Development of Natural Capital Valuation for Decision-Making Process

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Introduction

1. Background and Objectives

Building a decision support system based on the value of ecosystem services

Central, local government	Relevant administrative agency	Researchers	General users

Integrated linkage about development and natural value information	System support to enhance information accessibility	Maximize the acquisition and utilization of information

Finding resolution for the social conflicts

- Environmental problems caused by large-scale national projects and social conflicts caused channeled
- Natural environmental damage, pollution caused the social cost

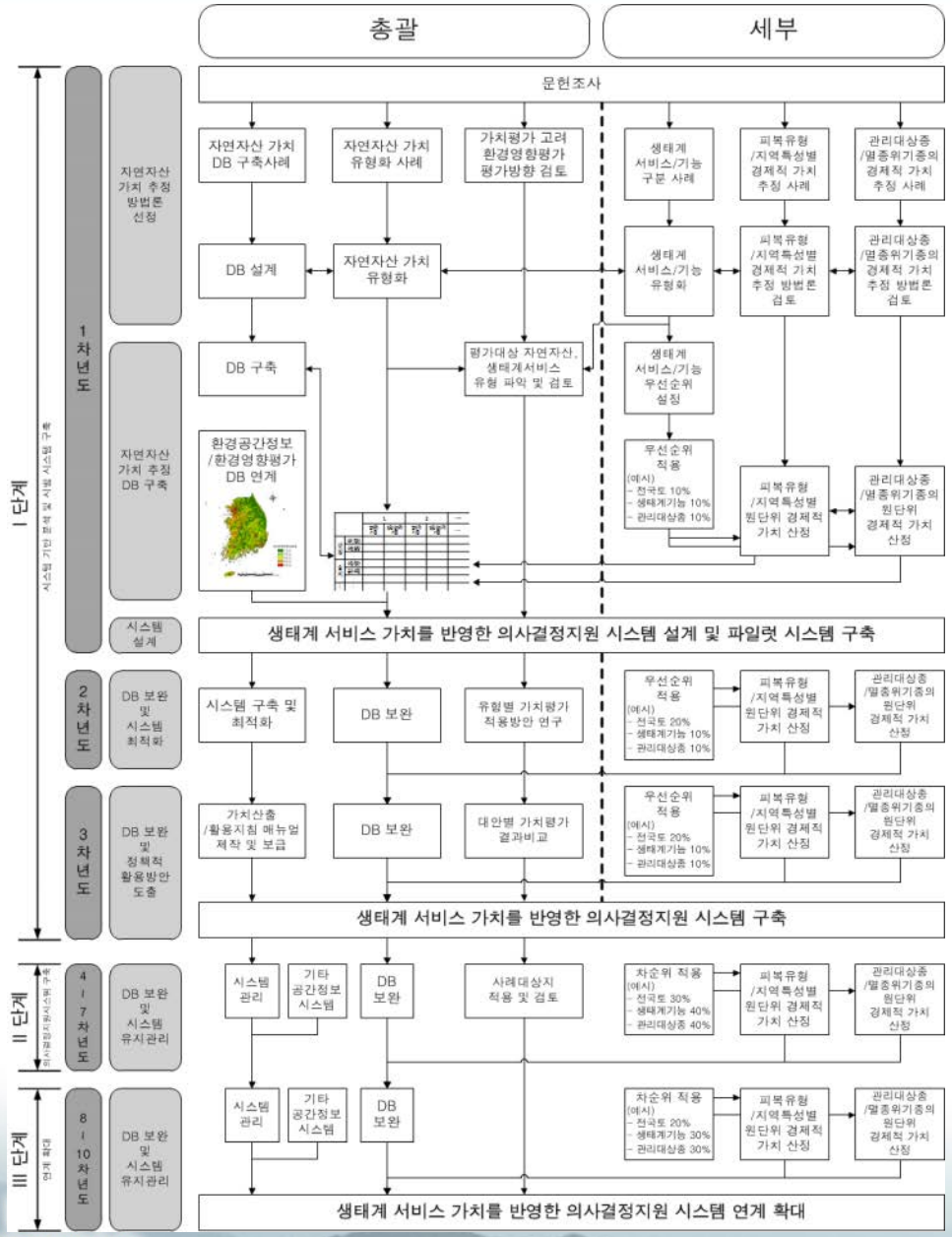
The needs to Cost-benefit analysis for natural capital

- Systematic factor assessment for conditions of location was need

Lack of the decision support systems

- The integration, analysis information system(for development values, natural values) was required
- Decision support system(considering the wide range and type of information) was required

2. Roadmap of project



Step 1 (2012 ~2014)

- Categorization of Ecosystem Services
- Quantification of Ecosystem Services
- Evaluation of Ecosystem Services
- Preparation of Matrix

Step 2 (2015 ~2018)

- Preparation of Decision Support System

Step 3 (2019 ~2021)

- Improvement of Decision Support System

Results

Difference between qualitative characteristics

Ecosystem Functions	Ecological feature		Forest type			Stand age			Reference
	Natural Forest	Artificial Forest	Coniferous forest	Deciduous forest	Mixed forest	1~20	21~40	41 <	
Water Storage and Conservation	★★★	★	★	★★★	★★				Murai and Iwasaki(1975)
				★★★	★				Kim(1993)
						★		★★★	Kim et al.(2003)
			★	★★★	★★				Kim(2003)
						★		★★★	Lee(2009)
			★	★★★	★★				KFS(2011)
Air Purification			★	★★★					Jo et al.(2001)
			★★★	★★	★	★		★★★	Choi et al.(2012)
Climate Regulation			★	★★★	★★	★		★★★	Jo and Ahn(2000)
						★		★★★	Lee(2009)
Water Purification			★	★					Lee(1997)
			★★★	★					Park(1998)
			★★★	★					Park et al.(1999)
	★	★	★	★					Goo et al.(2001)
			★	★					Lee et al.(2007)
			★★★	★					Choi et al.(2009)
			★★★	★★	★				Ma et al.(2011)

(cont.)

