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Predicting Future Urban Growth with Zonal Data and Satellite Images for Sustainable Urban Development

- The Case of Daegu Metropolitan Area, Korea -

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Introduction

The Background of Study

-Both rapid urbanization and the suburbanization in major metropolitan areas bring about land use conversion from agricultural/forest to urban uses at the rural-urban fringe.

-Due to the side effects of the rapid urban expansion, there is growing need for effective management and planning of urban region.

-To derive meaningful policy implications, adequate information about the causes and effects of urban change process should be available.

-The computer-based models for describing urban development patterns and determining the future impacts of growth management policy choices become operational: geographic information systems (GIS) and remote sensing

Introduction

The Purpose of Study

This paper develops maps of past changes in the built environment, uses them to calibrate a spatial predictive model, and generates maps of expected future change under various policy scenarios out to year 2020 with zonal data in combination with remote sensing technology

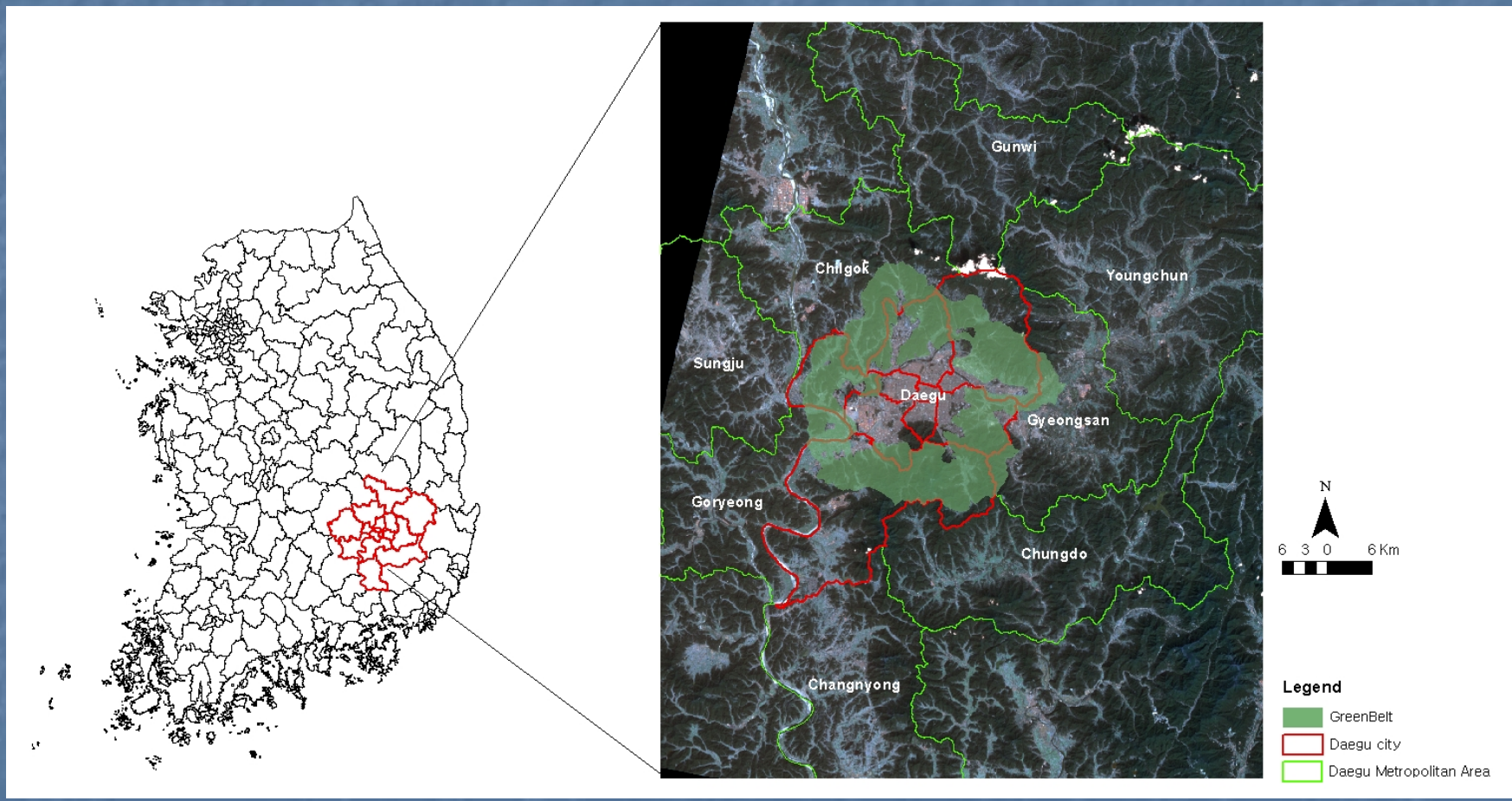
Study Area

- Daegu city is located Southeastern part of Korea. It contains 2.4 million inhabitants in an area of 811 km^2 for population density of 3,005.9 person/km^2.

- The study area contains seven Gus(District, the primary self-governing body in the greater city area), two cities and six Guns(the primary self-governing body in rural areas), as shown in Figure 1.

