aspect using GIS data from 1976 to 2006. The flow of urban area, GDP, road lenth per capita and population were also examined for evaluating the linkage of each other in Kitakyushu. In addition, relationship of forest area, urban area and carbon stock was studied for better understanding. Future studies will focus on Southeast Asian countries where that kind of researches are rarely done due to lack of efficient data. Association of Southeast Asian Nations (ASEAN) is the fourth largest trading entity in the world after the European Union, the United States and Japan, with its combined trade value[18]. Today, Southeast Asia has a total market of about 500 million and a combined GDP of more than US$ 700 billion[19]. The trend of land use change is occurred at very fast rate due to economic development[20]. In Southeast Asian region, study on the relationship of land use change, socio-economic development and carbon stock will be interesting. In the future studies, the period of study year will be extended up to the uptodate year to reflect the current situation of study area using GIS and Remote Sensing data for efficient results. To predict future land use change and trend of carbon stock in the region, a suitable dynamic model will be used for better assessment of the research.

In conclusion, research results indicated that land use change has grown more and more diversified and unbalanced. Land use change and carbon stock in Kitakyushu were revealed for decision makers toward low carbon society. The study was anticipated to better understand land use system and land use management strategies that could better balance urban expansion, forest area and carbon stock.

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