The 12th AIM International Workshop

20-Feburary, 2007

Assessing the Regional Effects of Climate and Land Use Change on the Korean Watersheds

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1. Objectives

● Climate Change and Land Use/Cover Change (LUCC) caused by anthropogenic pressures and natural processes are increasingly recognized as the major drivers of global environmental change which may be a synthesis of results of these two changes.
● Since they have a large effect on ecosystem processes, biogeochemical cycles, biodiversity and even more human activities, many scientists have gained great efforts to understanding the causes and effects of land use and climate changes.
● In addition, Land use change of Korean Peninsula, especially urban sprawl and deforestation, also have been accelerated by the rapid increasing of urban population during the last 30 years.
● To understand the effects on the future environment caused by climate and LULC changes. It is needed to develop diagnostic model of land use and ecosystem changes, and to analyze regionally comparable results of climate and land use change.

- The objective of this research is assessing potential effects of climate and land use change on the ecosystem and hydrologic processes in Korean watersheds by developing impact assessment model and regional dataset (land cover, river-network system etc)
- This presentation mainly focus on the development of impact assessment models- 1) land use allocation, 2) hydrologic model including their validation

2. Overview of research flow

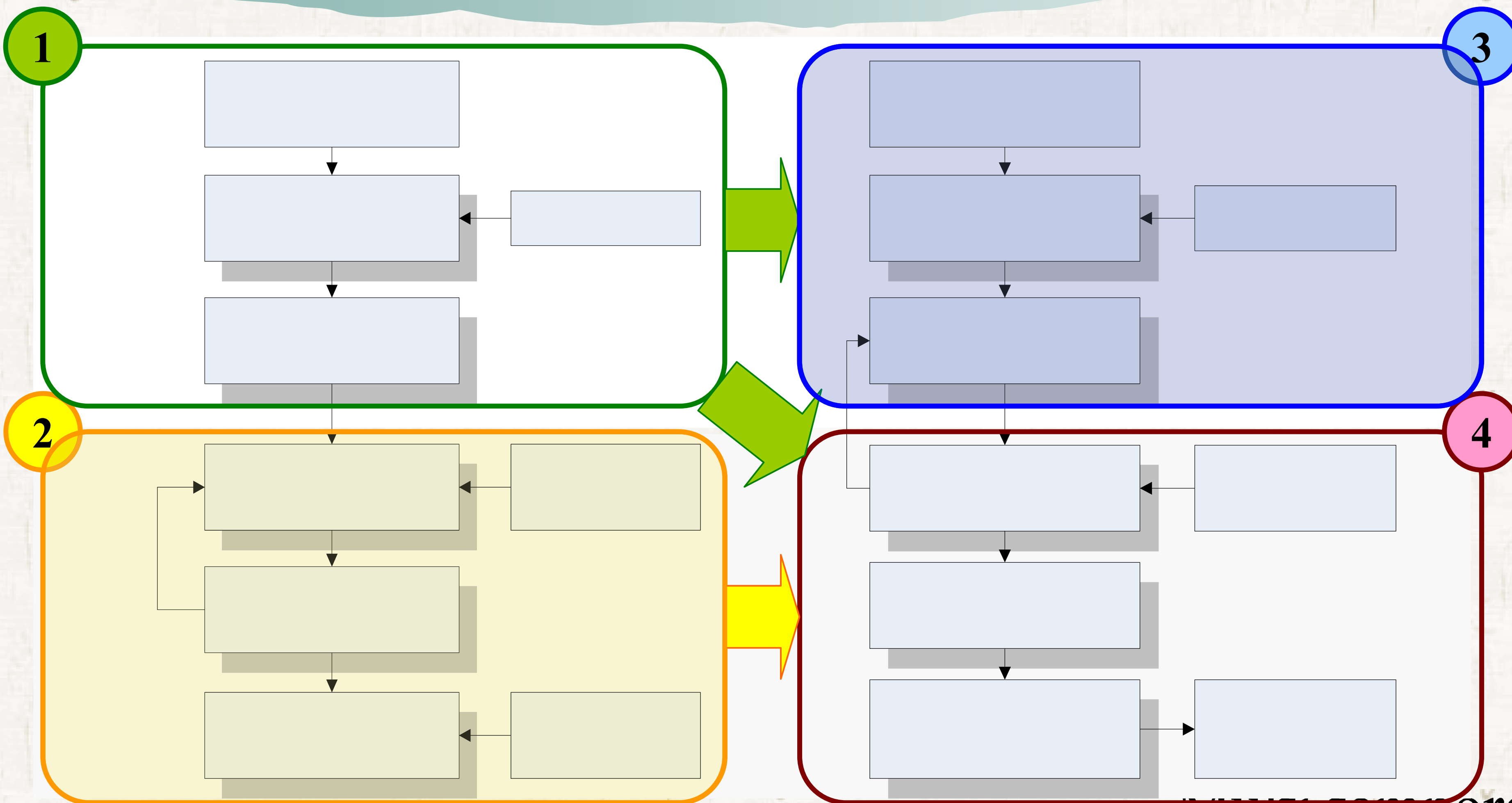


Figure 1. Framework for research flow and Relationship of Climate and Land Use change on the Ecosystems and Hydrologic processes in the Korean watershed

3. Mapping and Modeling LULC Change

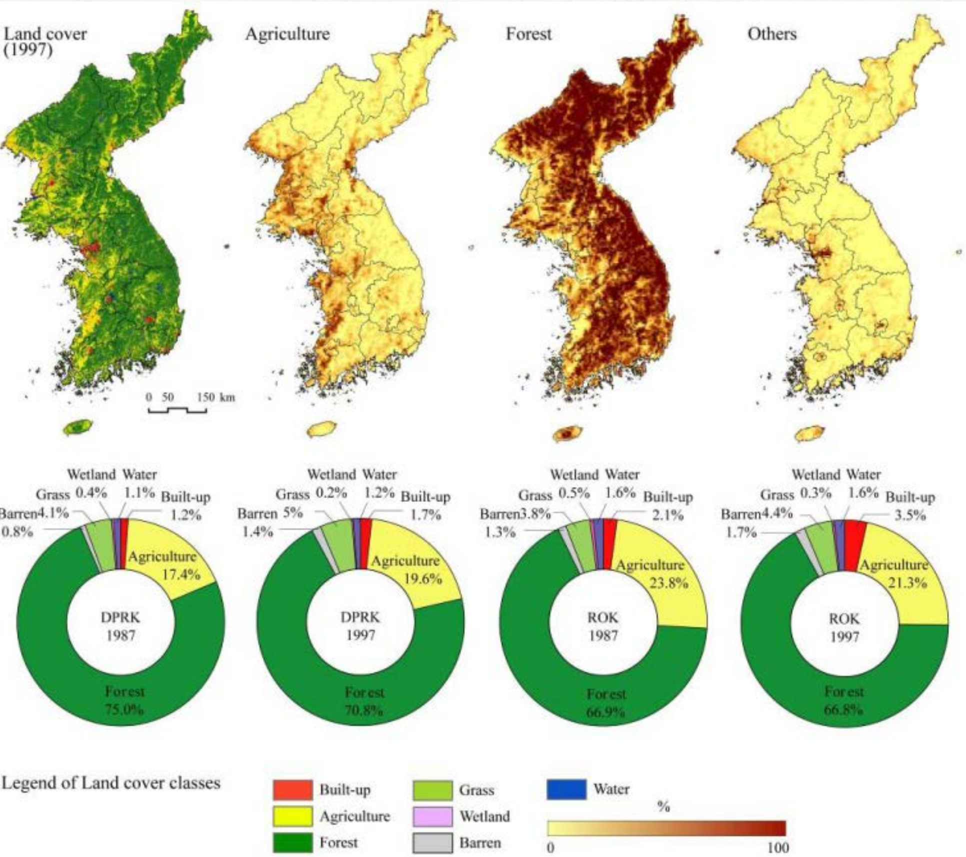
Remote Sensing Analysis

- Data: Landsat 5 TM and 7 ETM+ (Spatial resolution: 30m)
- Classification classes: Built-up, Agriculture, Forest, Grass, Barren, Wetland, Water (7 classes)
- Spatial domain and Target date: Korean Peninsula (ROK,DPK), End of 1980s (1985-1989, rep. 1987) and 1990s (1995-1998, 1997)
- Classification method: Hybrid methods (unsupervised: competitive training + supervised: maximum-likelihood with prior probability)
- Classification error criteria: Overall accuracy 80%
- Validation: 1) Statistical method using Kappa and overall accuracy, 2) Area comparison with statistical year book (forest, agriculture)

Statistical Analysis for detecting the changing pattern

- Descriptive variables: distance to road, existing city, river and conservation area, pop.density, topographic (slope, height etc), Soil (textures, pH, AWC etc), Climate variables (T, P, PET etc)
- Proximity analysis of urban expansion
- Markov transition matrix by using multi-logit regression for future change estimation

