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도시지역에서의 녹지상실의 환경적 경제적 효과*

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The Environmental and Economic Effects of Green Area Loss on Urban Areas*

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요 약

토지이용의 전환에 따른 기후의 변화와 토지가격의 변화를 파악하는 것은 도시민의 후생수준과 지속가능한 개발을 위해 매우 중요한 과제이다. 그러나 도시특성에 관한 정보가 부족하여 활발하게 연구되지 못하였다. 이제 원격탐사를 통한 위성영상의 구득이 쉬워졌고 또 통계청이 기초단위구 자료를 구축함에 따라 이 분야의 연구가 가능하게 되었다. 본 연구는 도시지역의 비도시용 토지가 도시적 용도로 전환됨에 따라 표면온도와 토지가격의 측면에서 어떠한 변화를 유발하는가를 분석하였다. 분석결과 녹지 및 농경지로 사용되던 토지가 공업용토지로 전환된 경우 가장 큰 표면온도의 상승을 초래하였고 상업용지와 단독주택지가 그 뒤를 이었다. 식생지수의 변화도 표면온도의 변화와 비슷한 변화를 보였다. 토지가격의 전환측면에서는 상업용토지로 전환될 경우 가장 큰 가격상승을 초래하였고 그 뒤를 이어 주거지 공업용지의 순으로 나타났다. 이처럼 도시지역의 토지이용의 전환은 표면온도를 상승시킬 뿐 아니라 토지가격도 상승시켜 사회적 부담을 주지만 그 혜택은 사회구성원 중 극히 일부에 한정되는 문제가 있다. 도시정책과 관련된 정책결정권자 및 계획가는 이 문제의 해결을 위해 도시성장관리 정책의 확립 등 보다 효과적인 정책수단을 강구하여야 할 것이다.

주요어: 표면온도, 표준식생지수, 토지이용전환, 도시성장관리

Abstract

Modeling urban climate caused by land use conversion is critical for human welfare and sustainable development, but has hampered because detailed information on urban characteristics is hard to obtain. With the advantage of satellite observations and the new statistical boundary system, this paper measures the economic and environmental effects of green area loss due to land use

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conversion in urban areas.

To perform this purpose, data were collected from the various sources basic statistical unit data from the National Statistical Office, digital maps from the National Geographic Information Institute, satellite images, and field surveys when necessary. All data (maps and attributes) are built into the geographic information system (GIS). This paper also utilizes Landsat TM 5 imagery of Daegu city to derive vegetation index and to measure average surface temperature. The satellite data were examined using standard image processing software, ERDAS IMAGINE, and the results of the digital processing were presented with ARCVIEW(v.3.3). SAS package was used to perform statistical analyses.

This study presents that there exists a strong relationship between land use change and climatic change as well as land price change. Based on results of the analysis, this paper suggests that planners should implement effective tools and policies of urban growth management to detect environmental quality and to make right decisions on policies concerning smart urban growth.

KEYWORDS: Surface Temperature, Vegetation Index, Land Use Conversion, Urban Growth Management

I. Introduction

The green areas with trees and forests provide us with essential health, recreational, aesthetic and other benefits. Unfortunately, as cities expand, agricultural land and habitats such as forest and wetlands are transformed into land for housing, roads and industry. In Korea, the rapid expansion of urbanized area due to urbanization as well as suburbanization trends toward/around major cities brought about a serious sprawl problem. Commercial and residential developments are taking place at the edge of cities especially along major connecting roadways. This kind of urban phenomena has been examined through urban growth model or urban land use change model. Among them, some researchers focused on the relationship between land use change and climate change (Carlson and Arthur, 2000; Solecki et al, 2004). But none of the research pays attention to the effects of land use conversion from non urban uses to urban uses in terms of environmental and economic aspect simultaneously.

The land use conversion, from non urban uses to urban uses, affects the environmental conditions as well as economic values of the lands. The conversion causes social costs due to green area loss and land price hike. Only small portion of the society, such as land owners and developers, earns gains from trade and development at the expanse of society as a whole. In short, the expansion of urban land has severe climatic and price impacts since the simultaneous removal of natural land cover and the introduction of urban materials (e.g., concrete, metal) alters the surface energy balance (Owen et al, 1998).