Difference between qualitative characteristics

Ecosystem Functions	Ecological feature		Forest type			Stand age			Reference
	Natural Forest	Artificial Forest	Coniferous forest	Deciduous forest	Mixed forest	1~20	21~40	41 <	
Prevention of Landslide	★★★	★				★		★★★	Kang et al.(1998)
	★★★	★				★	★★★		沼本晋也(2000)
			★	★★	★★★	★	★★★		Jeong and Ma(2006)
				★★★	★				Ma and Jeong(2007)
			★	★★★	★★★	★		★★★	Song(2009)
			★	★★★	★★	★		★★★	Lee(2009)
			★	★★★	★★	★	★★★	★★	Chun et al.(2009)
	★★★	★	★	★★★	★★				Park et al.(2010)
			★	★★★	★★				Kim et al.(2011)
Reduction of Soil Erosion			★★★		★				Park(2003)
						★		★★★	Youn et al.(2007)
						★		★★★	Lee(2009)
Recreation	★★★	★	★	★★	★★★	★	★★	★★★	Chung et al.(1999)
	★★★	★	★	★★	★★★	★	★★	★★★	Sung et al.(2004)
			★	★	★				KFS(2004)
						★	★	★	KFS(2008)
			★	★★★	★★★				Kim et al.(2010)

Forest types for ecosystem valuation

1st level	2nd level	3rd level (age class)	Area (ha)	Ratio (%)
Natural Forests (1100)	Coniferous forest (1110)	More than 41 (1111)	104,929	1.9
		21~40 (1112)	1,018,523	18.0
		1~20 (1113)	211,993	3.7
	Deciduous forest (1120)	More than 41 (1121)	291,994	5.2
		12~40 (1122)	1,008,729	17.8
		1~20 (1123)	109,803	1.9
	Mixed forest (1130)	More than 41 (1131)	132,804	2.3
		21~40 (1132)	1,391,334	24.6
		1~20 (1133)	207,004	3.7
Artificial Forests (1200)	Coniferous forest (1210)	More than 41 (1211)	22,553	0.4
		21~40 (1212)	57,0811	10.1
		1~20 (1213)	492,366	8.7
	Deciduous forest (1220)	More than 41 (1221)	53	0.0
		21~40 (1222)	38,463	0.7
		1~20 (1223)	56,227	1.0
Total			5,657,585	100

2. Classification of grasslands

Grassland types for ecosystem valuation

1st level	2nd level	3rd level	Area (ha)	Ratio (%)
Natural Grasslands (2100)	Alpine grassland (2110)	Alpine & subalpine grassland (2111)	9	0.0
		Sasa quelpaertenisis Nakai community (2112)	489	0.3
	Mountainous grassland (2120)	*Miscanthus sinensis* var. *purpurascens* community (2121)	11,534	7.8
	Low-lying grassland (2130)	Riparian grassland (2131)	8,416	5.7
	Other (2140)	Unclassified grassland (2141)	12,743	8.6
Artificial Grasslands (2200)	Pasture (2210)	Pasture (2211)	17,722	12.0
	Park grassland (2220)	Living area park (2221)	4,890	3.3
		Urban nature park (2222)	2,421	1.6
		Cemetery park (2223)	36,917	24.9
		Theme park (2224)	15,821	10.7
	Other (2230)	Transport facilities (2231)	18,649	12.6
		Sports facilities (2232)	7,604	5.1
		Unclassified grassland (2233)	10,913	7.4
Total			148,100	100

2. Classification of grasslands

Sample area of grasslands

Sasa quelpaertenisis Nakai community (2112)

Miscanthus sinensis var. *purpurascens* community (2121)

Riparian grassland (2131)

Living area park (2221)

Cemetery park (2223)

Transport facilities (2231)

Wetland types for ecosystem valuation

1st level	2nd level	3rd level	Area (ha)	Ratio (%)
Natural Wetlands (3100)	Marine/Coastal Wetlands (3110)	Seashore wetlands (3111)	-	-
		Estuary wetlands (3112)	4,768	2.2
		Lake/Marsh wetlands (3113)	481	0.2
		Unclassified wetlands (3114)	30,094	14.1
	Inland Wetlands (3120)	River wetlands (3121)	85,155	39.9
		Lake wetlands (3122)	29,775	13.9
		Palustrine wetlands (3123)	46,925	22.0
		Unclassified wetlands (3124)	3,703	1.7
Artificial Wetlands (3200)	Artificial Wetlands (3210)	Agricultural land (3211)	1,361	0.6
		Urban and industry (3212)	11,384	5.3
Total			213,646	100

3. Classification of wetlands

Sample area of wetlands

Estuary wetlands
(3112)

Lake/Marsh wetlands
(3113)

River wetlands
(3121)