3.1 Land cover classification results and validation



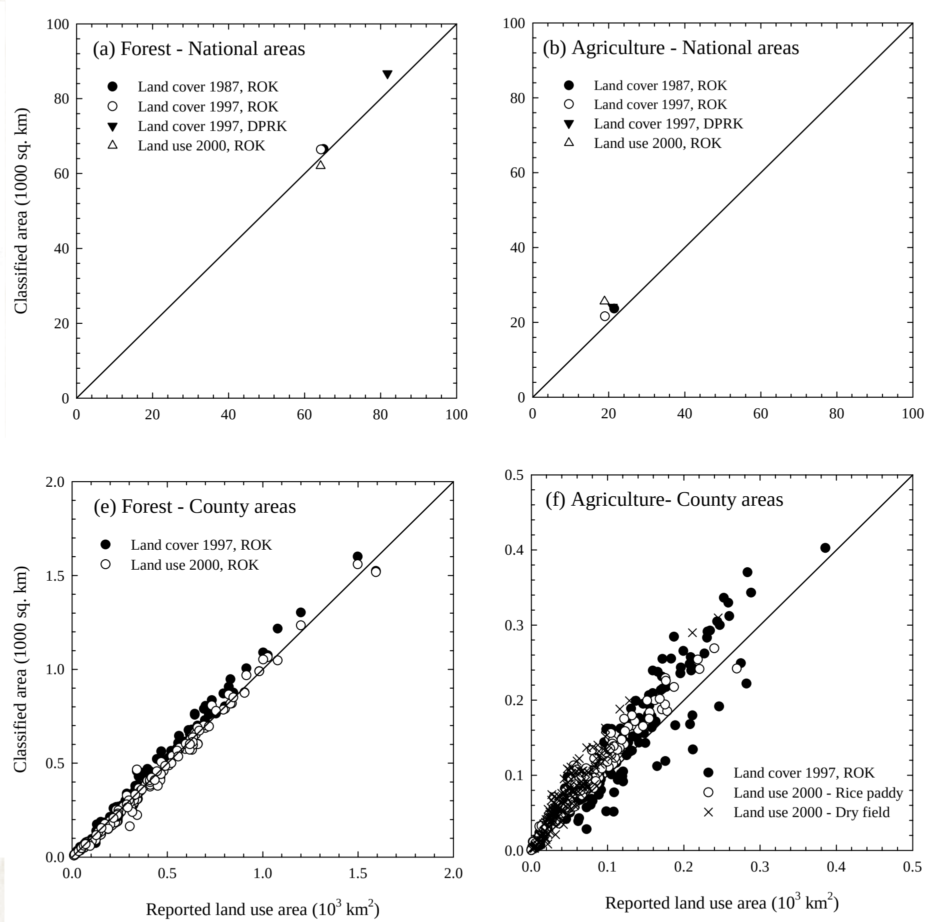
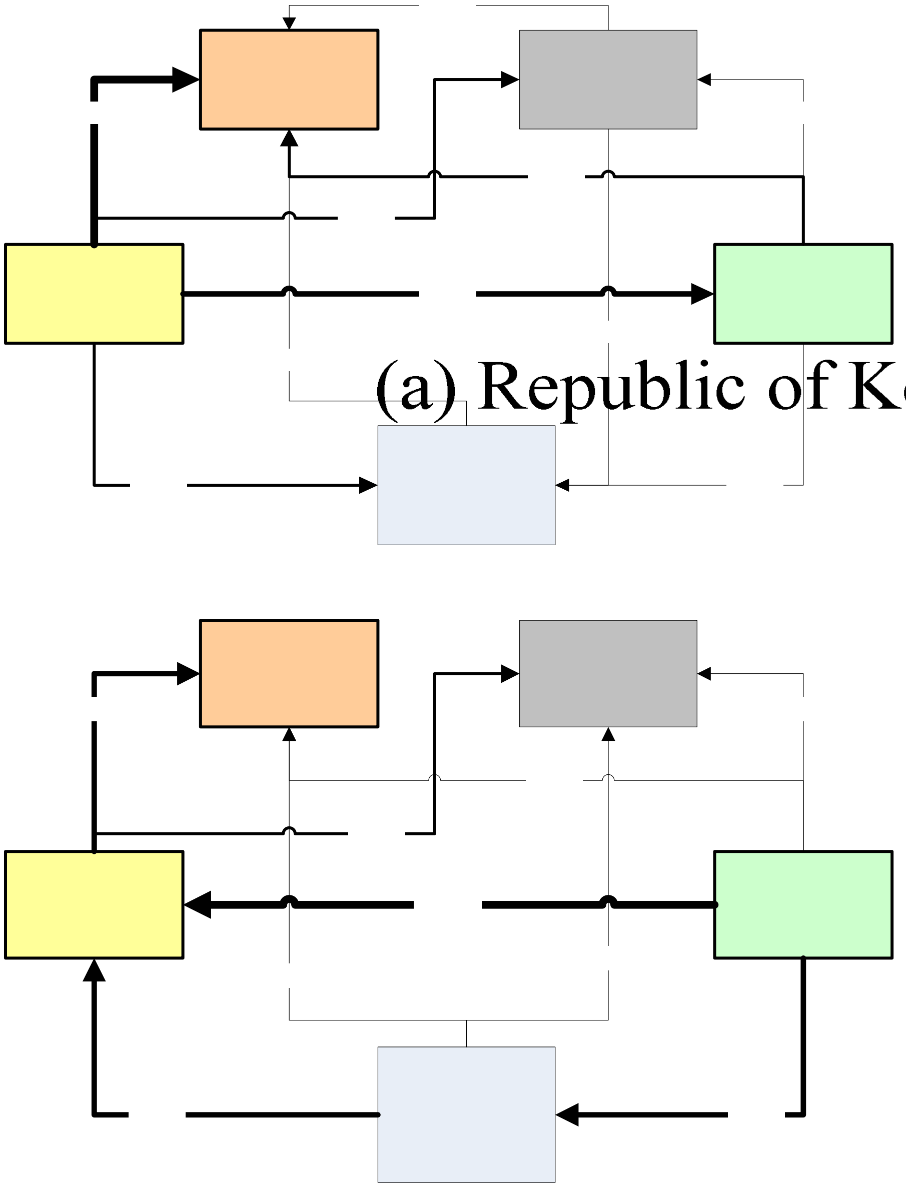
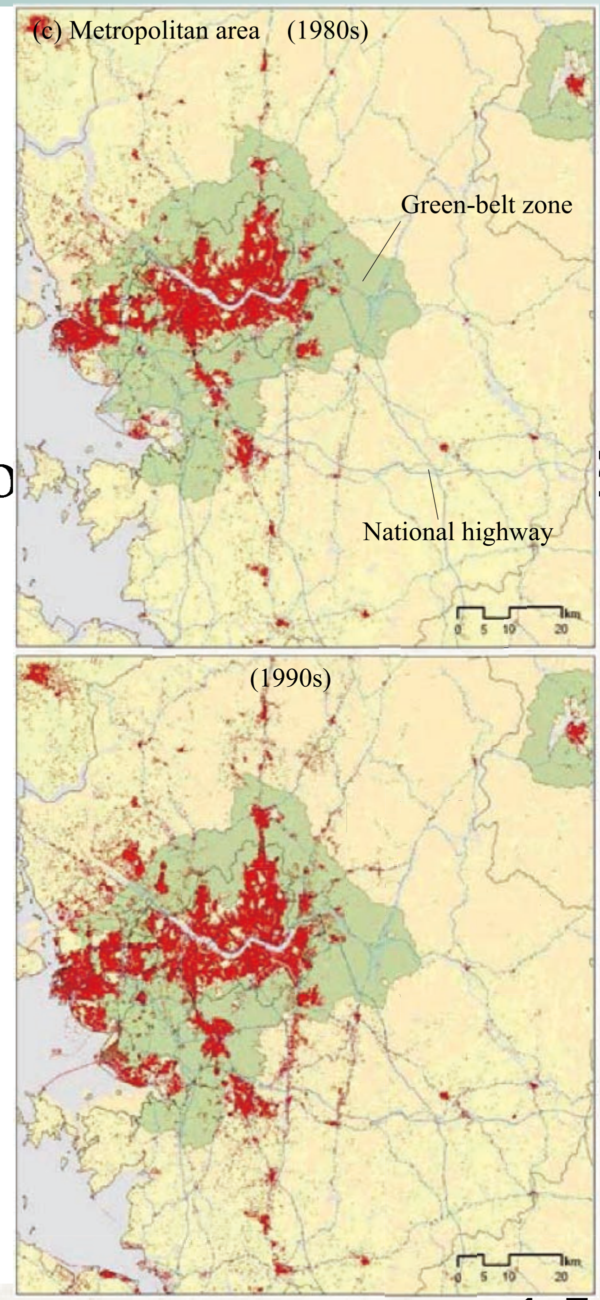


Figure 2 Current status of land cover distribution on the Korean Peninsula (left) and Comparison of the major land use classes in terms of remotely sensed land cover and census data set (Right)

3.1 Major change among the classes



(a) Republic of Ko



21.1% of wh

0.41%

1.50%

Figure III Net change and Relative conversion of land cover classes (Left) and Urban sprawl in the Metropolitan area surrounding Greenbelt zone

3-1. Relationship of Land Cover Fraction and Urban population density

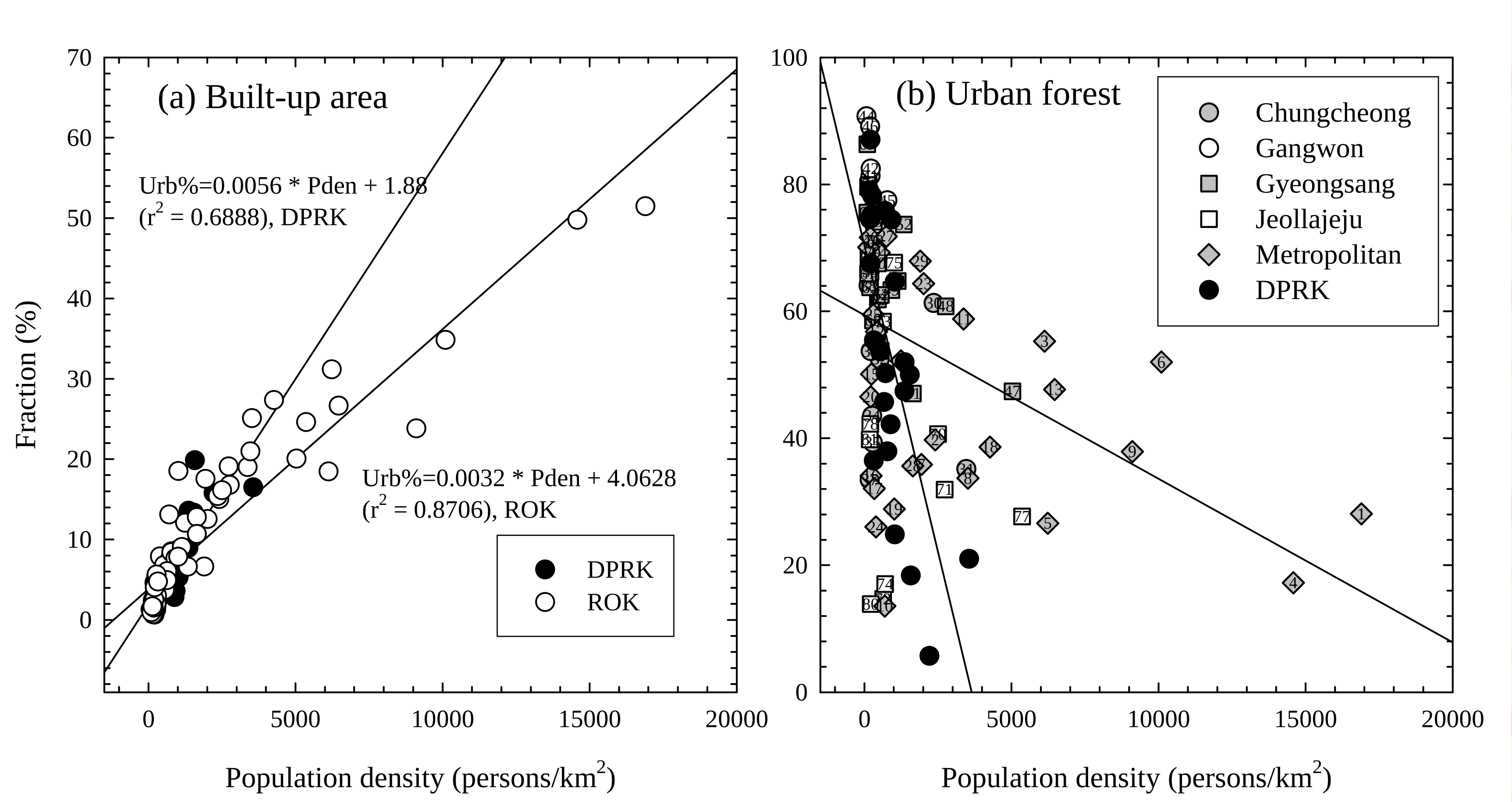
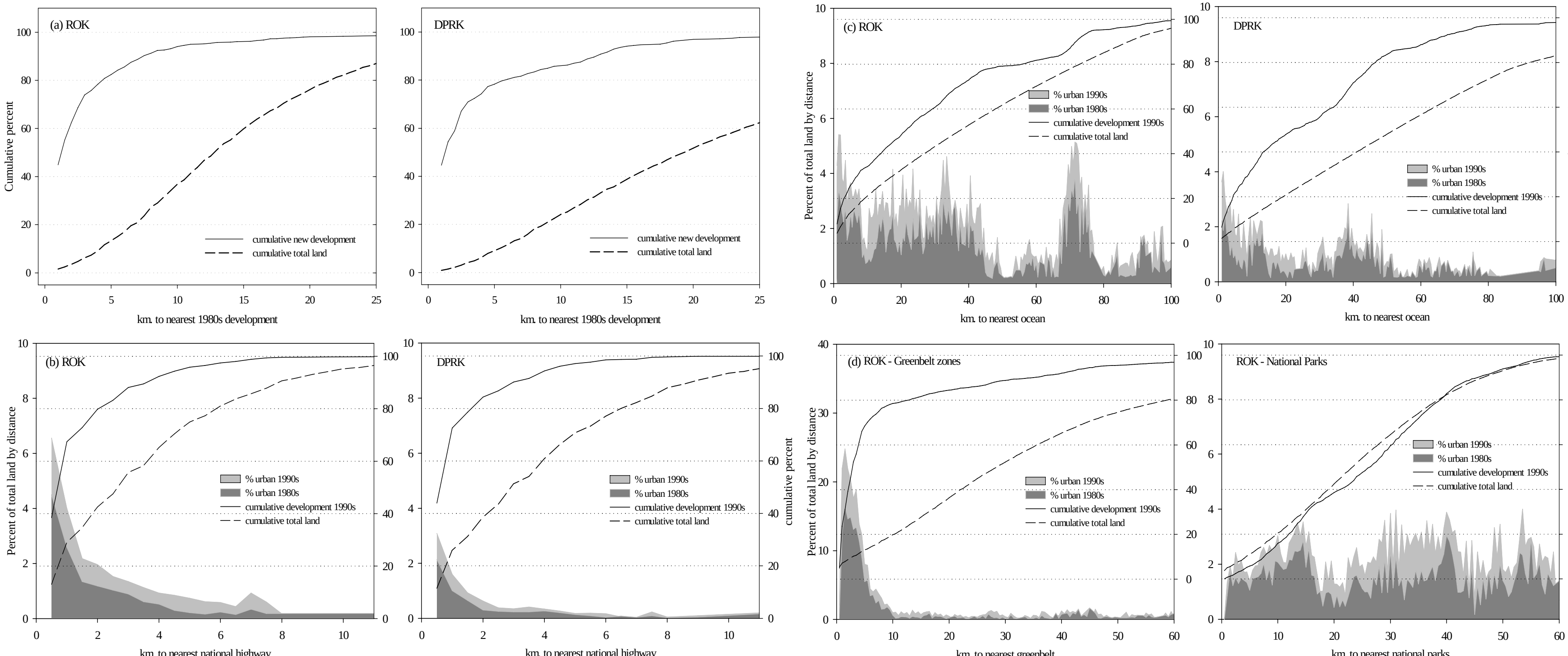


Figure 4 Land cover distribution of major cities relating with urban population density: Built-up (Left) and Urban forest (Right)

3-1. Proximity analysis to urbanized area

(a) Distance to existing built-up area (c) Distance to nearest sea



(b) Distance to nearest highway (circa. ’80s road) (d) Distance to greenbelt and national park

Figure 5 Relationship with urbanized area and proximity (km) to (a) existing urban (b) road (c) Ocean and (d-1) Greenbelt zone (d-2) National parks (Conservation area). (Left) ROK, (Right) DPK excepting (d)