In cities around world, many of the benefits and services provided by green areas actually save money that would be spent on such things as water purification, stormwater runoff and health care. A failure to recognize their financial and ecological benefits and services leads to a failure to protect these valuable assets. When cities lose trees and forests, they must incur additional expenses to replace lost services. In fact, many cities lost a considerable amount of money in air pollution removal services and stormwater management services by allowing their tree canopy decline. However, since regional land cover changes brought by human activity tend to occur incrementally, communities often do not realize the extent of their development and therefore, the possible changes in their environment. In this regard, satellite data holds great potential for practical application to regional planning and urban ecology, providing essential information in terms of temporal and spatial aspect.

In this paper, we illustrate how satellite derived surface temperature and vegetation fraction change in response to surface development in the case of Daegu city. By doing this, this paper examines the environmental and economic effects of green areas. The environmental effects are analyzed by surface temperature and vegetation fraction, and the economic effects are measured by land price. All effects are visualized and quantified.

II. STUDY AREA. DATA and APPROACH

2-1. Study area

Daegu city was chosen as the focus for this study because it epitomizes the rapid suburbanizing patterns of growth prevalent in many parts of Korea. The city is located Southeastern part of Korea. It contains 2.4 million inhabitants in an area of 811 km2 for population density of 3,005.9 person/km2. The city, as a regional center, extends out along highways and railroads. The study area contains seven Gus(District, the primary self governing body in urban areas) and on Gun(the primary self governing body in rural areas). A smaller area of interest was selected to correspond to Dalseo Gu located southeast of Daegu for better visual presentation and understanding, when necessary.

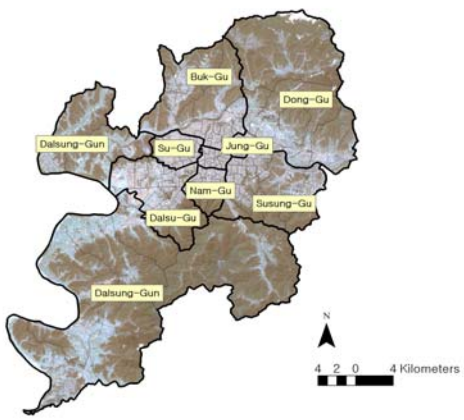

FIGURE 1. Study area

2-2. Data and approach

Monitoring land use change is very important for urban and regional planning. However, continuous updating of land use information within a city is not economically efficient. Remote sensing technology can provide a method for acquiring regular, recent information for climate and land use change. For this reason, this paper utilizes Landsat TM 5 imagery of 1989(October 12) and 2000(October 16) of Daegu city to derive vegetation index and to measure surface temperature changes.

The land use attribute data was not available in primary administration unit until 2001 in Korea. Even worse, the existing land use maps need more detailed ground survey. Under these circumstances, digital images acquired by satellite sensors can be a reasonable substitute for conventional land use maps. Fortunately, however, Korea National Statistical Office established "the basic survey unit" which is similar with the census block in year 2001, and thus, the land use data is available by the basic survey unit. It provides 18 land use types along with primary information on population and housing. Because market price of land by land use is very difficult to obtain, this study employs the official land price released by the Korean Ministry of Construction and Transportation (MOCT). The MOCT has released the land price of every parcel (called 'standard parcels') within the nation every year from 1989. This official land price is being used for land use planning and imposing land property taxes. It is known that the official price is about 30 percent of the market price, by date.

The satellite data were examined using standard image processing software, ERDAS (v.8.6) and the results of the digital processing were presented with ARCVIEW (v.3.3). The statistical analyses were performed by SAS package. The satellite image was transformed into Transverse Mercado(TM) coordinate system by using 1:25,000 scale standard topographic maps. Geometric correction was based on the first order polynomial equations. The pixel size was maintained at 30m.