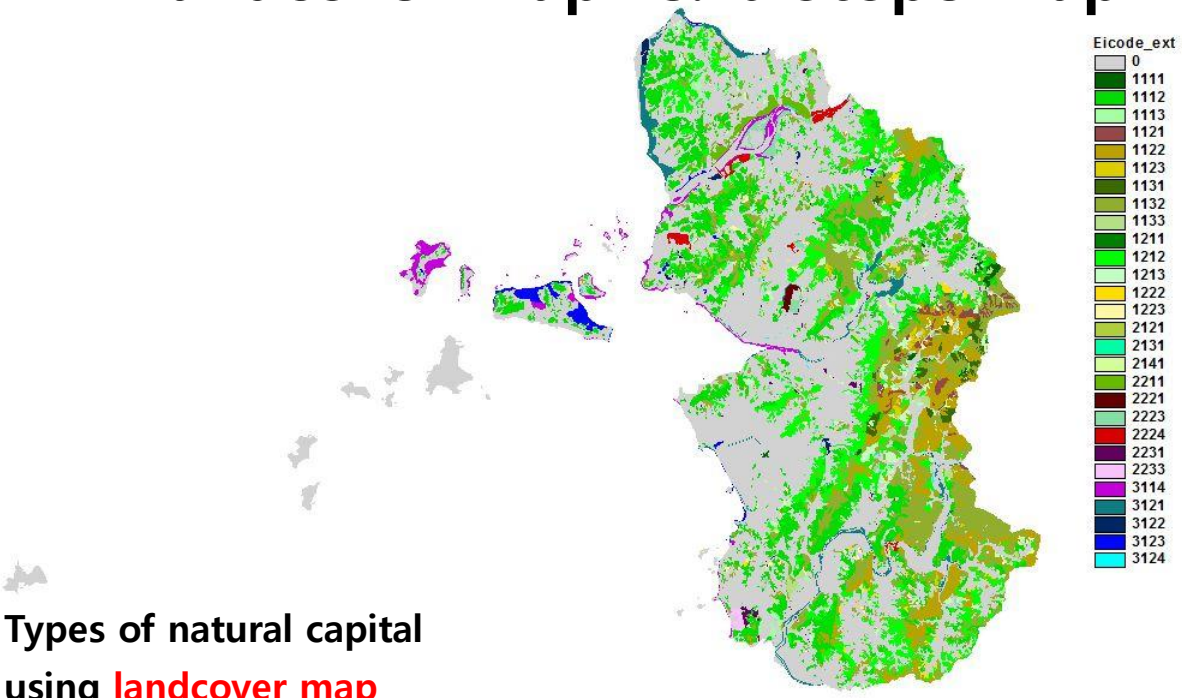
Lake wetlands
(3122)

Palustrine wetlands
(3123)

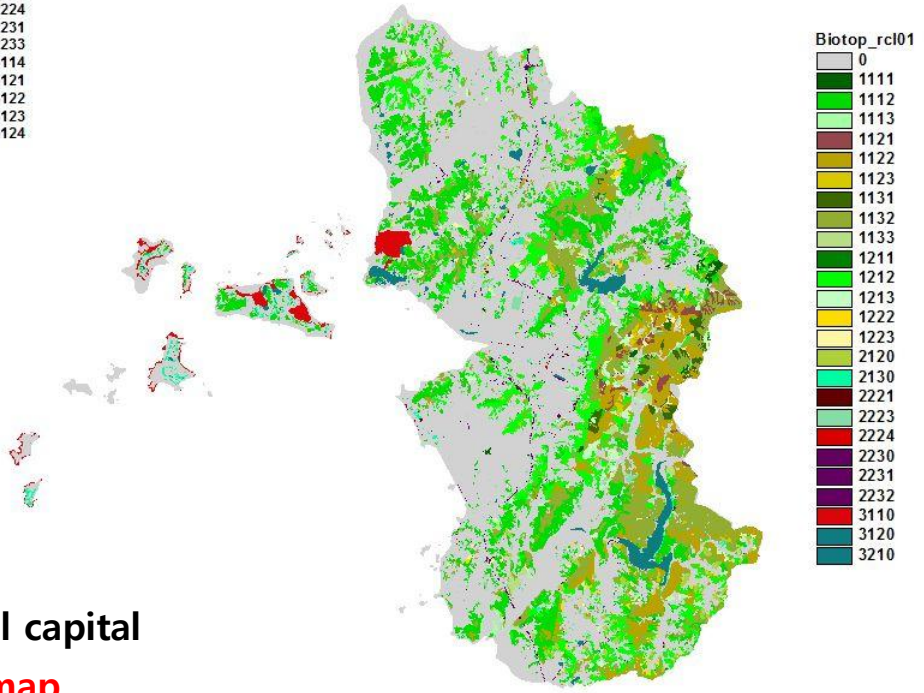
Urban and industry
(3212)