3-1. Future land cover change estimation using Markov transition matrix

- Future population at provincial level: SRES A2 scenario
- Transition probability, (Pij) is estimated by multi-logit regression:

$$\ln(p_{1i} / p_{1j}) = f(X_1, X_2, ..., X_m), \quad i \neq j \neq 1$$

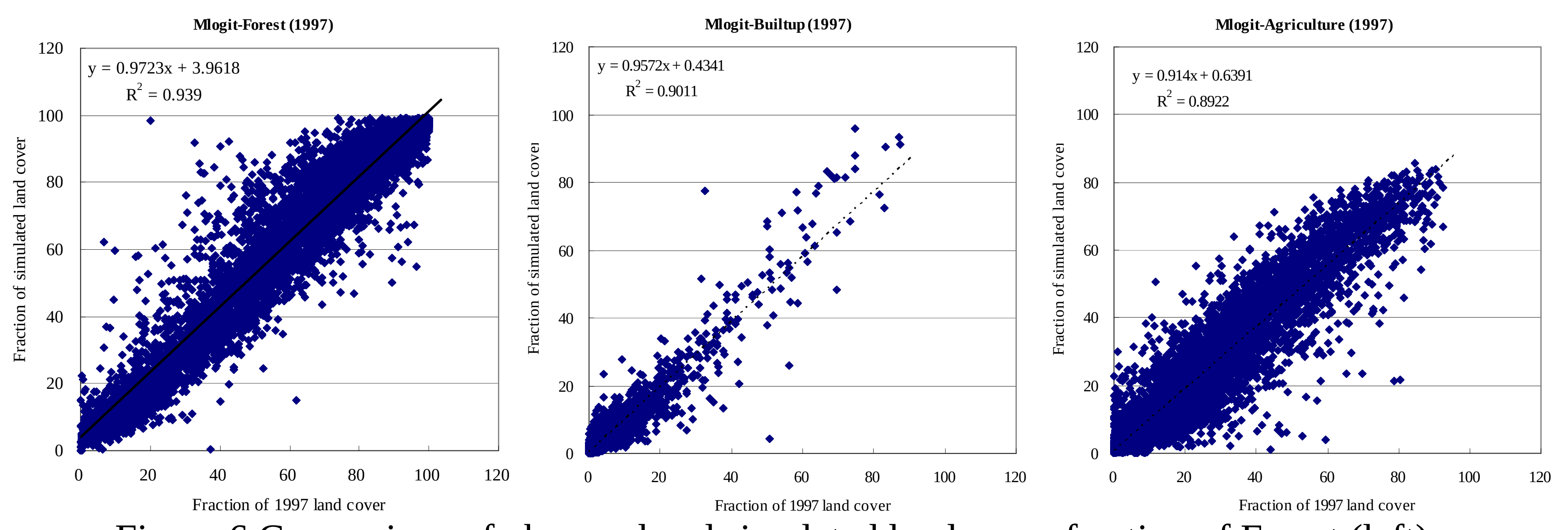
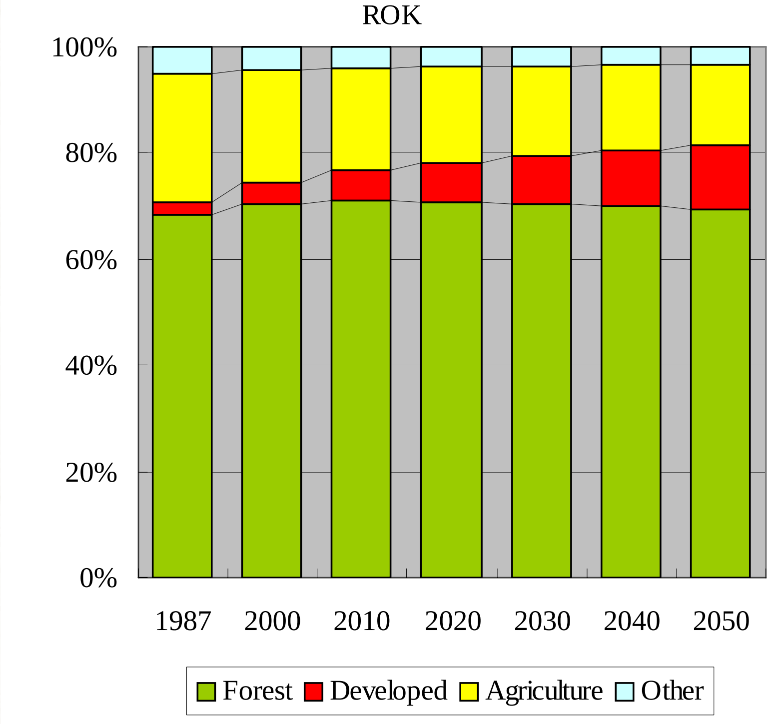


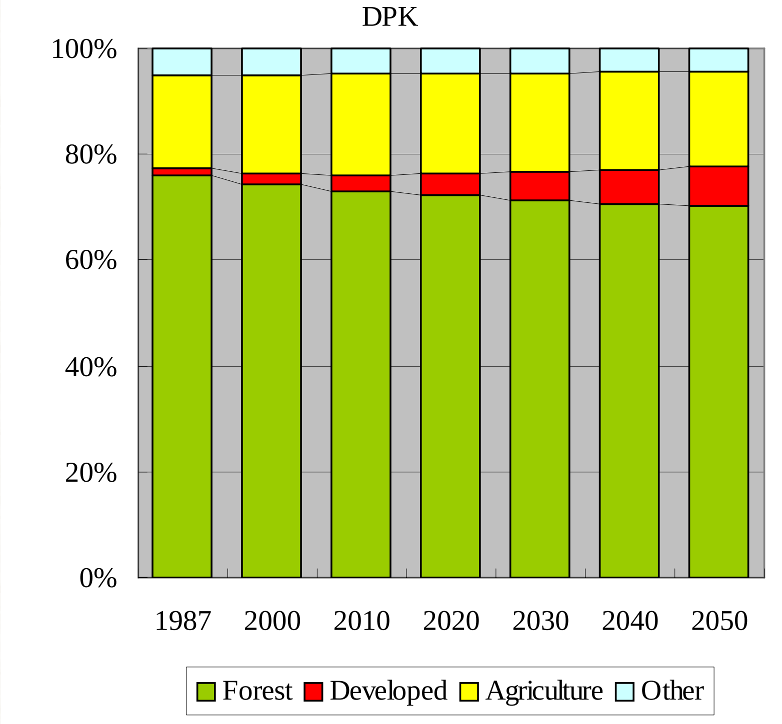
Figure 6 Comparison of observed and simulated land cover fraction of Forest (left), Built-up (middle) and Agri. (right) at 5 by 5 km grid

3-1. Estimated future land cover change

Table 1. Land cover change simulation results by Markov transition matrix, start form 1987 and SRES A2 (provincial level)

Nation	Classes	1987	2000	2010	2020	2030	2040	2050
DPK	Forest	91.733	89.530	88.025	86.925	86.042	85.277	84.574
	Agriculture	21.328	22.567	22.977	22.920	22.584	22.077	21.462
	Developed	1.405	2.453	3.639	4.920	6.279	7.713	9.204
	Other	6.022	5.939	5.848	5.724	5.583	5.423	5.249
ROK	Forest	66.411	68.340	68.871	68.784	68.387	67.829	67.183
	Agriculture	23.533	20.548	18.748	17.468	16.450	15.572	14.774
	Developed	2.112	3.849	5.482	7.093	8.698	10.298	11.889
	Other	5.007	4.326	3.963	3.718	3.528	3.364	3.216





3-2. Land Use Change Model

1. Land use suitability, S_{cj}:
- Regression of descriptive variables for Built-up, Agri., Forest, Others and Water (5 types)
- 5 by 5 km grid

2.Conservation weight, E_{cj}:
-Using Land Environment Mapping (LEI) criteria (5 grades)
- for the negative change, changing amount is adjusted using weight

1. LU allocation probability, M_{cj}
-Modified form of constrained logistic model
-Double constrains: 1) national demand constrain 2) grid cell fraction constrain
-Water fraction is fixed

2. Suitability adjusting factor, β:
- Optimization of parameters
- Minimize RMSE(Fo,Ag.Bu) sum

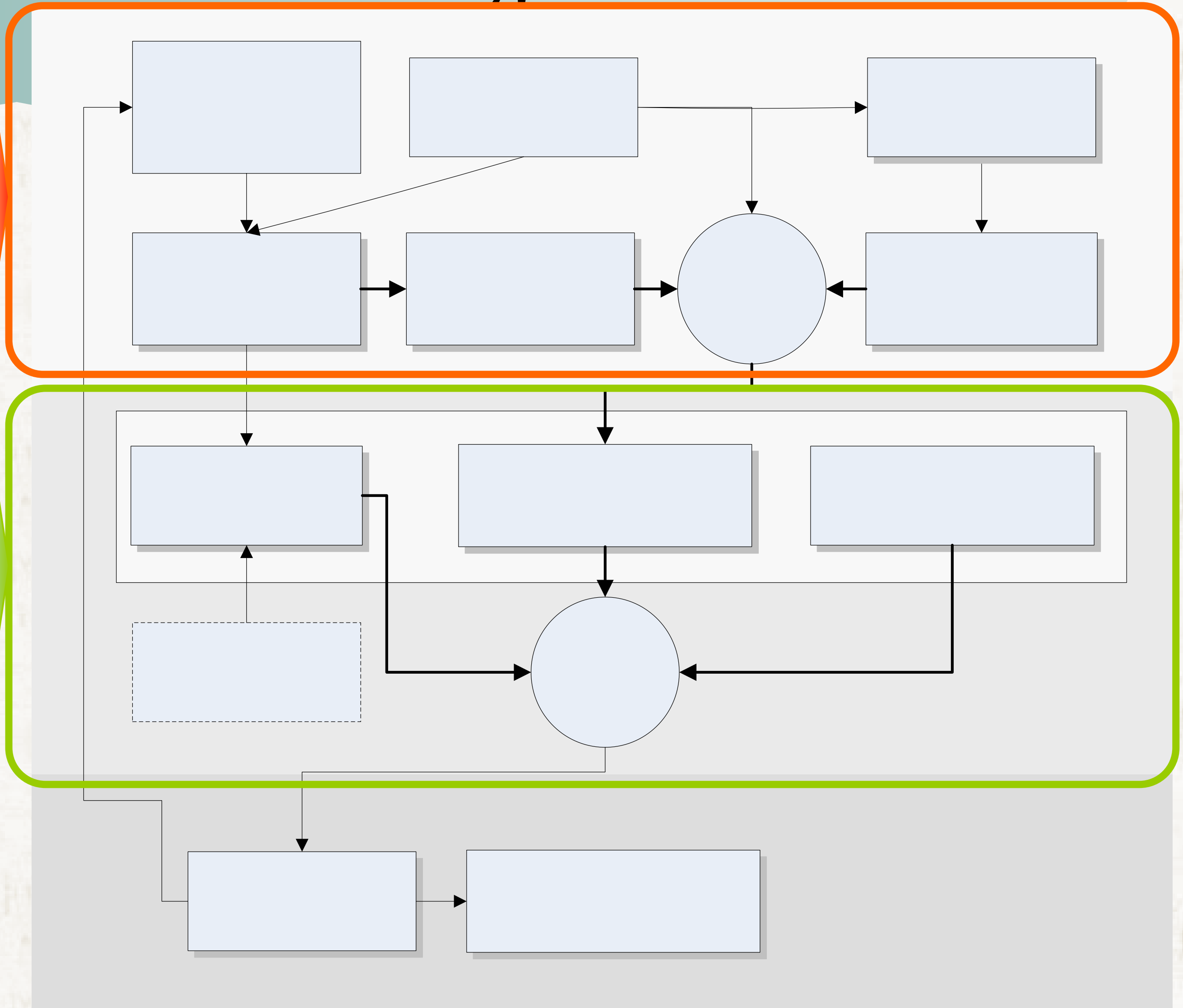


Figure 7 Framework of land use change modeling and Ecosystem effects analysis by using land use suitability and management option