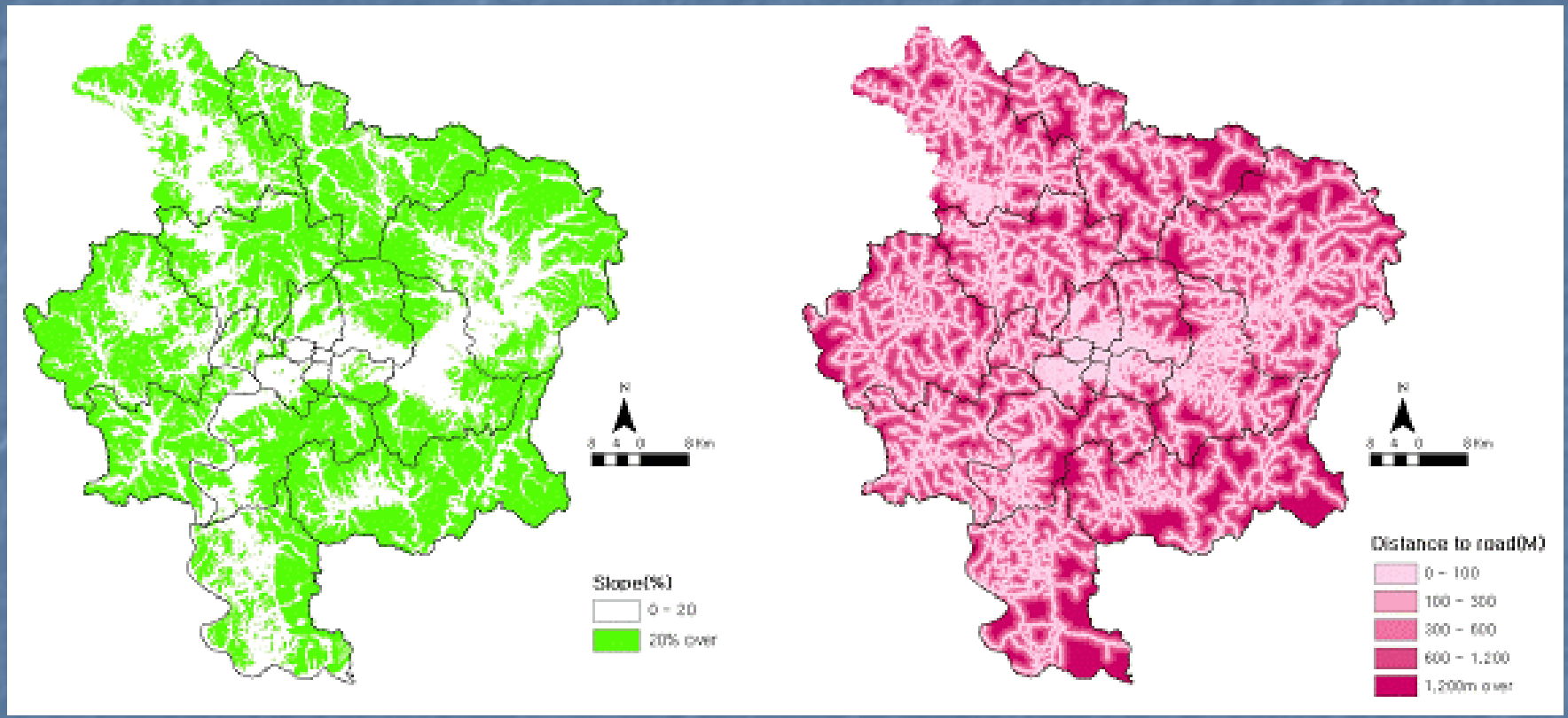
Study Area

Study Area



Study Area

- The Slope and Road Features of the Study Area



Study Area

Description of the Study Area

	No. of the primary adm. unit	No. of the Basic statistical unit	area(□)	population	No. of household
City of Daegu	138	15,690	881.2	2,438,106	762,119
Changnyong Gun	14	584	527.2	64,049	24,562
Chilgok Gun	8	616	452.0	100,273	31,185
Chungdo Gun	9	350	691.3	47,296	17,181
Goryeong Gun	8	243	383.8	34,979	12,366
Gunwi Gun	8	275	611.9	28,262	10,907
Gyeongsan City	14	1,504	411.4	225,250	70,710
Sungju Gun	10	365	615.8	46,327	16,541
Youngchun City	16	963	916.3	108,996	38,455

Data

-Zonal data and Satellite data

Zonal data: attributes/vector