4. Pilot testing for enhancement of types

Landcover map vs. biotope map



Types of natural capital using **landcover map**

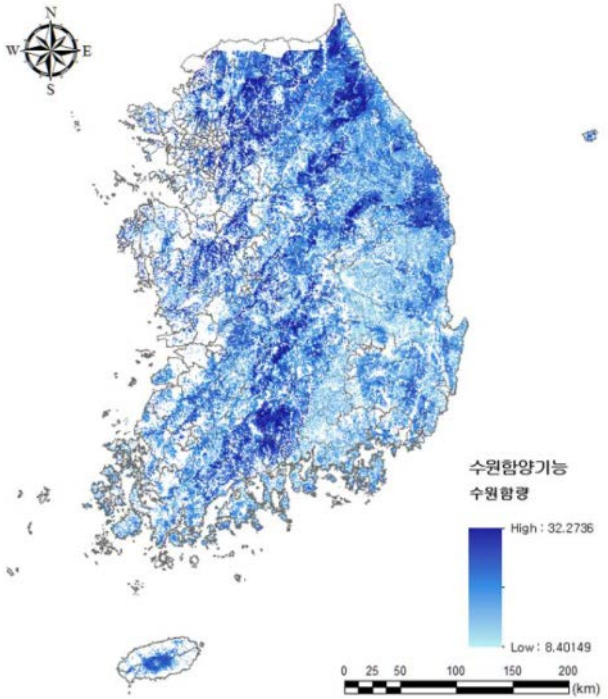


Types of natural capital using **biotope map**

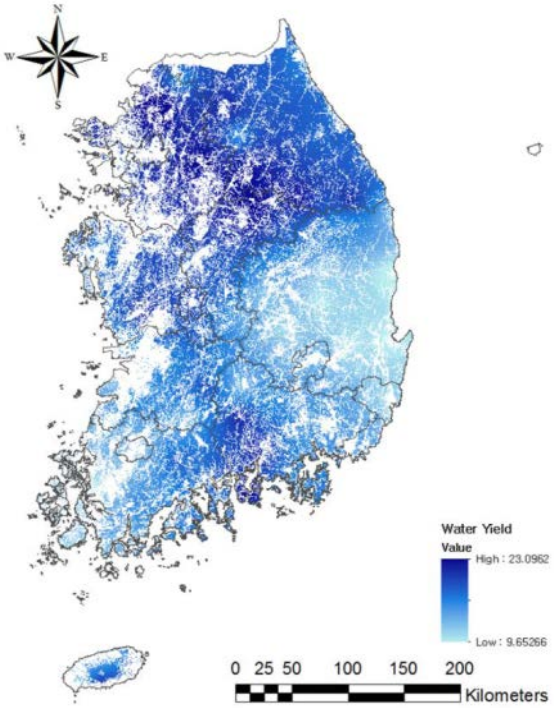
Landcover map vs. biotope map

Categories	Landcover map	Biotope map	notes
Total	61,001.95m^2	61,001.95m^2	
Forest types	27,847.16m^2	25,192.60m^2	
Grassland types	1,566.57m^2 (include pasture)	2,549.75m^2 (exclude pasture)	Biotope map classified detailedly than landcover map
Wetland types	2,263.99m^2	1,990.73m^2	
Other types	29,324.23m^2	31,268.87m^2	

Provisioning services

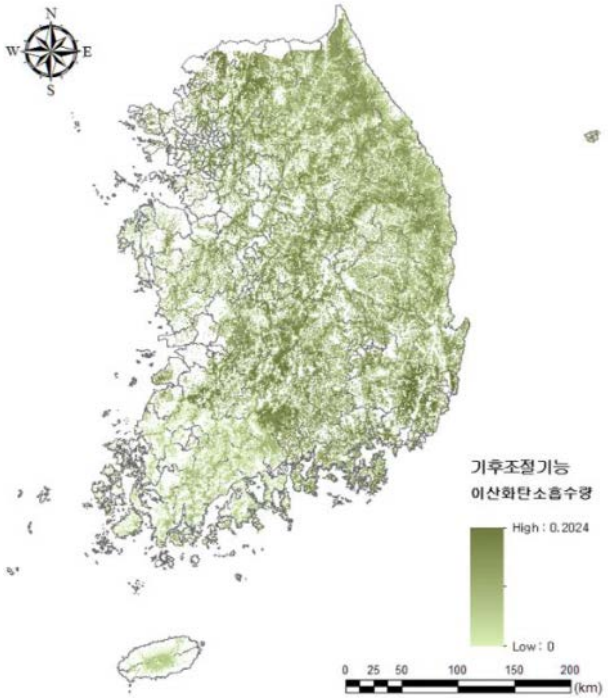


Water availability
(KFRI statistic model)

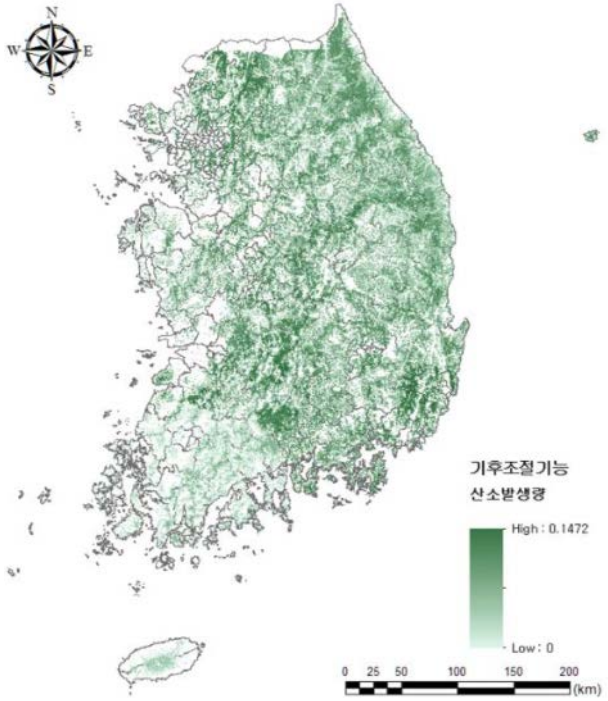


Water yield
(InVEST model)

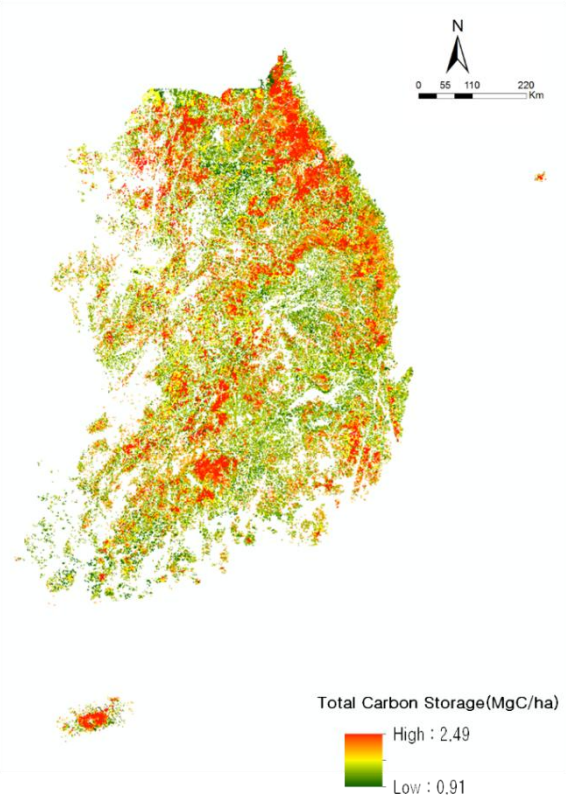
Regulating services



CO_2 sequestration
(KFRI statistic model)