3-2. Spatial allocation method

- Step 1: Estimated land use fraction at cell, c and land use type, j

$$M_{cj} = a_j \cdot b_c \cdot \exp(\beta_j \cdot S_{cj})$$

- Step 2: Adjusting Mcj considering conservation weight Ecj at cell, c and land use type, j

$$M'_{cj} = x_{cj}^{t-1} + \left(M_{cj} - x_{cj}^{t-1}\right) \cdot E_{cj}$$

- Step 3: Calculate coefficients, aj and bc by double constrains

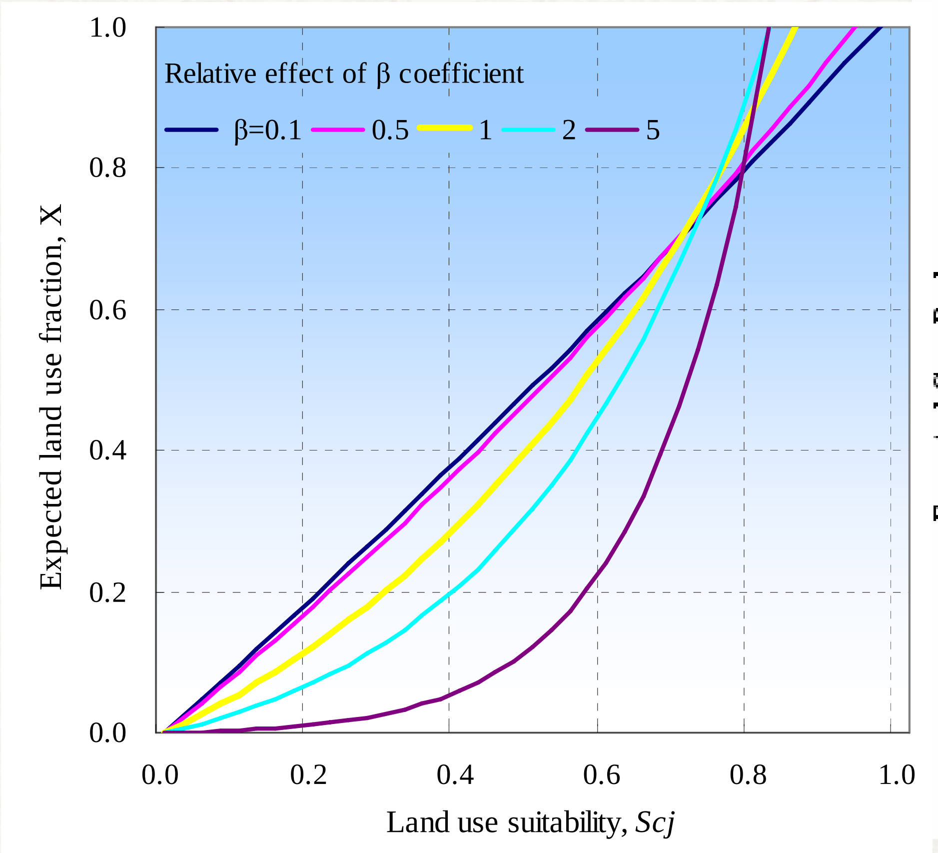
$$\sum_j M_{cj} = 1$$

$$\sum_c (M_{cj} \cdot L_c) = D_j$$

Step 4: Global optimization of βj

$$\text{minimize}\left(\sum_j \left(\left(\sum_c (x_{cj} - M_{cj})^2\right) / N\right) / j\right) \quad \text{for } \forall M_{cj} > 0$$

3-2 Suitability adjust coefficient, β_j



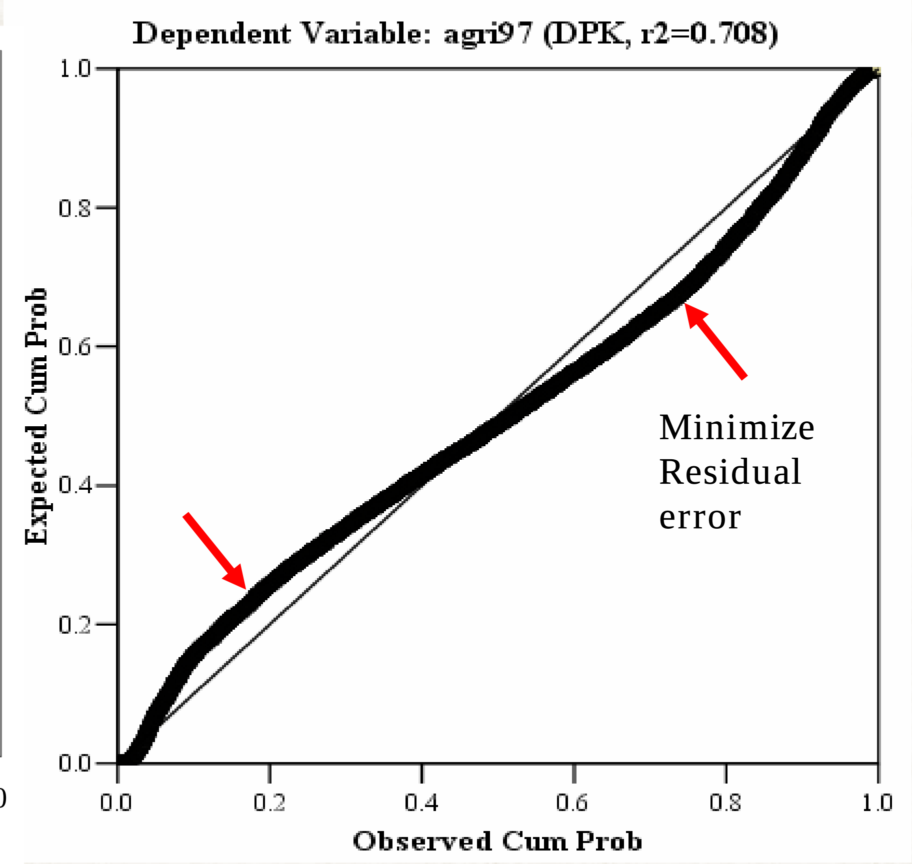


Figure 8 Relative effect of β coefficient on Expected land use fraction, Xi

3-2. Conservation weight, E_{cj}

- Spatial importance and criteria for the environmental land management:
  - Legal system-ecosystem(14 categories) , water quality(11) and Land Use (28)
  - Natural properties-Biodiversity Naturality (3), Richness, Rarity, Weakness (2), Stability (2), Connectivity (1)
- National Land Environmental Index (LEI)
  - Absolute conservation area (grade 1) - A very valuable land for environmental conservation Weight 0.0 for negative land use change
  - Priority conservation area (grade 2) Weight. =0.5,
  - Others(3,4,5) Weight = 1.0
- Spatial averaged conservation weight

$$E_{cj} = \sum_g N_g \cdot W_g / \sum_g N_g$$

3-2. Conservation weight, E_{cj}

Table 2. Relative change of land cover classes during 1987-1997 by the LEI region

	LEI index				
LC classes	grade 1	grade 2	grade 3	grade 4	grade 5
Buit-up	0.12	0.13	0.36	0.21	1.00
Agriculture	-0.24	-0.57	-0.67	-0.19	-1.00
Forest	0.30	0.68	0.08	-0.32	-1.00
Others*	-0.15	0.22	0.59	0.50	1.00

(a) Legal criteria (b) Environmental criteria (c) Final results

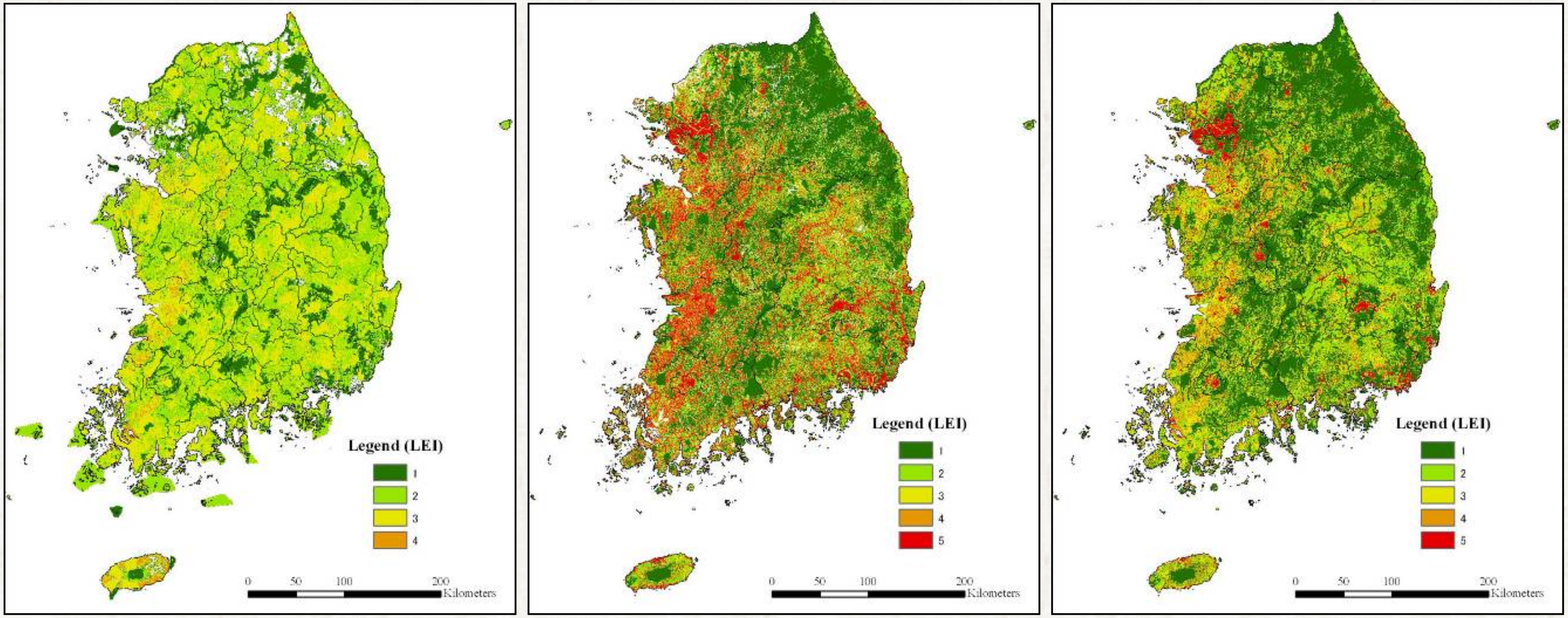


Figure 9. Spatial analysis results of assessing Land Environment Index.

3-2. Optimization of LU model

Table9. optimization results of land use change model with natural protection

Type	ID	LU types	Land use demand ('97) constrains				Model optimization and spatial error of land use fraction							
			ROK		DPK		ROK-before		ROK-after		DPK-before		DPK-after	
			Observed	Simulated	Observed	Simulated	β	RMSE(%)	β	RMSE(%)	β	RMSE(%)	β	RMSE(%)
Time varing ('87 to '97)	1	Forest	66304.7	66304.6	86676.4	86676.3	0.250	24.92	3.015	12.41	0.250	21.68	2.638	9.96
	2	Agriculture	21600.1	21600.1	23982.8	23982.8		19.62		10.32		16.26		9.23
	3	Built-up	3429.8	3429.8	2121.1	2121.1		2.29		2.16		3.23		3.23
	4	Others	5937.9	5937.9	7792.3	7792.3		9.64		9.64		7.62		7.62
	5	Water	7427.5	7427.5	4190.1	4190.1		0.00		0.00		0.00		0.00
Self-correlation ('97 to '97)	1	Forest	66304.7	66304.7	86676.4	86676.3	0.250	24.84	3.045	12.26	0.250	21.27	2.770	8.89
	2	Agriculture	21600.1	21600.1	23982.8	23982.8		19.60		10.25		16.09		8.61
	3	Built-up	3429.8	3429.8	2121.1	2121.1		4.67		3.56		7.21		5.65
	4	Others	5937.9	5937.9	7792.3	7792.3		9.64		9.64		7.47		7.47
	5	Water	7427.5	7427.5	4190.1	4190.1		0.00		0.00		0.00		0.00