Satellite data: image/raster

- Image Data: Landsat TM 5 imagery of 1985, 1990, 1995 and 2000 of Daegu metropolitan area to identify changes of urban extents
- Attribute Data: "the basic statistical unit"

The Basic Statistical Unit

Korea National Statistical Office established "the basic statistical unit" which is similar with the census block in year 2001

It provides 18 land use types along with primary information on population and housing.

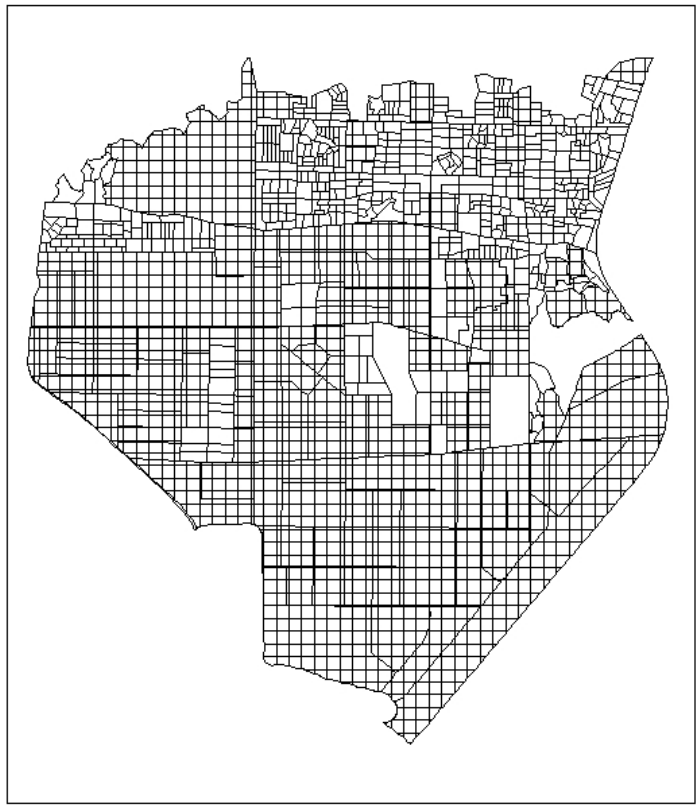
One critical problem of the statistical unit to predict future urban growth is the variation of the size. In densely-populated areas, the size of the basic statistical unit is small while fringe of city or rural areas is large