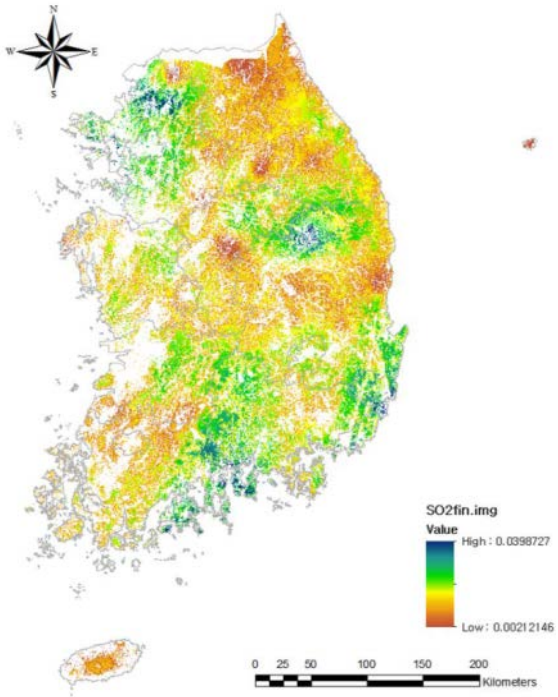


O_2 production
(KFRI statistic model)

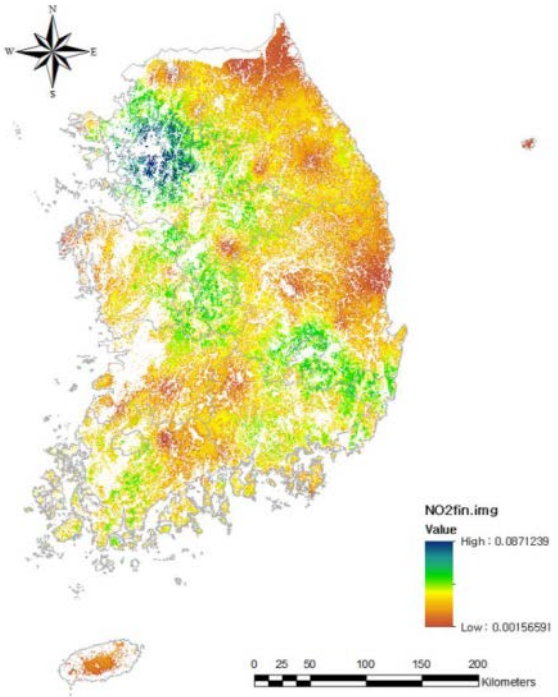


Carbon storage
(InVEST model)

Regulating services

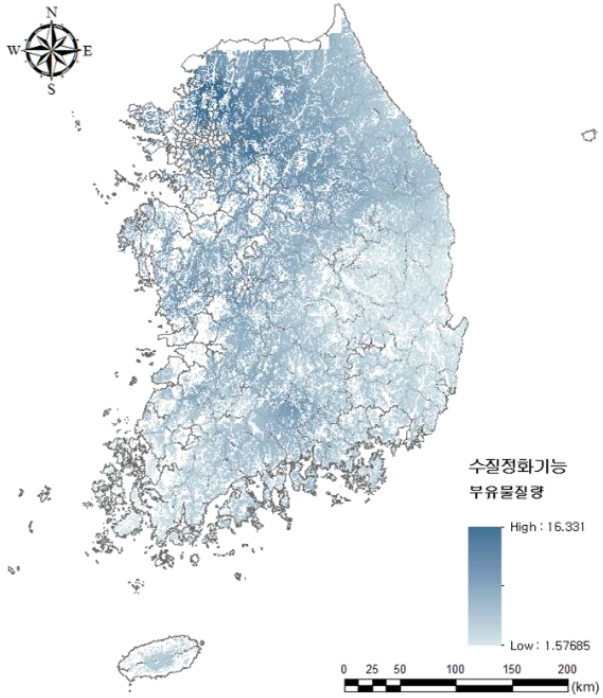


SO_2 absorption
(KFRI statistic model)

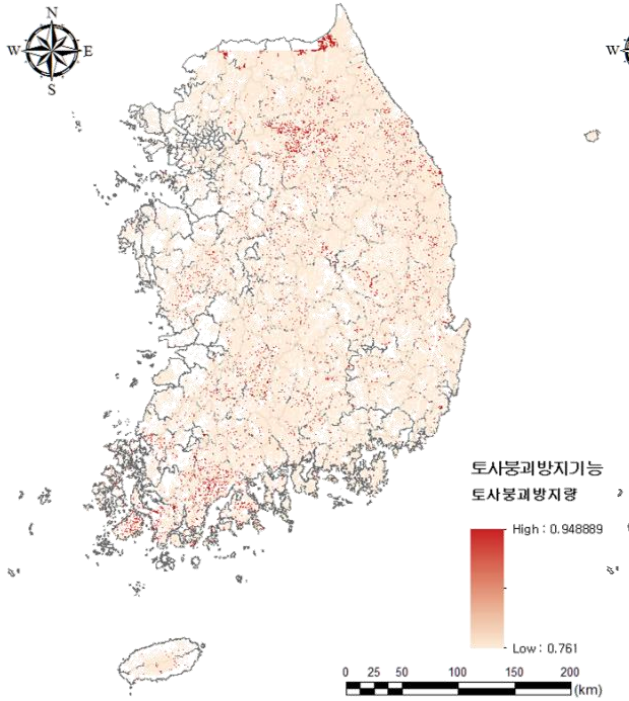


NO_2 absorption
(KFRI statistic model

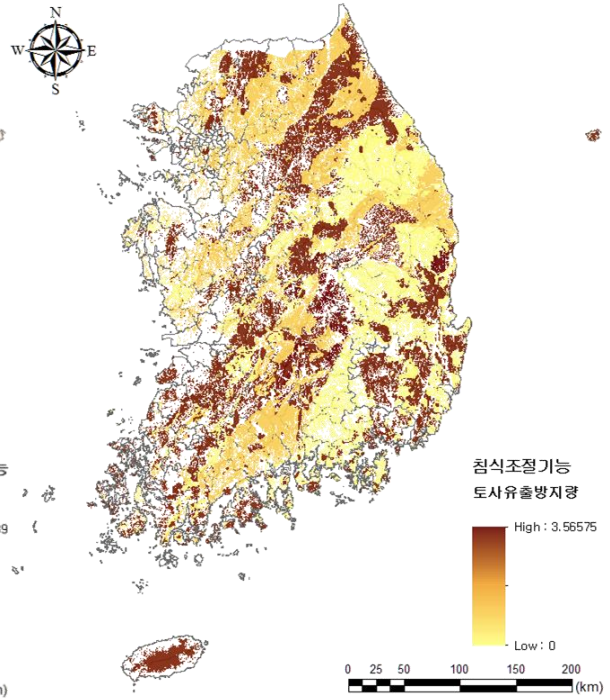
Regulating services



Water purification
(KFRI statistic model)