The urban area identified by land cover analysis is classified into five categories single detached housings, apartment housings, commercial use, manufacturing use and green area – to measure the environmental and price effects by land use. Statistics performed on classified images for Daegu city showed a progressive increase in urban or built –up land occurring largely at the expense of farmland and forested area. These land use transformation makes urban temperature higher.

In order to compare the surface temperature of 1989 and 2000 in standardized manner, average surface temperatures of all basic survey units are converted to z score calculated by following simple formula.

$$z = \frac{(X - \mu)}{\sigma}$$

The Greek letter μ and σ are used to represent mean and standard deviation of theoretical frequency distribution. This formula enables one to find the point z on the standard normal curve that corresponds to any point x on a nonstandard normal curve. The variable z possesses the mean 0 and the standard deviation 1. By this manner, this conversion makes possible to measure the temperature differences even though the weather of two dates are different.

III. ECONOMIC and ENVIRONMENTAL EFFECTS of GREEN AREA LOSS

3-1. The expansion features of urban area

Between 1989 and 2000, the urbanized area has been increased by 43.7㎢ as shown in Table 1. The area by land use was calculated by utilizing land use data of the basic statistical unit, as explained earlier. High proportion of the converted land was allocated to the residential uses, especially to the multi family housings. The land allocated to manufacturing use by industrial zoning was 20.8 percent of the total.

3-2. environmental effects

3-2-1. The distribution of surface temperature

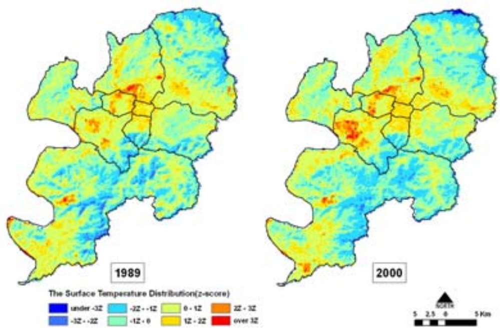

FIGURE 2. The surface temperature: Daegu City

TABLE 1. Land use type of the newly developed lands: 1989-2000

Land use	Area(㎢)	Share(%)
Single detached housings	4.1	9.4
Multi family housings	9.2	21.1
Commercial uses	1.9	4.4
Manufacturing use	9.1	20.8
Other mixed use	7.3	16.6
Mixed use of housings and commercial buildings	3.0	6.9
Mixed use of housings and manufacturing facilities	0.9	2.1
Cultural and public uses	8.2	18.7
Total	43.7	100.0

TABLE 2. The surface temperature: Daegu City(2000)

Land use classification	Temperature(℃)	Z-score
Single detached housings	18.28	0.98
Apartment housings	17.33	0.63
Commercial use	19.12	1.30
Manufacturing use	20.52	1.84
Green areas	14.93	0.30
Average	15.60	1.00

TABLE 3. Surface temperature by land use: Daegu City 1989 2000 (unit: z score)

From green area to	1989	2000	Changes(%)
Single detached housings	0.34	0.98	188.2
Apartment housings	0.34	0.63	85.3
Commercial use	0.34	1.30	282.4
Manufacturing use	0.34	1.84	441.2
Green area	0.34	0.40	17.6

The surface temperature was calculated by the general conversion formula explained in many papers Figure 2 illustrates the standardized surface temperature distribution of the study area. The figure tells us that the surface temperature of urbanized areas is higher than that of non urban areas in general. The surface temperature is the lowest in mountainous areas and the highest in urban centers and traditional manufacturing areas. In addition, high temperature areas are observed along east west axis of the city, and they expand rapidly as time passes. There are many urban heat islands across the city. Such phenomenon confirms that some forms of planning efforts to reduce dangers to human settlements in urban areas. The surface temperature by land use in 2000 is shown in Table 2.