Data

Dividing the basic statistical unit into the grid cell

Legend

Basic statistical unit



Legend

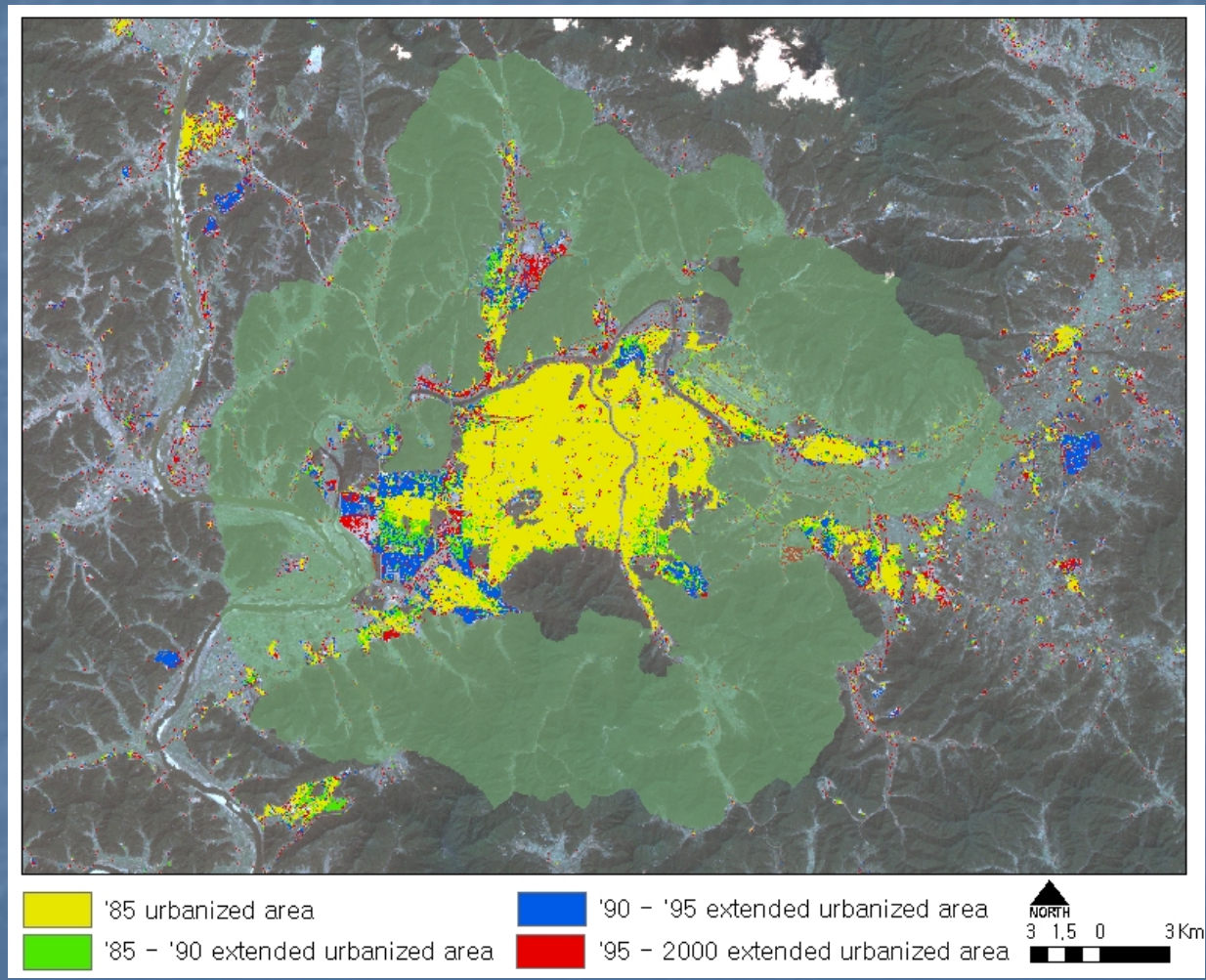
Grid cell

N

1,000 500 0 1,000 M

Data and Study Area

Historical Trend of Urban Extents



Method

Flowchart of the Daegu Metropolitan Area Urban Growth Model

Step 1: Identifying the Size of Future Urban Growth (future land demand)

- urban growth ratio/sprawl index
  1) infill type urban growth
  2) expansion type urban growth
  3) historical growth trend

↓

Step 2: Identifying Developable Land(Land Inventory)

- exclusionary zones as non-developable land
  1) land use restrictions: greenbelt, the prime agricultural land
  2) physical constraints: elevation, slope, streams, reservoirs
  3) environmental constraints: wildlife reserves, national/regional parks

↓

Step 3: Calculating Development Probability of Developable Land by Grid Cell

- logistic regression analysis(binary logit model)
- drivers of land use change
  1) socio-economic factors: household, % change of household
  2) spatial linkage factor: commuting ratio to the central city
  3) physical factor: slope
  4) accessibility factors: distance to city center, distance to road, distance to highway IC
  5) proximity factor: distance to existing developed area