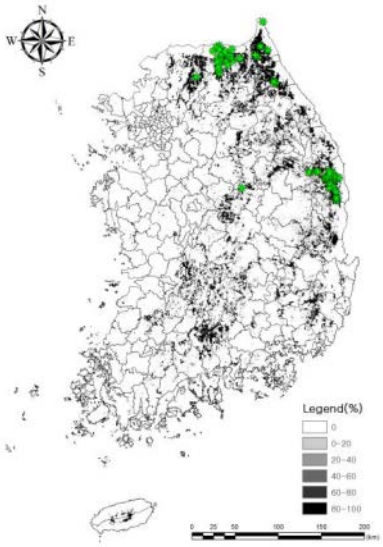
Prevention of landslide
(KFRI statistic model)



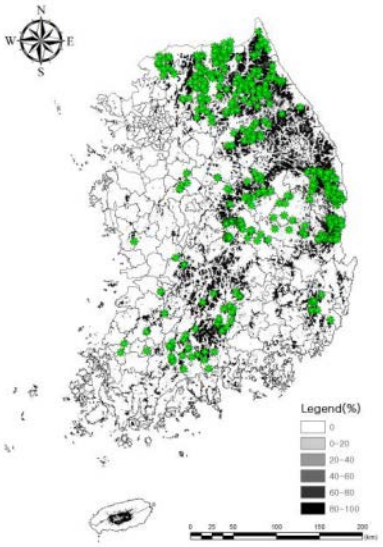
Reduction of soil erosion
(InVEST model)

Supporting services

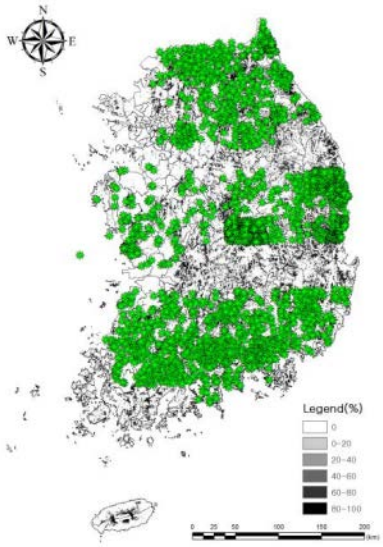
- Spatial distribution probabilities of endangered mammals



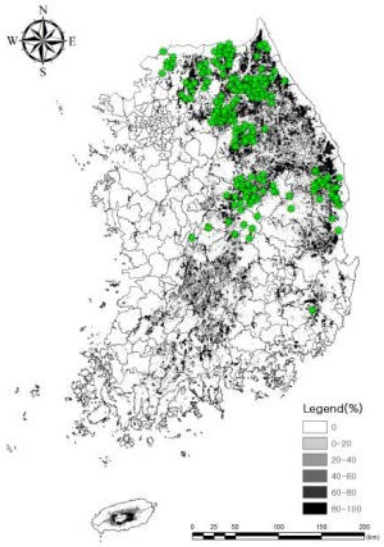
Goat
(*Naemorhedus caudatus*)



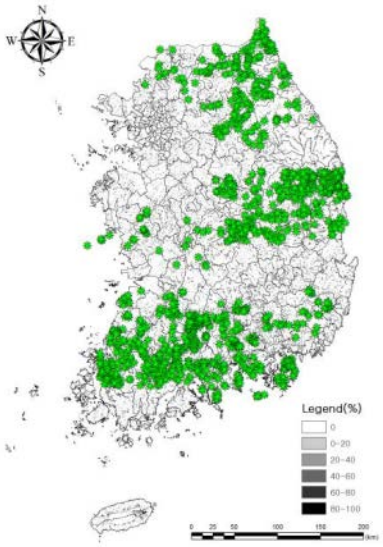
Marten
(*Martes flavigula*)



Leopard Cat
(*Prionailurus bengalensis*)



Flying Squirrel
(*Pteromys volans aluco*)



Otter
(*Lutra lutra*)

Provisioning services - water availability

Level I	Level II (Stand)	Level III (Tree age)	Area (ha)	Amount (ton/yr)	Economic Value ($/yr)	Unit area ($/ha/yr)	Ratio (%)
Natural Forest	Coniferous Forest	Over 5th age-class	104,849	231,925,988	103,292,261	986	1.9
		3rd ~4th age-class	1,016,215	2,065,965,095	920,130,231	905	17.1
		1st ~2nd age-class	211,143	382,379,973	170,253,745	806	3.2
	Broadleaf Forest	Over 5th age-class	291,958	822,445,686	366,301,766	1,255	6.8
		3rd ~4th age-class	1,007,548	2,621,639,896	1,167,651,654	1,159	21.7
		1st ~2nd age-class	109,624	264,961,208	117,974,272	1,076	2.2
	Mixed Forest	Over 5th age-class	132,728	303,548,936	135,189,649	1,019	2.5
		3rd ~4th age-class	1,388,433	2,599,146,576	1,157,633,341	834	21.5
		1st ~2nd age-class	206,405	291,031,050	129,604,728	628	2.4
Artificial Forest	Coniferous Forest	Over 5th age-class	22,543	54,531,517	24,239,711	1,075	0.5
		3rd ~4th age-class	570,061	1,237,032,370	550,949,639	967	10.2
		1st ~2nd age-class	491,716	989,824,308	440,805,773	897	8.2
	Broadleaf Forest	Over 5th age-class	53	136,952	57,577	1,086	0.0
		3rd ~4th age-class	38,402	100,344,426	44,679,373	1,163	0.8
		1st ~2nd age-class	56,156	133,033,564	59,246,231	1,055	1.1
Total			5,647,834	12,097,947,545	5,388,355,410	954	100.0