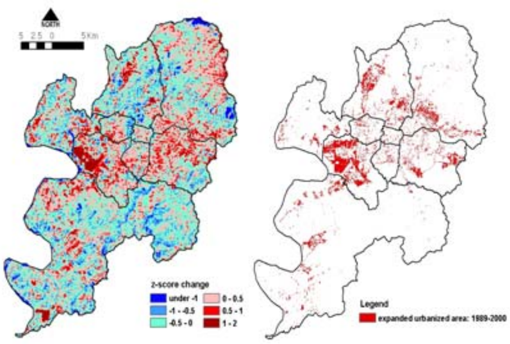

FIGURE 3. The surface temperature change and urban expansion

Figure 3 demonstrates the spatial distribution of the new land development (right) and surface temperature change(left) between 1989 and 2000. There are many urban heat islands(UHI), caused by the temperature difference between urban and rural area, across the city. Giridharan et al(2005) found out that the UHI effect depends on urban features such as urban textures, street pattern and orientation along with the differences in net long wave radiation between urban and rural area. By focusing on residential buildings only, they left the direct effects of other land use changes unmentioned. However, Figure 3, the result of this study, highlights the coincidence of the distribution of the temperature change and the new land development. The most profound changes in the area were in the western parts of Dalseo Gu where extensive housing and industrial sites were built in green area.

A step further, Table 3 shows temperature changes caused by land use conversion from 1989 to 2000 in Daegu city as a whole. In Table 3, the land use of all lands in 2000 was green area in 1989. Therefore, the surface temperature of green area in 1989 was applied to all land uses in Table 3. Among land use changes, green area to manufacturing use is the highest climatic impact and to apartment housing use is the lowest climatic impact in general.

3-2-2. Spatial distribution of vegetation index

The vegetation level, the density of green vegetation across the Earth's landscapes, is converted into NDVI (Normalized Difference Vegetation Index) by using the following equation.

$$NDVI = \frac{Band\ 4 - Band\ 3}{Band\ 4 + Band\ 3}$$

where "Band4" is near infrared light, and "Band3" is red light. NDVI, range between 1 and +1, can be interpreted as the difference in reflectance is divided by the sum of the two reflectances. An NDVI value of 1 means no green vegetation and close to +1 indicates the highest possible density of green leaves. The NDVI is most frequently used index for satellite imagery, and thus, it is employed in this study.

The NDVI of the two years are illustrated in Figure 4. The spatial distribution of the vegetation level (NDVI) is very similar with that of the surface temperature(Figure 1) high in green areas and low in urbanized areas. Also, the low vegetation areas are expanding as urbanized areas expand.

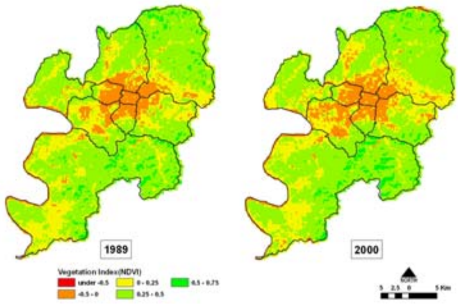

FIGURE 4. The NVDI of 1989 and 2000

3-3. Effects on land price

Because green area means so much to so many, it is often difficult to estimate its value on an economic level. However, in order to secure it for historical or ecological preservation, recreational use or simply as magnificent scenery, one should quantify the value of these lands. However, unfortunately, there is a high tendency for local government to allow land development in green areas because they are heavily dependent on the property tax for operating revenues. Keeping this in mind, a part of Dalseo Gu was selected to calculate the effects of land use change on land value in order to show the price effect of the land use change in detail. Figure 4 displays the land use change and Table 5 presents land price change from 1989 to 2000. Extensive single family and multiple dwelling residential development along

TABLE 4. The NDVI by land use: Daegu City: 1989 2000

From green area to	1989	2000	Changes(%)
Single detached housings	0.012	0.010	16.7
Apartment housings	0.085	0.007	
Commercial use	0.068	0.017	
Manufacturing use	0.078	0.051	34.6
Green area	0.223	0.218	2.2

with industrial site development (Figure 5 right) has taken place on the sites of former agricultural land or green areas (Figure 5 left).

The price of lands for urban use converted from green area has increased rapidly as Table 5 displays. Among them, the land for commercial use has the highest price effect, and for residential use is next. On the contrary, the price of the green area is decreased most likely due to more restricted land use regulation to preserve neighborhood and regional parks.