↓

Step 4: Identifying the Size and Location of Future Urban Growth

1) infill type urban growth
2) expansion type urban growth
3) historical growth trend

↓

Step 5: Creating Maps of Future Urban Extents

Identifying the Size of Future Urban Growth

The growth ratio: population

$$S_{1-0} = \frac{(U_1 - U_0)/U_0}{(P_1 - P_0)/P_0} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$U_1 = S_{1-0} \bullet U_0 (P_1 - P_0)/P_0 + U_0 \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$\Delta U_{1-0} = U_1 - U_0 \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Identifying the Size of Future Urban Growth

The growth ratio: household

$$S'_{1-0} = \frac{(U_1 - U_0)/U_0}{(H_1 - H_0)/H_0} \quad \text{.....(4)}$$

$$U_1 = S'_{1-0} \bullet U_0 (H_1 - H_0)/H_0 + U_0 \quad \text{.....(5)}$$

The growth ratios of the study region

Index of growth ratio	Region	Growth ratio			
		1985-1990	1990-1995	1995-2000	1990-2000
Population-urbanized area(S)	Daegu city	1.75	3.41	13.65	5.65
	Cities/Towns	4.23	7.38	11.14	10.24
	Whole area	2.74	5.26	11.89	8.23
Household-urbanized area(S′)	Daegu city	0.89	1.38	1.92	1.64
	Cities/Towns	1.38	2.22	3.30	2.95
	Whole area	1.14	1.83	2.78	2.38