Regulating services - CO_2 sequestration

Level I	Level II (Stand)	Level III (Tree age)	Area (ha)	Amount (ton/yr)	Economic Value ($/yr)	Unit area ($/ha/yr)	Ratio (%)
Natural Forest	Coniferous Forest	Over 5th age-class	104,849	904,487	29,340,991	280	1.4
		3rd ~4th age-class	1,016,215	8,983,372	291,423,513	287	13.5
		1st ~2nd age-class	211,143	1,863,418	60,449,579	286	2.8
	Broadleaf Forest	Over 5th age-class	291,958	4,511,307	146,347,977	501	6.8
		3rd ~4th age-class	1,007,548	16,058,965	520,963,792	517	24.2
		1st ~2nd age-class	109,624	1,671,201	54,214,044	494	2.5
	Mixed Forest	Over 5th age-class	132,728	1,587,007	51,479,159	388	2.4
		3rd ~4th age-class	1,388,433	17,349,934	562,844,946	406	26.1
		1st ~2nd age-class	206,405	2,523,378	81,856,526	396	3.8
Artificial Forest	Coniferous Forest	Over 5th age-class	22,543	210,193	6,817,059	302	0.3
		3rd ~4th age-class	570,061	5,085,926	164,991,251	290	7.7
		1st ~2nd age-class	491,716	4,239,271	137,521,498	279	6.4
	Broadleaf Forest	Over 5th age-class	53	895	28,788	544	0.0
		3rd ~4th age-class	38,402	593,484	19,247,827	501	0.9
		1st ~2nd age-class	56,156	881,639.36	28,598,253	509	1.3
Total			5,647,834	66,464,477.36	2,156,165,508	382	100.0

Regulating services - O_2 production

Level I	Level II (Stand)	Level III (Tree age)	Area (ha)	Amount (ton/yr)	Economic Value ($/yr)	Unit area ($/ha/yr)	Ratio (%)
Natural Forest	Coniferous Forest	Over 5th age-class	104,849	657,904	142,847,325	1,362	1.4
		3rd ~4th age-class	1,016,215	6,528,732	1,417,821,597	1,395	13.6
		1st ~2nd age-class	211,143	1,352,515	293,697,785	1,391	2.8
	Broadleaf Forest	Over 5th age-class	291,958	3,279,092	712,106,295	2,439	6.8
		3rd ~4th age-class	1,007,548	11,681,081	2,536,821,099	2,518	24.3
		1st ~2nd age-class	109,624	1,214,421	263,700,422	2,405	2.5
	Mixed Forest	Over 5th age-class	132,728	1,144,770	248,557,800	1,873	2.4
		3rd ~4th age-class	1,388,433	12,438,525	2,701,317,192	1,946	25.8
		1st ~2nd age-class	206,405	1,819,565	395,147,599	1,914	3.8
Artificial Forest	Coniferous Forest	Over 5th age-class	22,543	152,909	33,164,071	1,472	0.3
		3rd ~4th age-class	570,061	374,563	804,516,596	1,411	7.7
		1st ~2nd age-class	491,716	3,082,211	669,326,947	1,361	6.4
	Broadleaf Forest	Over 5th age-class	53	650	115,153	2,173	0.0
		3rd ~4th age-class	38,402	431,554	93,676,984	2,439	0.9
		1st ~2nd age-class	56,156	640,987	139,162,428	2,478	1.3
Total			5,647,834	48,129,479	10,452,497,484	1,851	100.0

Regulating services - carbon storage

Level I	Level II (Stand)	Level III (Tree age)	Area (ha)	Amount (ton/yr)	Economic Value ($/yr)	Unit area ($/ha/yr)	Ratio (%)
Natural Forest	Coniferous Forest	Over 5th age-class	104,849	35,181,995	1,141,339,189	10,886	2.0
		3rd ~4th age-class	1,016,215	265,816,815	8,623,349,288	8,486	15.3
		1st ~2nd age-class	211,143	40,571,663	1,316,199,054	6,234	2.3
	Broadleaf Forest	Over 5th age-class	291,958	166,472,781	5,400,504,054	18,497	9.6
		3rd ~4th age-class	1,007,548	418,622,182	13,580,456,626	13,479	24.1
		1st ~2nd age-class	109,624	18,551,200	601,789,699	5,490	1.1
	Mixed Forest	Over 5th age-class	132,728	59,596,383	1,933,361,681	14,566	3.4
		3rd ~4th age-class	1,388,433	437,835,899	14,203,779,941	10,230	25.2
		1st ~2nd age-class	206,405	32,780,486	1,063,438,169	5,152	1.9
Artificial Forest	Coniferous Forest	Over 5th age-class	22,543	7,561,895	245,333,515	10,883	0.4
		3rd ~4th age-class	570,061	142,837,710	4,633,757,650	8,129	8.2
		1st ~2nd age-class	491,716	88,845,293	2,882,222,592	5,861	5.1
	Broadleaf Forest	Over 5th age-class	53	30,028	978,801	18,468	0.0
		3rd ~4th age-class	38,402	13,869,928	449,960,438	11,717	0.8
		1st ~2nd age-class	56,156	8,227,948	266,924,707	4,753	0.5
Total			5,647,834	1,736,802,208	56,343,452,979	9,976	100.0