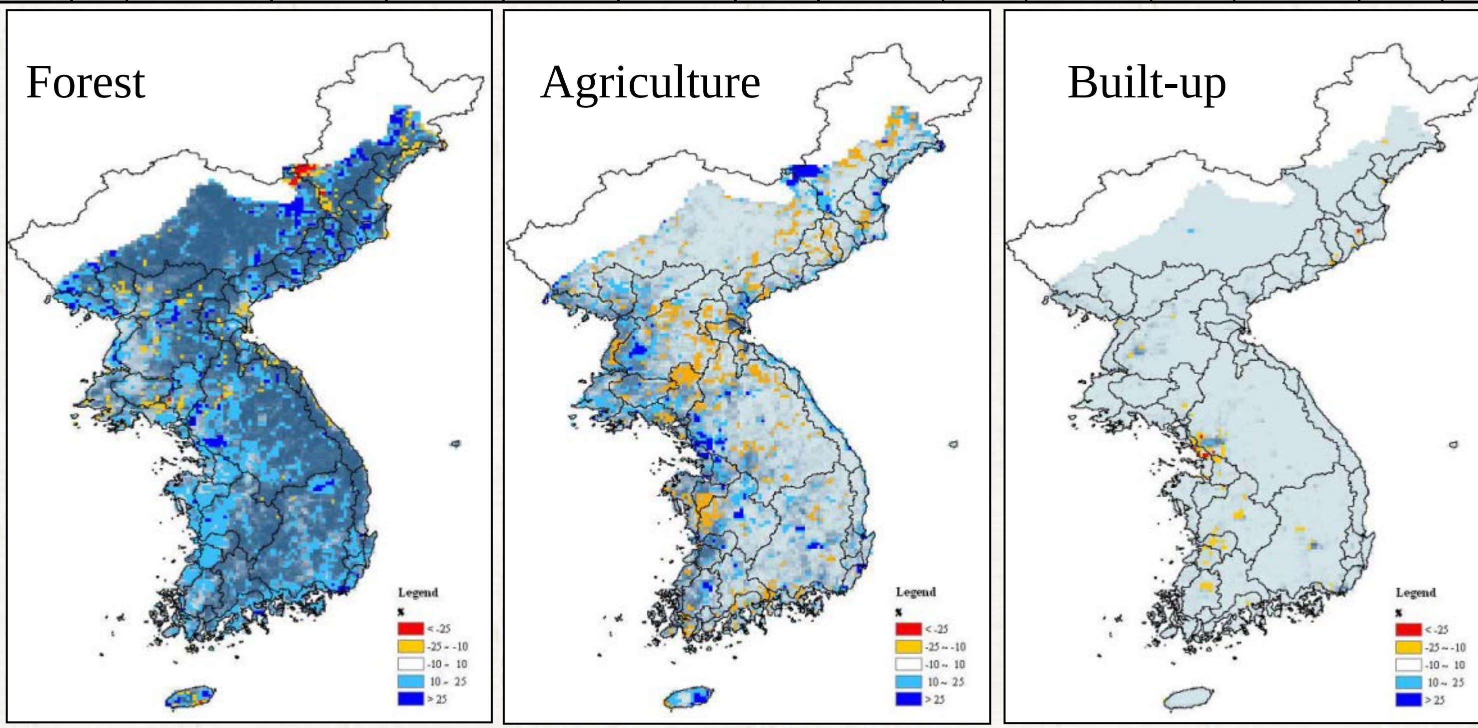


Figure 10. Spatial difference(%) of LU modeling by time varying types with legal criteria except water quality(E0)

3-3. Projecting future land use change and conservation priority

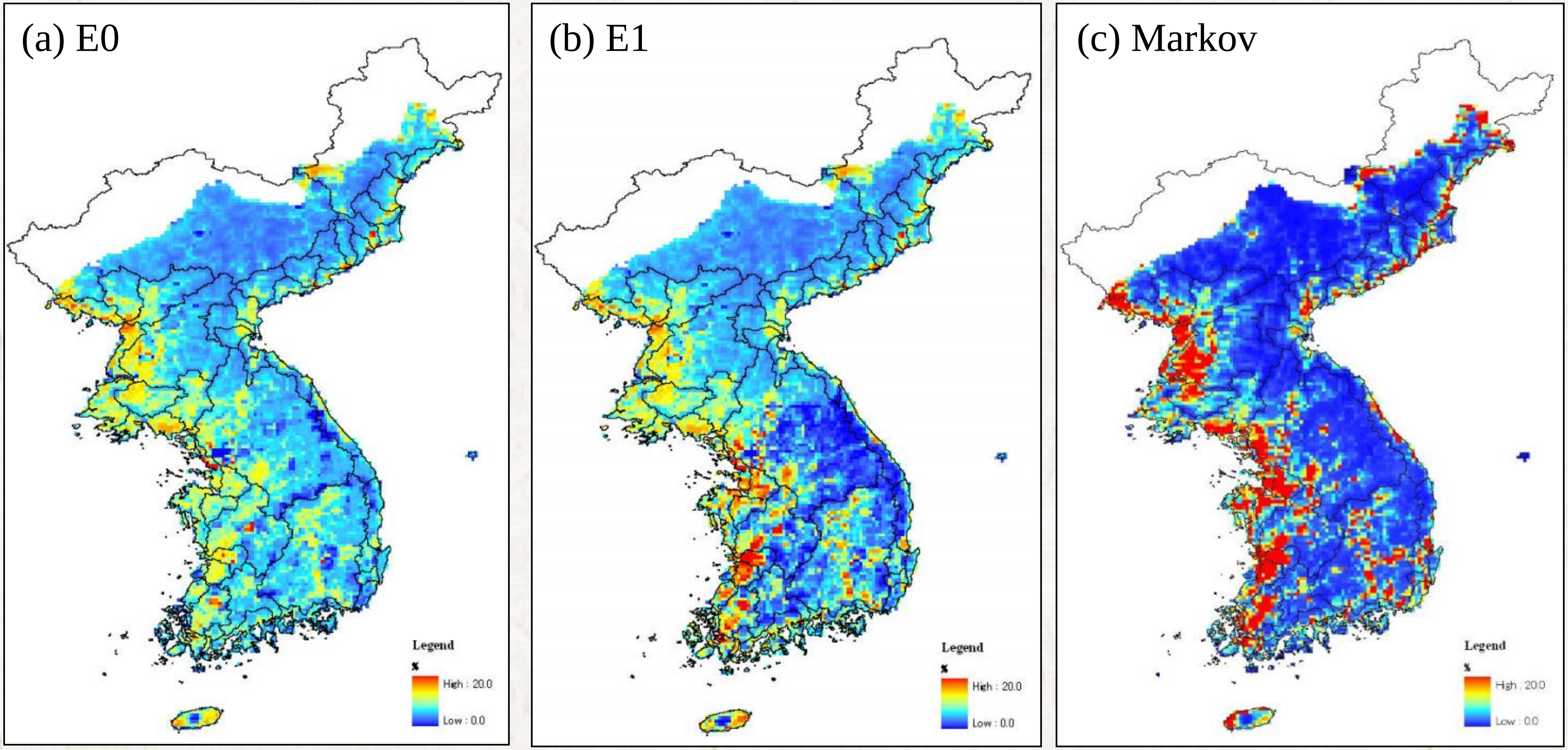


Figure 11. Projection of potential land use change 2050 (%change of Built-up)

3-3. Projecting future land use change and conservation priority

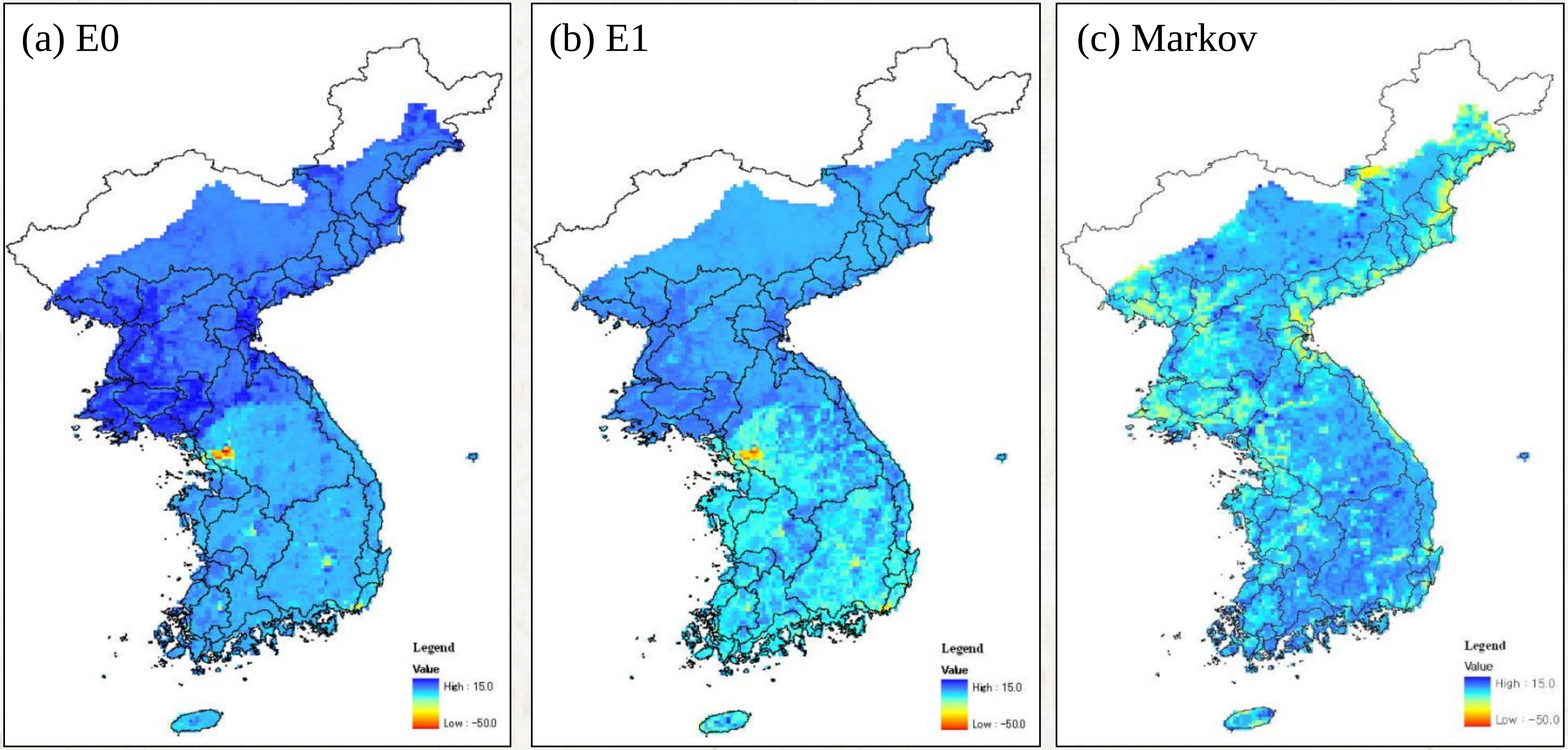


Figure 12. Projection of potential land use change 2050 (%change of Forest)