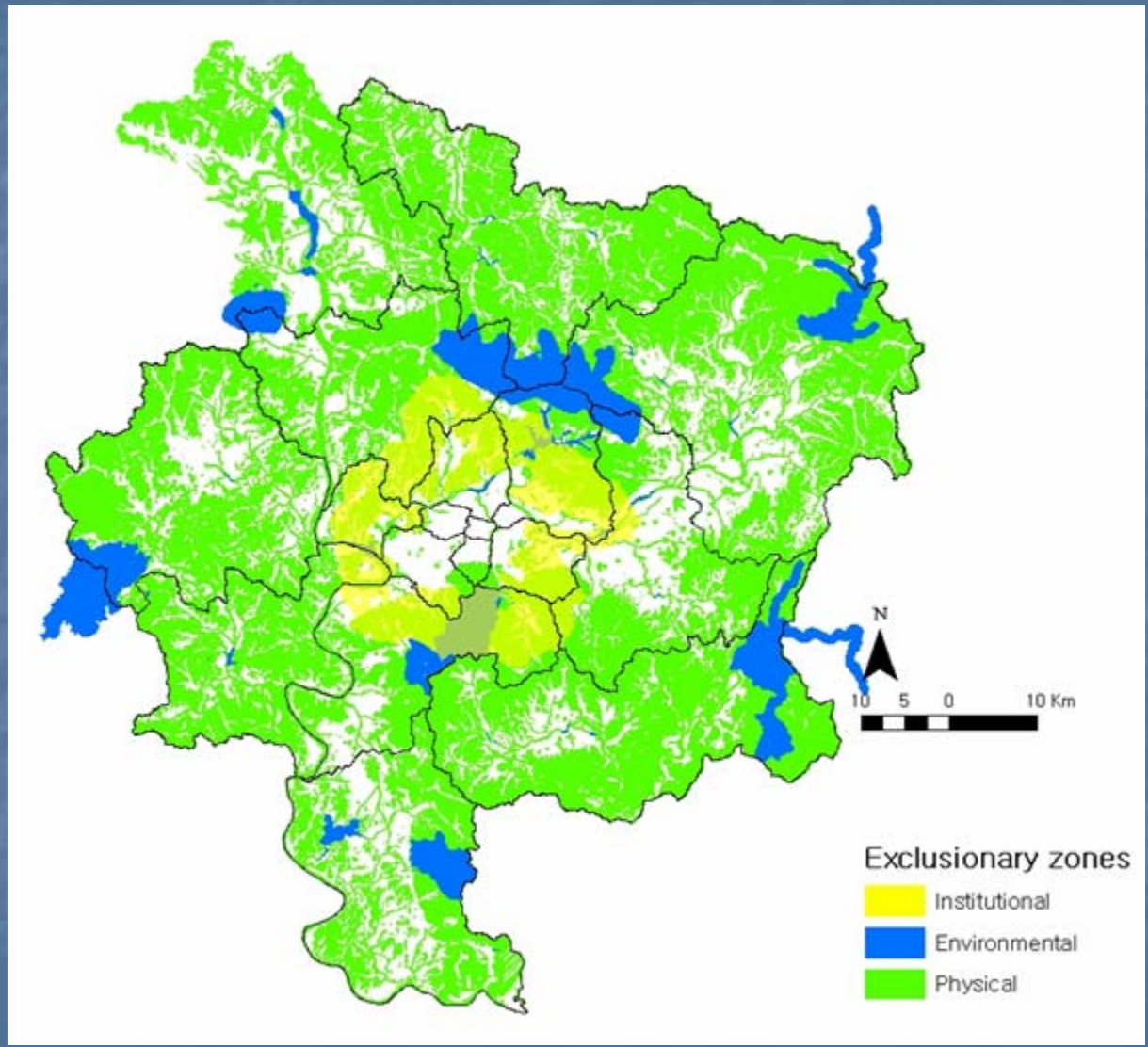
Methods

- Summary of Predicted Urban Growth by 2020 (Unit: km²)

	Developed Area in 2000	Predicted Urban Growth by Growth Ratio				Predicted Urban Growth By Trend Analysis
		S′=1	S′=2	S′=3	S′=4	
Daegu city	149.3	198	248	297	346	215
Cities/towns	77.7	99	119	140	161	609
Total	227.0	297	367	437	507	824

Methods

- Exclusionary zones



Methods

Areas of Exclusion from Development

Type of restriction	Name of restrictions	area(□)
Institutional restriction	Greenbelt	546.23
Environmental restriction	Parks	243.04
	Catchments area	133.06
	Ecological reserve	8.55
	Wild life habitat	13.75
	Dams	75.15
	Preserves for local plant & species	0.19
Physical restriction	Slope(15 degrees or above) Altitude(200m or above)	3,141.82
	Rivers/Streams	575.38