IV. CONCLUSION

It is known that modeling urban climate caused by land use conversion is critical for human welfare and sustainable development. Detailed information on urban characteristics with the advantage of satellite observations and the new statistical boundary system enables us to measure the economic and environmental effects of green area loss due to land use conversion in urban areas.

This study examines the environmental and economic effects of green area loss in the case

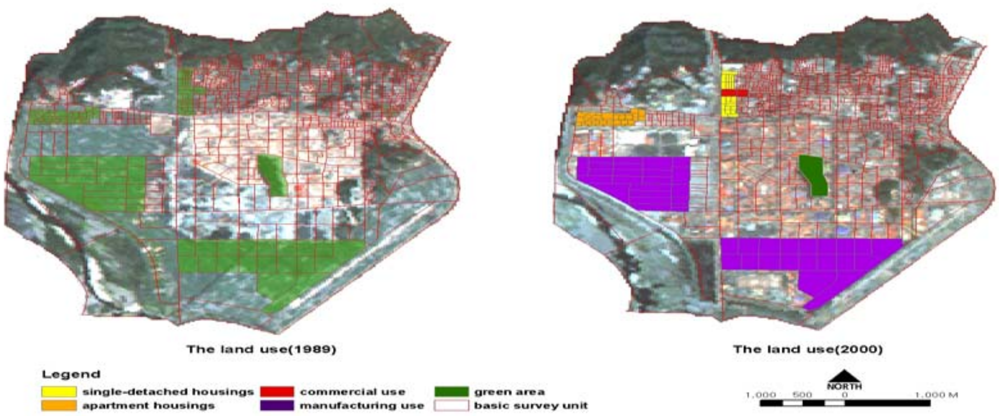

FIGURE 5. Land use change of selected area

TABLE 5. The land price by land use (unit: Korean Won*, per m^2)

From green area to	1990	2000	Changes(%)
Single detached housings	87,188	609,333	598.9
Apartment housings	75,000	522,167	596.2
Commercial use	85,692	982,625	1046.7
Manufacturing use	54,273	157,100	189.5
Green area	36,615	18,438	49.6

*: Current price($1= ₩950 approximately)

of Daegu metropolitan city. It is clear that the land use conversion affects surface temperature as well as vegetation level. It also makes the land prices higher than previous uses as expected. We know that there are many other factors which affect surface temperature, such as season, year, urban characteristics, and so on. However, for the data consistency, we consider only one factor – land use change, assuming all other factors remain unchanged.

The most distinctive result of the land use conversions in suburban areas is about the winners and losers of the conversion. We know that the open space, trees and forests are valuable social assets. As this study illustrates, a birth of urbanized area means a dead of green area. In this case, the society loses all benefits of the green areas. Even worse, the society pays costs brought by the green area loss if a proper institutional mechanism absent. On the contrary, land owners of suburban areas get tremendous monetary gains from the land use conversion, as price increases imply. Therefore, they try to convert their undeveloped lands into urban uses by mobilizing various pressures on local governments instantaneously. Local governments in many cases favor such land use conversions expecting higher tax revenues, especially property related taxes.

Of course, the price increase of the converted lands means the increase in productivity of the lands. Higher land efficiency may contribute to achieve high social productivity as well. The problem is that the benefits from land price increase are limited to small portion of members only, and the negative effects are charged upon whole society.

In addition, the results of this study are also related with urban spatial structure. It is said that the dispersed development pattern brings about sprawl, while the infill development pattern contributes sustainable development. We should remember that planning paradigm after 1990s has been changed from “growth” to “sustainable development.” We should also keep in mind that most of environmental disasters have global effects. Planners around world pay serious attention to make cities and regions sustainable and to realize smart growth. They know that the task of spatial planning is to design, implement and manage alternative futures for a complex, dynamic socio spatial environment that emerges from a wide range of intertwined social, political, economic and environmental processes. In this regard, planners should find a win win strategy which makes developments environment friendly. KAGIS

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