3-3. Land use change in the major BS

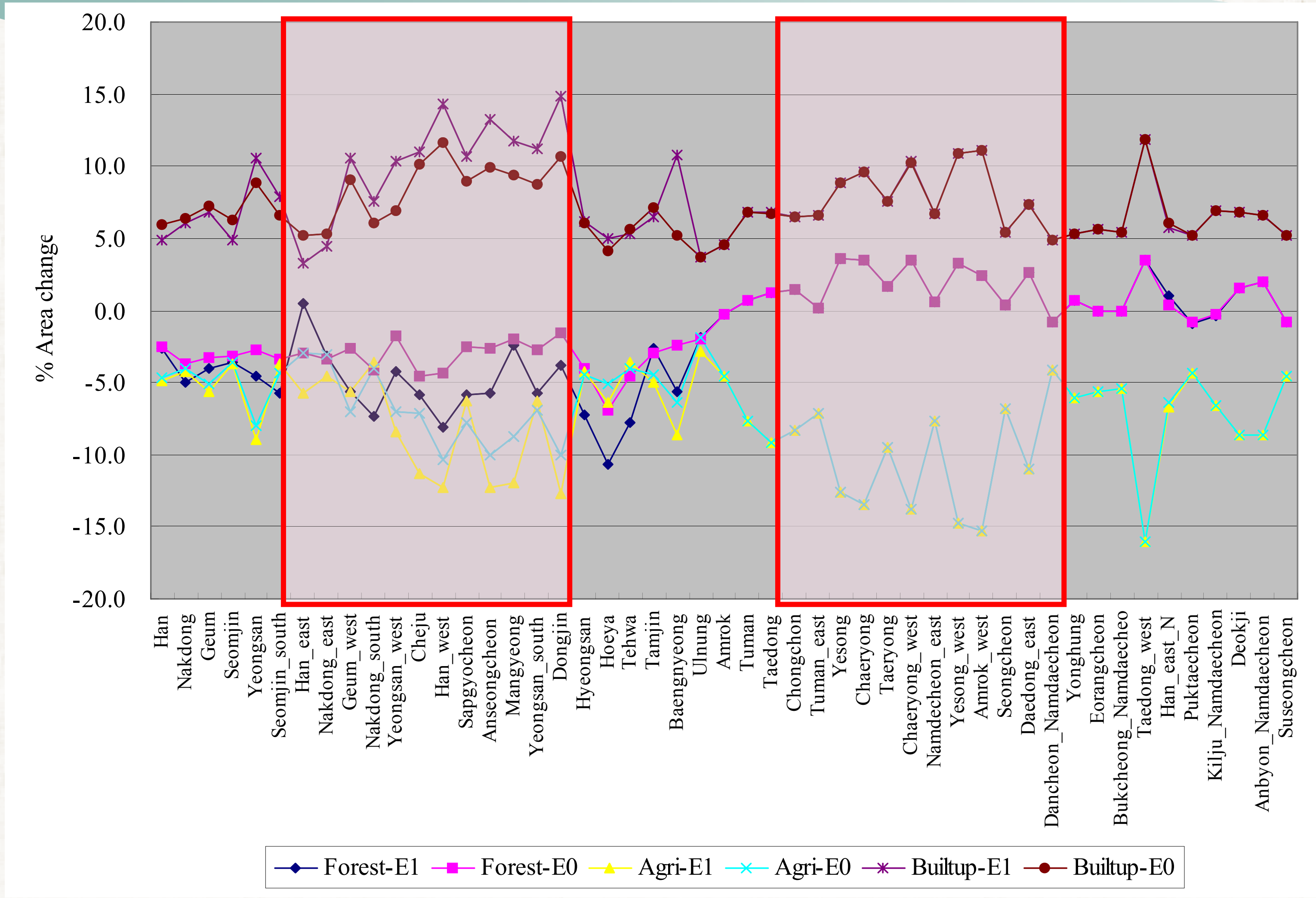
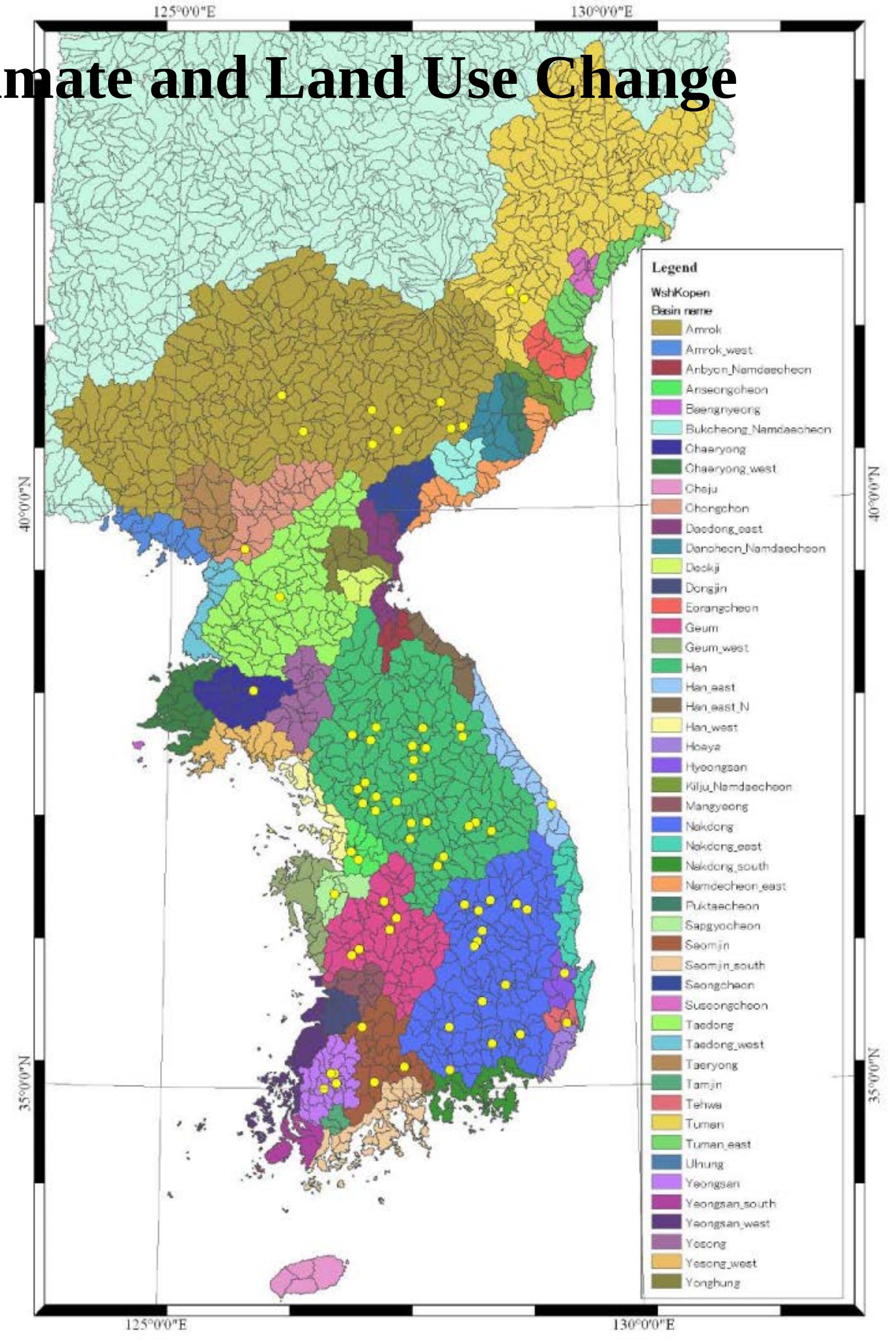


Figure 13. Land use change of the major Korean watersheds (E0 and E1 management)

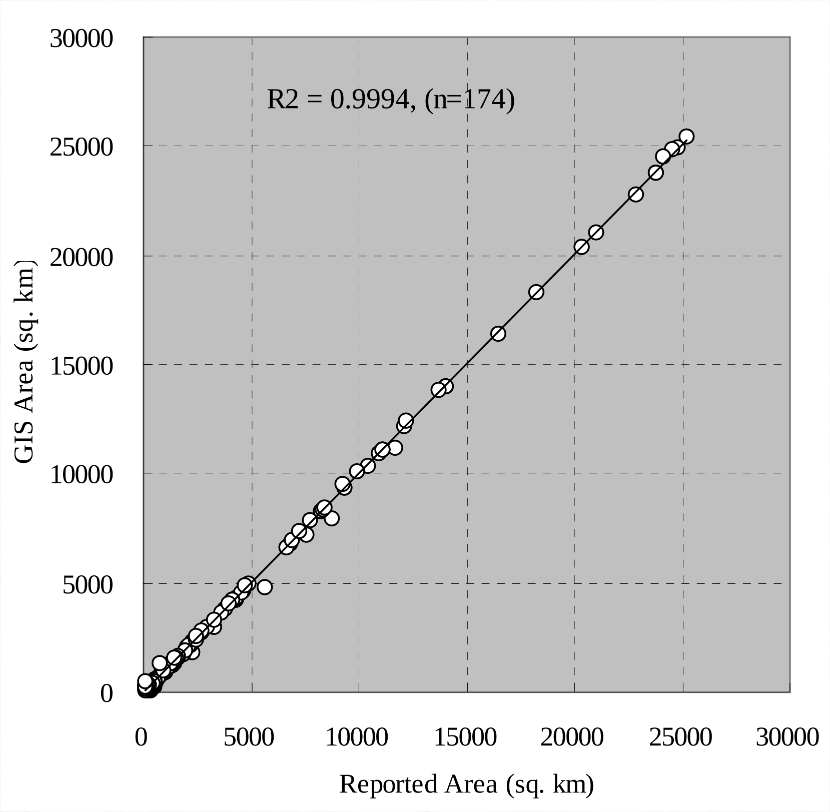
4. Modeling the Effects of Climate and Land Use Change

Development of Korean River Network

- Spatial domain: Korean Peninsula (ROK,DPK)
- Data: DEM-SRTN 3sec DEM (100m), River-ROK; Digital topo-map layer, DPK; Digitizing 1:250000 paper map, Basin boundary-ROK: national unit basin map
- Delineation method: ArcHydro tool same method with GDBD (BS criteria: 250km2)
- Validation: 1) Reported basin area comparison – Yellow colored circles in Fig 14.
- Figure 14 Korean Major Basin and unit basin



4-1 River Network Systems of Korean Peninsula



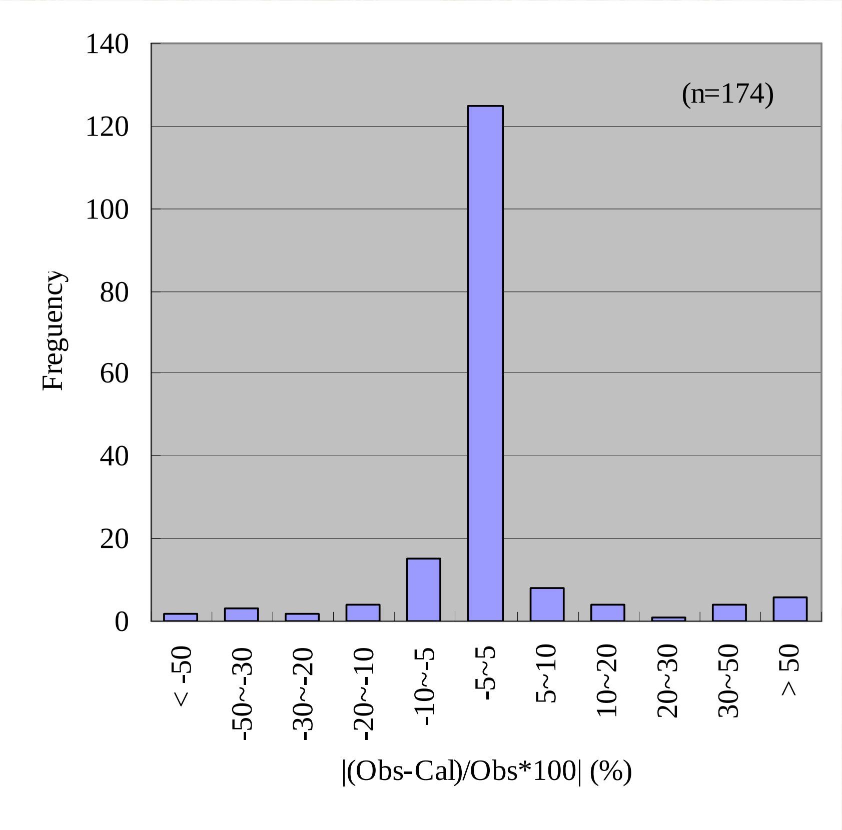


Figure 15. Basin area comparison: (Left) Delineated area (sq. km) (Right) Frequeny of % difference of BS area (N=174)