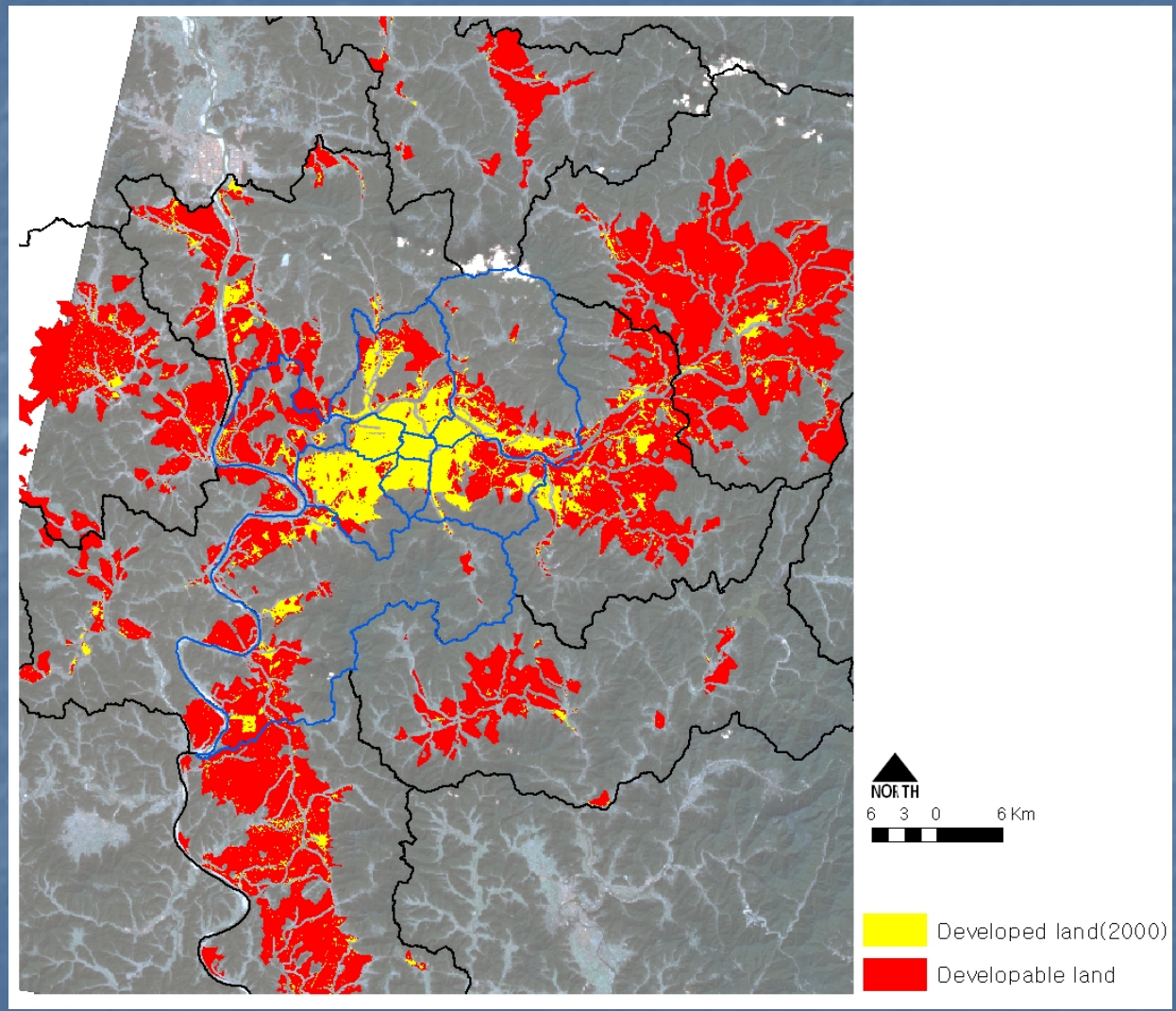
Methods

Land Classification by City/Town(new)

	area(□)	developed land	developable land	non-developable land
Daegu	881.2	149.3	163.8	568.1
Changnyong	527.2	13.9	177.2	336.1
Chilgok	452.0	11.7	76.1	364.2
Chungdo	691.3	2.1	66.7	622.5
Goryeong	383.8	3.5	57.0	323.3
Gunwi	611.9	1.7	83.1	527.1
Gyeongsan	411.4	23.4	120.6	267.4
Sungju	615.8	8.0	135.9	471.9
Youngchun	916.3	13.4	268.3	634.6

Method

Identified Developable land



Models

- Identification of Location of Future Urban Growth

The logistic relation was used since the dependent variable is binary (urban cell=0, nonurban cell=1): Binary Logit model

$$P_i = \frac{e^u}{(1+e^u)} \quad \ldots\ldots\ldots\ldots\ldots (6)$$

$$u = \alpha + \sum \beta_i X_{ij} \quad \ldots\ldots\ldots\ldots\ldots (7)$$

Models

Identification of Location of Future Urban Growth

key driving variables behind land cover and land use changes

1. Accessibility: measured as the straight line distance.
   a) to the Daegu city center
   b) to the local city center
   c) to the nearest road, and
   d) to the nearest highway interchange

2. Proximity: to the nearest developed zone

3. Slope: derived from 30m digital elevation map of the National Geographical Information Institute

Models

Key driving variables behind land cover and land use changes (cont'd)

4. Socio-economic data represented by number of households is obtained from census data of year 1990 and 2000.

5. The degree of spatial linkage between the central city and hinterlands was represented by the commuting ratio.

6. Data for accessibility, socio-economic and physical characteristics of the zone required for the model were developed and managed within ESRI ArcGIS 9.0, ArcInfo 9.0, and ArcView 3.3.