4-2. Hydrological modeling system

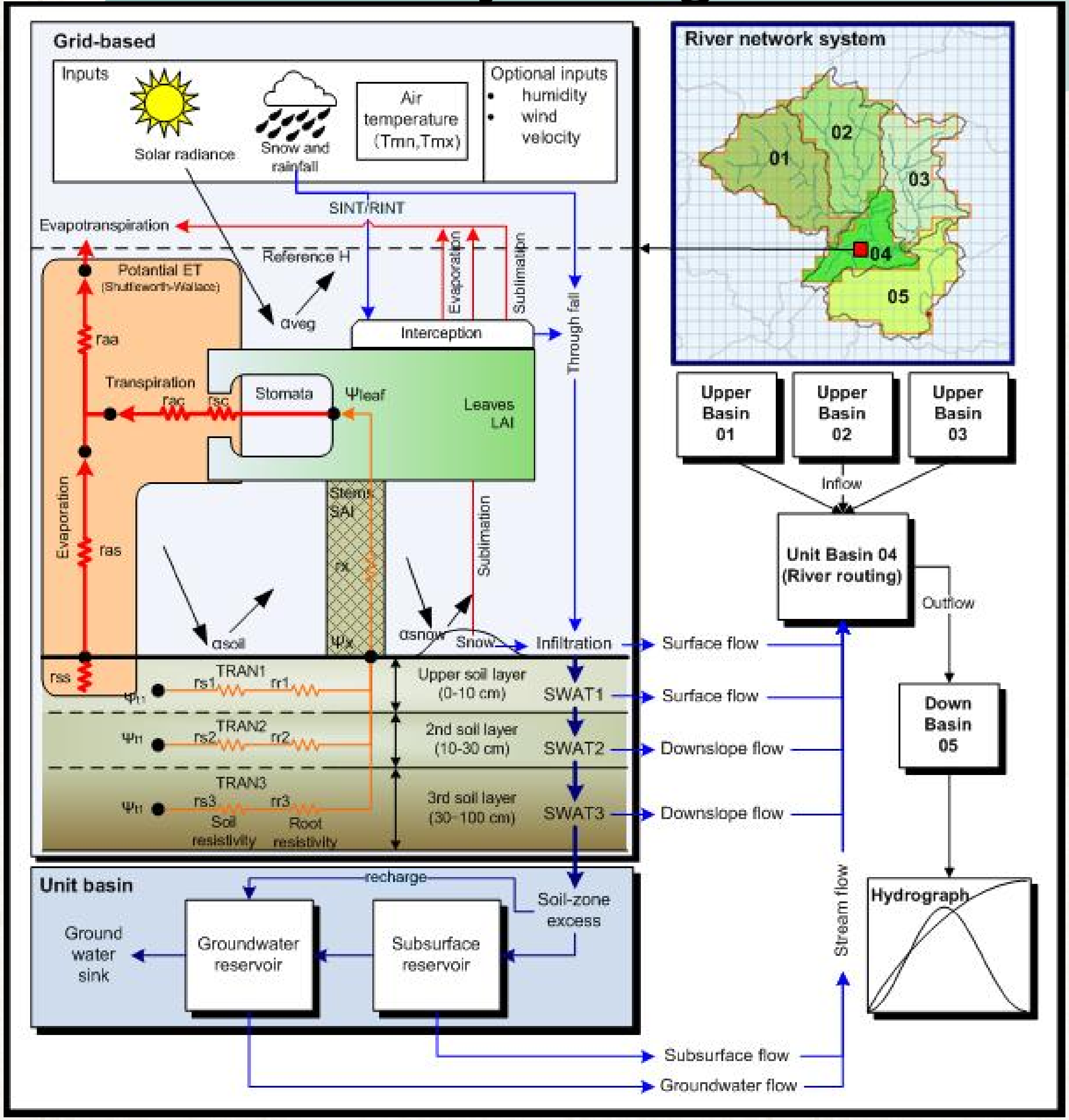


Figure 16. Flow diagram of the semi-distributed hydrologic modeling system

4-2. Study region and station info. for validation

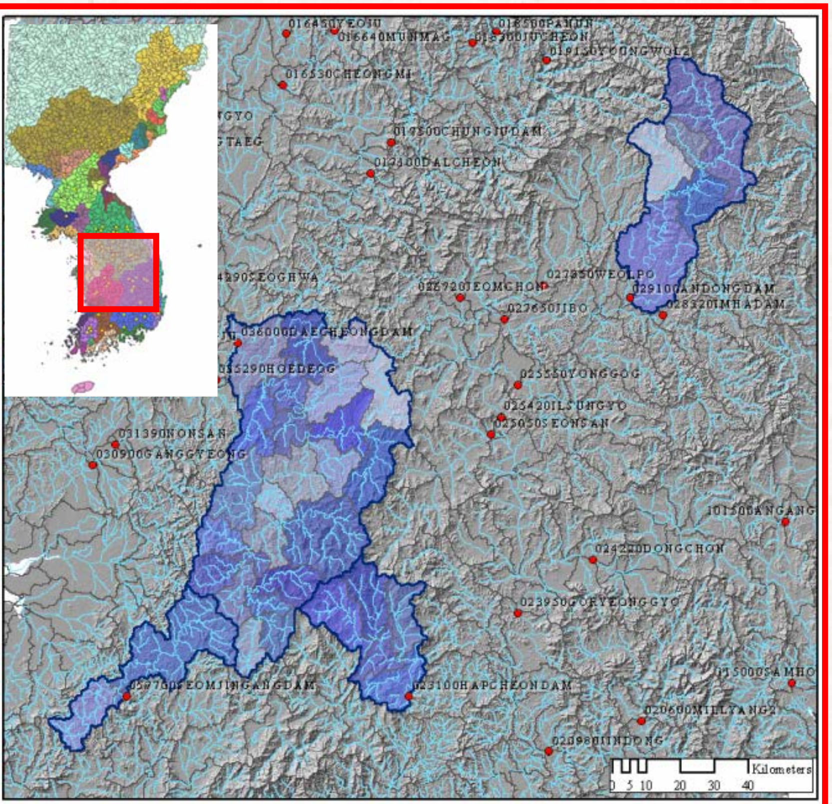


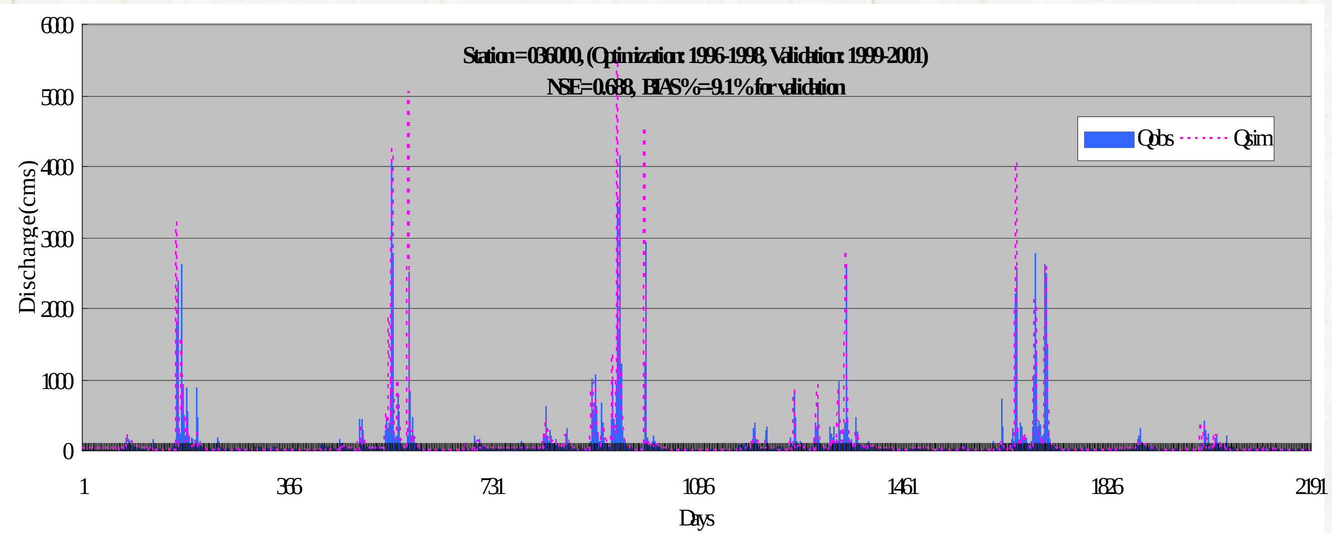
Table 10. Location and topographic information of discharge monitoring stations for model validation

		Topographic				
Code	Guage name	Latitude of centroid (deg)	Dainage area (km2)	Mean elevation (m)	Mean slope (deg)	Mean aspect (deg)
1. Republic of Korea (ROK)						
015100	Soyanggangdam	38.0327	2694.3	657.7	17.60	181.60
015700	Hwacheondam	38.4824	4086.1	580.3	15.51	183.71
017500	Chungjudam	37.2814	6659.3	616.1	16.88	181.08
021500	Namgangdam	35.4172	2287.5	432.0	14.32	175.43
023100	Hapcheondam	35.7095	929.0	508.4	14.08	179.34
028320	Imhadam	36.5497	1366.9	400.5	13.86	183.24
029100	Andongdam	36.8809	1593.3	563.5	15.21	177.18
036000	Daecheongdam	36.1258	4189.8	366.3	13.38	182.29
052270	Juamdam	34.9428	1028.6	273.3	12.34	181.66
057700	Seomjingangdam	35.6357	763.7	363.9	12.67	182.50
2. Democratic Peoples Republic of Korea (DPRK)						
031255	Mirim	39.39773	12396.8	465.1	15.22	182.30
031258	Samdung	38.99291	2801.9	476.6	17.87	183.40
031259	Dokchon	39.94235	3346.0	818.0	18.16	183.76
031265	Kumchang	41.08397	18278.1	1319.8	14.67	180.83
031496	Jonchon	40.53503	2146.1	982.7	18.47	185.38
031497	Songchon	39.33842	1731.3	432.9	15.78	184.47

4-2. Model optimization and validation

Table 11. Parameters of fitted model, with efficiency criterion over calibration and validation pe riods for 15 Korean basins

Station No.	Station	Period of record		Optimization parameters							Nash-Sutcliffe efficiency		Bais (in percent)	
		Calibration	Validation	INFEXP	CLIN	CSQ	SGR	GSC	CRGLMX	QDEPTH	Calibration	Validation	Calibration	Validation
015100	Soyanggangdam	1992-1999	2000-2001	1.9997	0.10046	0.03587	0.14754	0.02564	1	500	0.885	0.877	-14.684	-5.985
015700	Hwacheondam	1992-1999	2000-2001	1.9976	0.11996	0.02447	0.07659	0.01687	1	1000	0.743	0.829	6.013	6.488
017500	Chungjudam	1992-1999	2000-2001	1.9987	0.10010	0.01464	0.09014	0.02276	1	500	0.685	0.801	-2.897	-7.542
023100	Hapcheondam	1992-1999	2000-2001	1.8416	0.81418	0.04693	0.28914	0.01001	1	500	0.866	0.836	0.195	-1.345
029100	Andongdam	1992-1999	2000-2001	1.9957	0.10173	0.02976	0.14149	0.02732	1	500	0.716	0.853	-7.121	-2.295
036000	Daecheongdam	1992-1999	2000-2001	1.9986	0.20154	0.02559	0.07977	0.01217	1	500	0.741	0.747	1.133	2.001
052270	Juamdam	1996-1999	2000-2001	1.1026	0.10432	0.29988	0.20985	0.01010	1	500	0.836	0.570	-0.651	8.779
057700	Seomjingangdam	1992-1999	2000-2001	1.8607	0.47897	0.13847	0.12611	0.01141	1	500	0.904	0.865	0.106	4.497



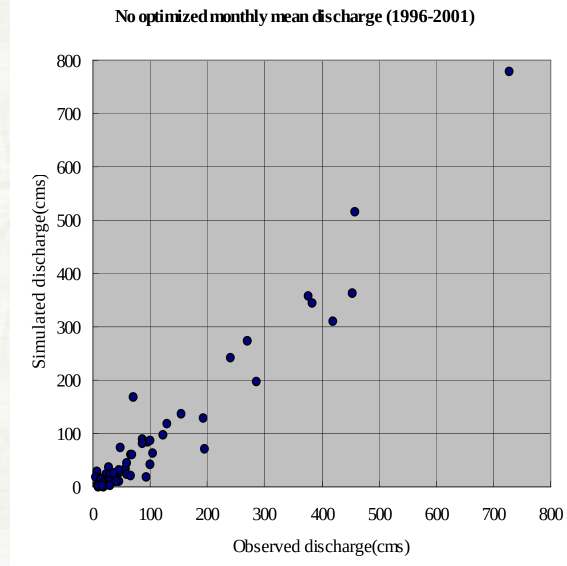


Figure 17. Location and topographic information of discharge monitoring stations

4-2. Land surface parameterization

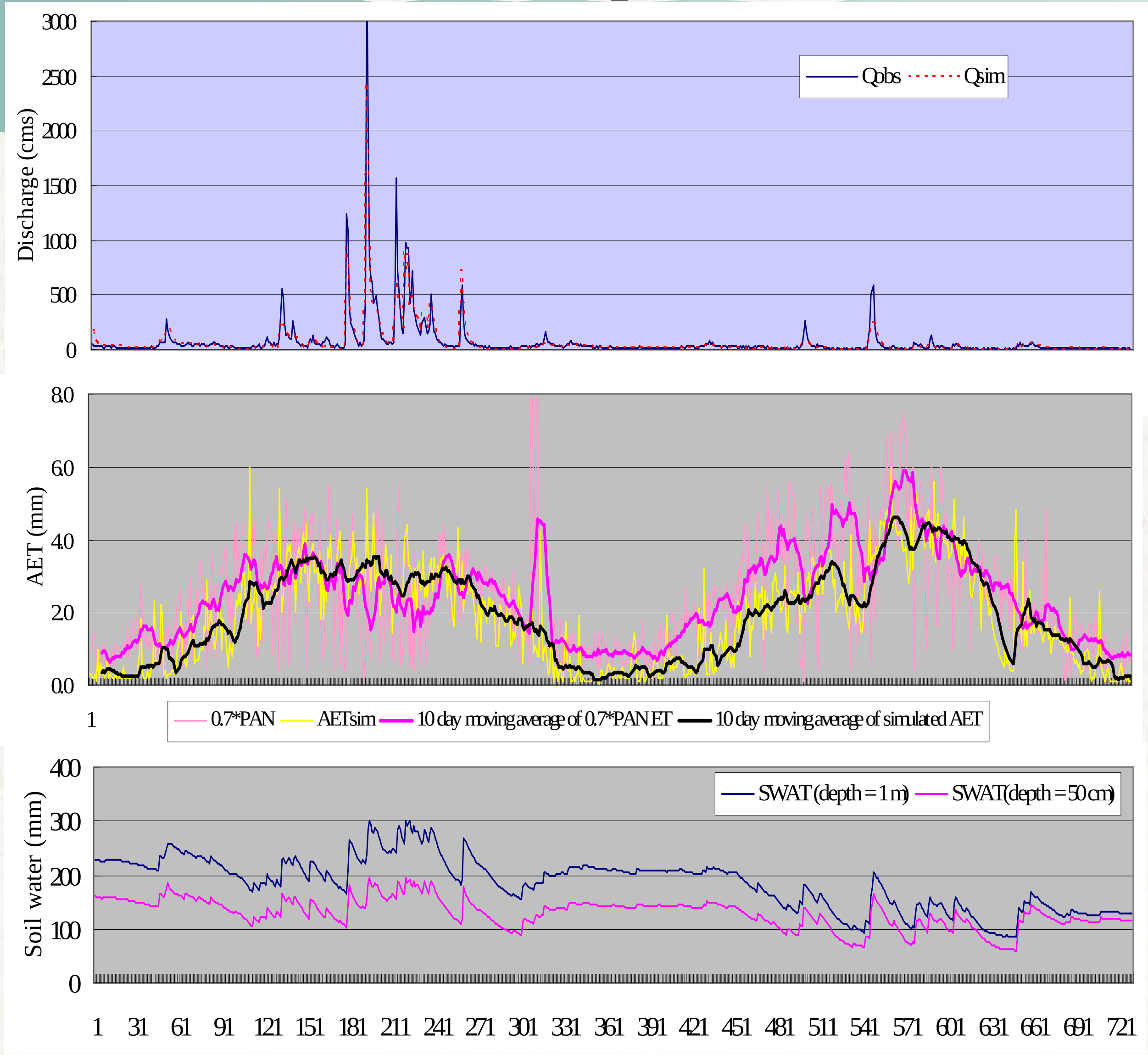


Figure 18. Land surface parameterization and estimated hydrologic component (Station = 036000, 1993/01/01-1994/12/31)