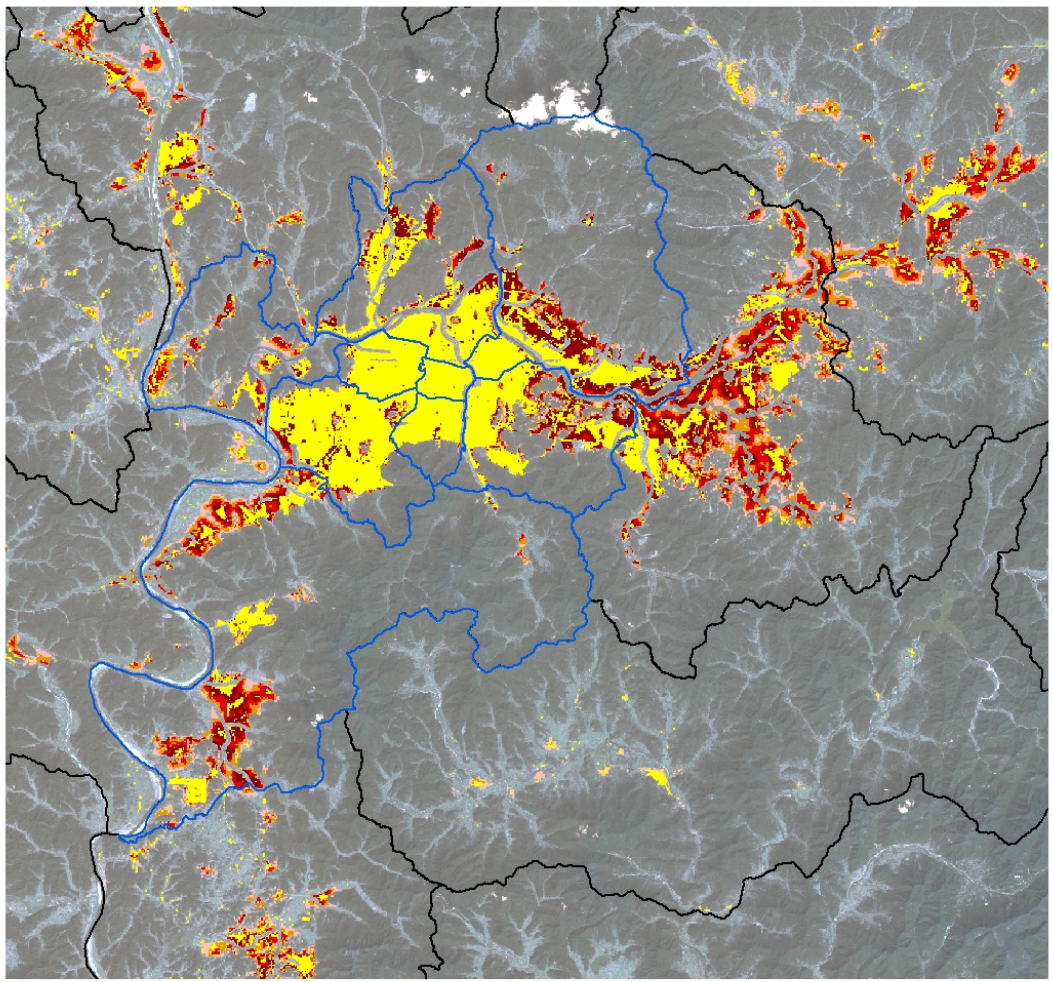
Results

- Statistical Results from Binary Logit Analysis(1990-2000)

Parameter	Estimate	P-value
Intercept	-1.071900	<.0001
Households('90)	0.000009	<.0001
Changes of households('90-2000)	0.436200	<.0001
Commuting Ratio	0.472500	<.0001
Distance to local city center	-0.000030	<.0001
Distance to Daegu city center	0.000012	<.0001
Distance to urbanized edge	-0.001530	<.0001
Distance to road	-0.001430	<.0001
Distance to highway interchange	-0.000040	<.0001
Slope	-0.066800	<.0001
Somers' D		0.725
Number of Observations		129,340

Results

Predicted Urban Growth



Conclusion

- There has been growing concern to construct an updated and accurate database concerning land-use conversions, their meanings, and their pace. Without proper information on these changes, it is impossible to forecast the consequences of current trends. This paper provides a new method of understanding of urban growth and land use change.

- This study presents in detail the steps of simulating urban growth of a region and analyzes its results.

  Merits: differs from the most of cellular automat based model. It uses census block data (the basic statistical unit).

  Shortcomings: the most critical problem is that it does not incorporate actual or imputed land prices into drivers of land use transformation.

- Despite the limitations of generalizing the method taken here and also the limitations of any simulation process, we are sure that it has potential of being used to help in planning many urban issues.