4-3. Projecting potential effects of climate change on the Korean watersheds: Examples for evapotranspiration

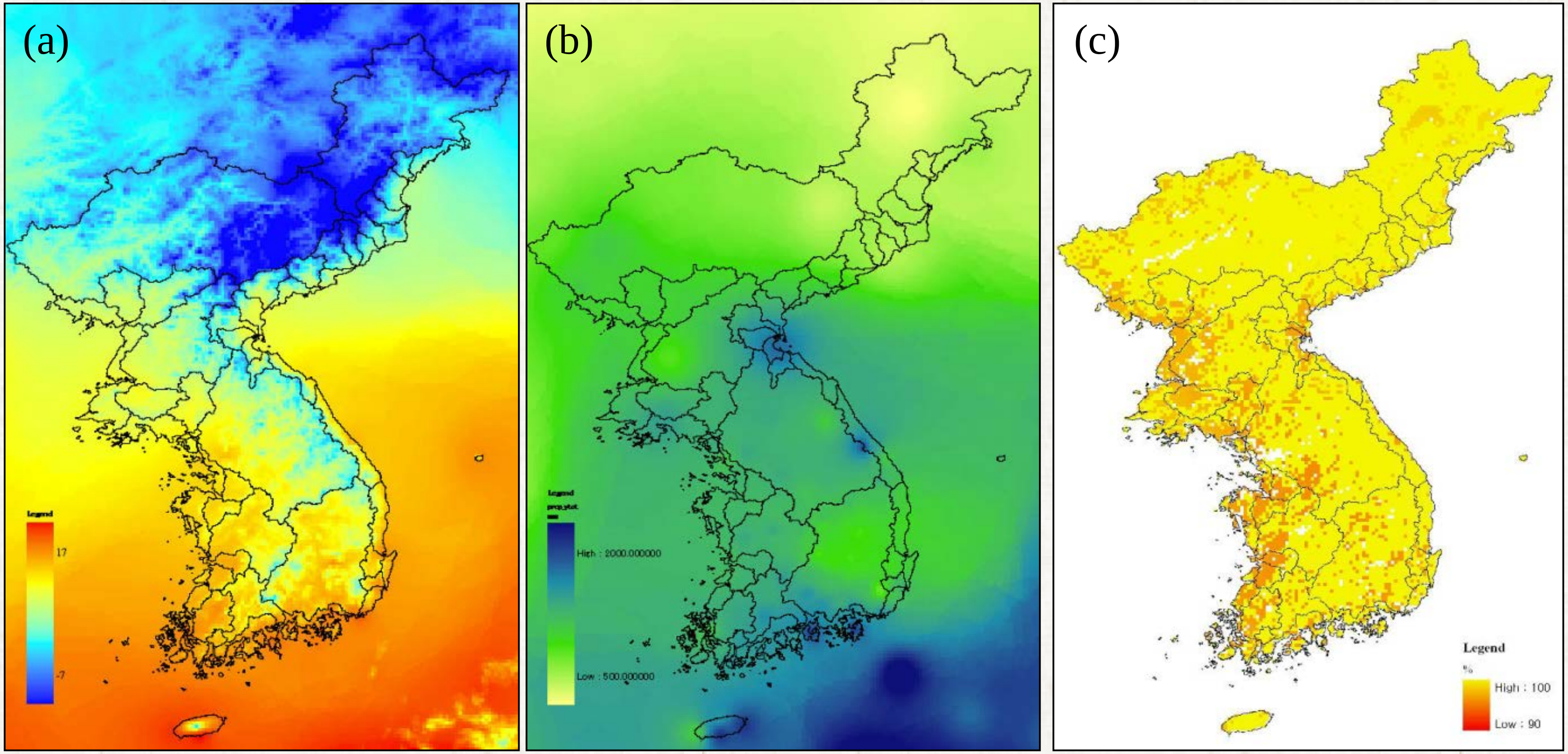


Figure 19. Spatial distribution of current climate(1971-2000, daily KMA and ECMWF-Reanalyzes results, (a) annual mean temperature, (b) precipitation) and (c) simulated vegetation water stress ratio (Actual Trans. / Potential Trans.)

4-3. Future Evaporation Change

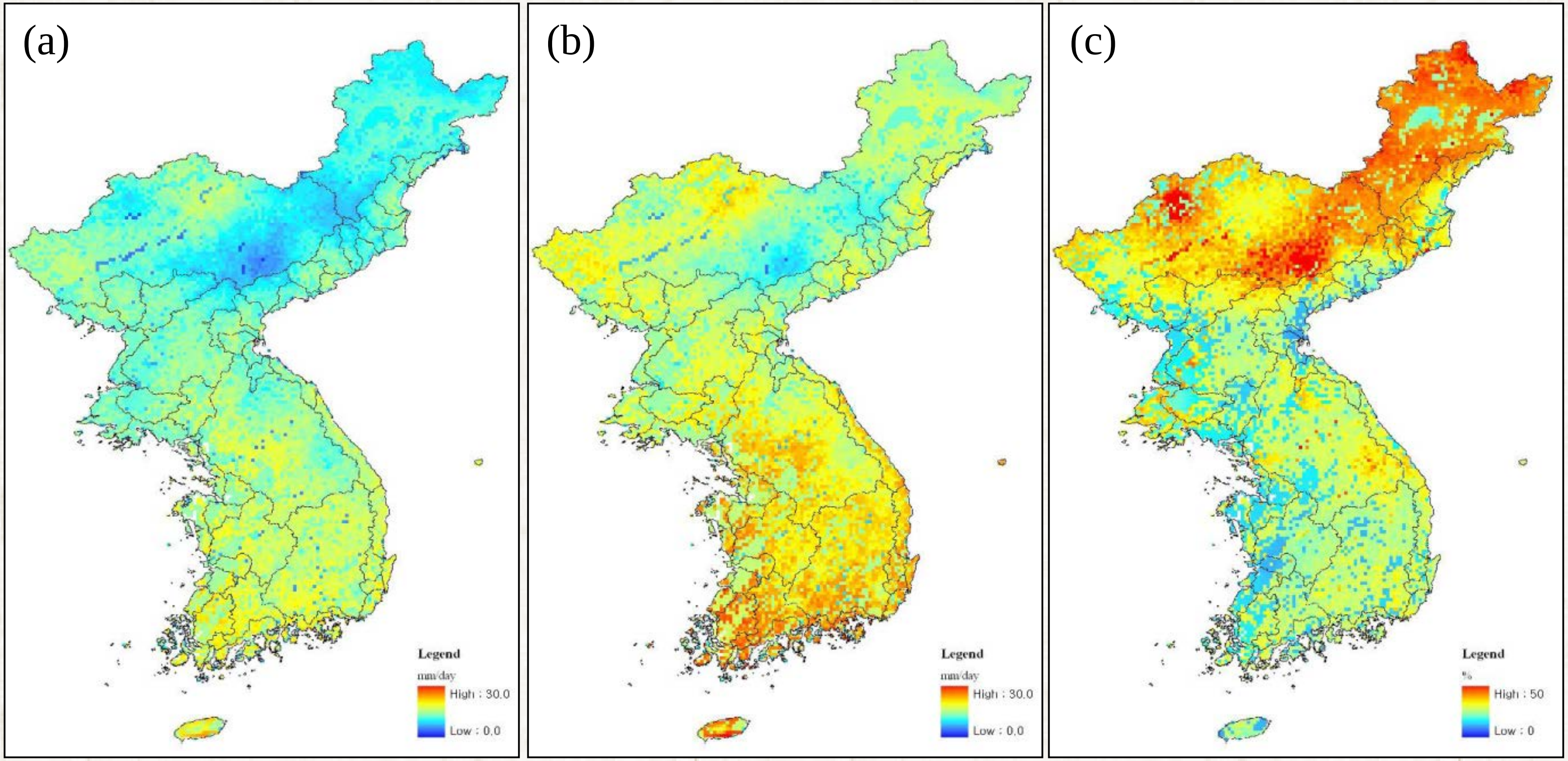


Figure 20. Change of annul evaporation rate under the same land cover condition (mm/day); (a) current (b) MRI-RCM 2050s (c) Change rate

4-3 Future Transpiration Change

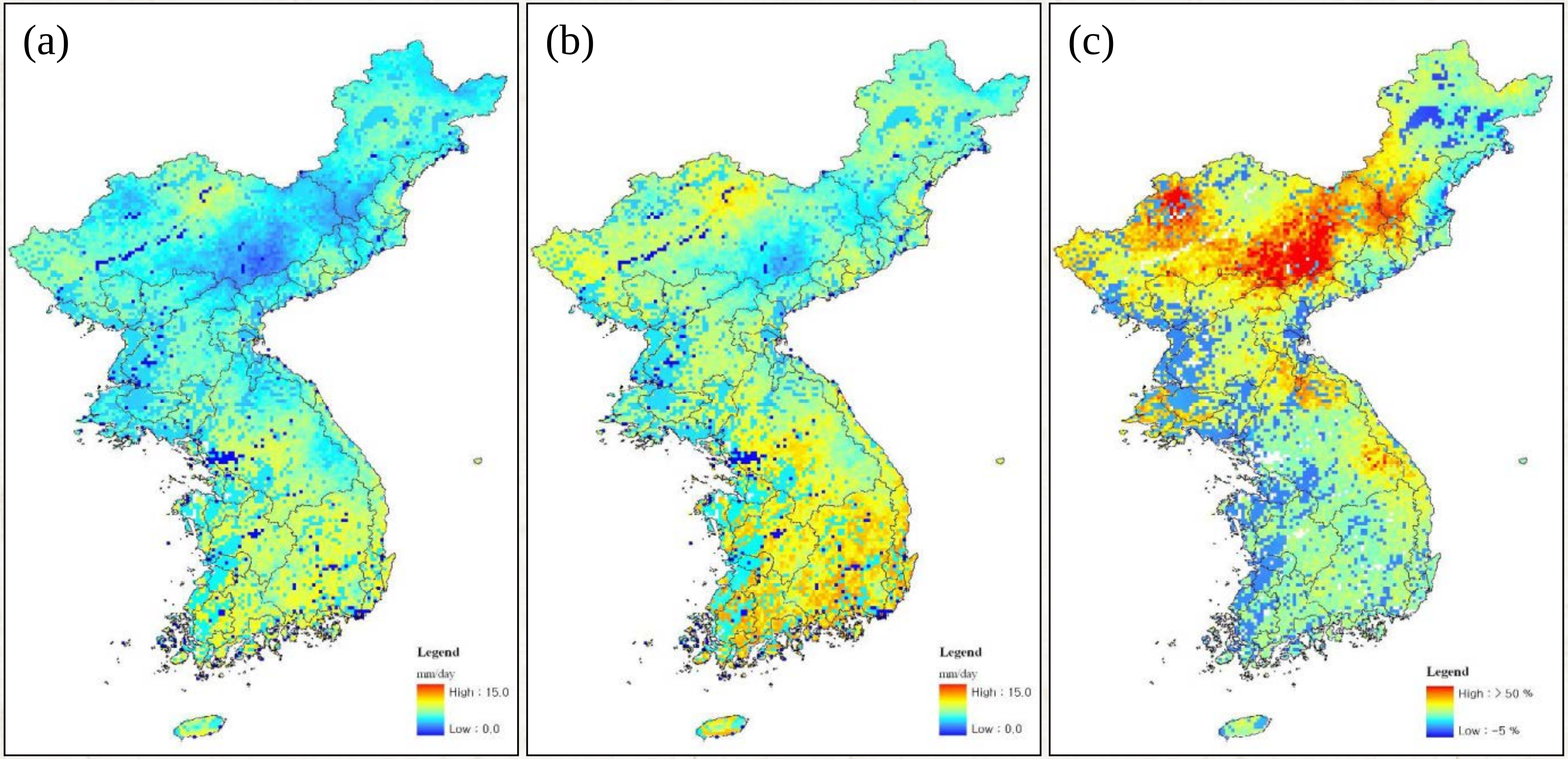


Figure 21. Change of annul transpiration rate under the same land cover condition (mm/day); (a) current (b) MRI-RCM 2050s (c) Change rate

Thank You