Regulating services - water purification

Level I	Level II (Stand)	Level III (Tree age)	Area (ha)	Amount (ton/yr)	Economic Value ($/yr)	Unit area ($/ha/yr)	Ratio (%)
Natural Forest	Coniferous Forest	Over 5th age-class	104,849	57,920,808	33,446,196	319	1.7
		3rd ~4th age-class	1,016,215	531,669,006	307,055,536	302	15.5
		1st ~2nd age-class	211,143	94,124,892	54,357,985	257	2.7
	Broadleaf Forest	Over 5th age-class	291,958	182,496,250	105,393,804	361	5.3
		3rd ~4th age-class	1,007,548	678,874,617	392,073,013	389	19.7
		1st ~2nd age-class	109,624	72,799,389	42,042,369	384	2.1
	Mixed Forest	Over 5th age-class	132,728	77,557,536	44,788,768	338	2.3
		3rd ~4th age-class	1,388,433	812,539,056	469,271,599	338	23.6
		1st ~2nd age-class	206,405	113,645,196	65,631,466	318	3.3
Artificial Forest	Coniferous Forest	Over 5th age-class	22,543	20,117,276	11,613,183	515	0.6
		3rd ~4th age-class	570,061	420,687,707	242,961,363	426	12.2
		1st ~2nd age-class	491,716	314,129,508	181,417,830	369	9.1
	Broadleaf Forest	Over 5th age-class	53	19,610	5,757	108	0.0
		3rd ~4th age-class	38,402	25,924,062	14,969,893	389	0.8
		1st ~2nd age-class	56,156	37,222,274	21,493,312	383	1.1
Total			5,647,834	3,439,727,187	1,986,573,893	351	100.0

Regulating services - prevention of landslide

Level I	Level II (Stand)	Level III (Tree age)	Area (ha)	Amount (ton/yr)	Economic Value ($/yr)	Unit area ($/ha/yr)	Ratio (%)
Natural Forest	Coniferous Forest	Over 5th age-class	104,849	7,913,196	43,838,756	418	1.8
		3rd ~4th age-class	1,016,215	76,691,372	424,908,898	418	17.8
		1st ~2nd age-class	211,143	16,194,640	89,721,478	425	3.8
	Broadleaf Forest	Over 5th age-class	291,958	22,169,580	122,827,972	421	5.1
		3rd ~4th age-class	1,007,548	76,452,808	423,584,638	421	17.7
		1st ~2nd age-class	109,624	8,632,251	47,823,051	436	2.0
	Mixed Forest	Over 5th age-class	132,728	10,070,304	55,791,640	420	2.3
		3rd ~4th age-class	1,388,433	105,174,804	582,720,358	420	24.4
		1st ~2nd age-class	206,405	15,822,114	87,660,239	425	3.7
Artificial Forest	Coniferous Forest	Over 5th age-class	22,543	1,705,820	9,448,306	419	0.4
		3rd ~4th age-class	570,061	43,068,592	238,620,095	418	10.0
		1st ~2nd age-class	491,716	40,076,844	222,043,817	451	9.3
	Broadleaf Forest	Over 5th age-class	53	3,952	17,273	326	0.0
		3rd ~4th age-class	38,402	2,938,705	16,276,880	424	0.7
		1st ~2nd age-class	56,156	4,800,004	26,588,833	473	1.1
Total			5,647,834	431,714,986	2,391,918,292	423	100.0

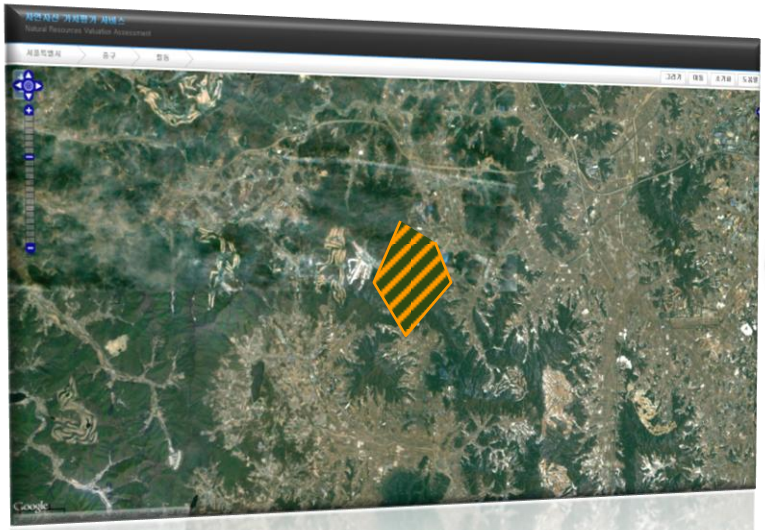
Regulating services - reduction of soil erosion

Level I	Level II (Stand)	Level III (Tree age)	Area (ha)	Amount (ton/yr)	Economic Value ($/yr)	Unit area ($/ha/yr)	Ratio (%)
Natural Forest	Coniferous Forest	Over 5th age-class	104,849	30,324,192	131,159,293	1,251	1.9
		3rd ~4th age-class	1,016,215	292,314,379	1,264,783,229	1,245	18.1
		1st ~2nd age-class	211,143	58,085,534	251,321,473	1,190	3.6
	Broadleaf Forest	Over 5th age-class	291,958	82,926,296	358,759,243	1,229	5.1
		3rd ~4th age-class	1,007,548	289,504,936	1,252,634,586	1,243	18.0
		1st ~2nd age-class	109,624	31,623,264	136,801,792	1,248	2.0
	Mixed Forest	Over 5th age-class	132,728	38,380,356	166,050,660	1,251	2.4
		3rd ~4th age-class	1,388,433	396,529,905	1,715,722,468	1,236	24.6
		1st ~2nd age-class	206,405	57,960,840	250,745,707	1,215	3.6
Artificial Forest	Coniferous Forest	Over 5th age-class	22,543	6,292,287	27,176,114	1,206	0.4
		3rd ~4th age-class	570,061	161,539,513	698,921,273	1,226	10.0
		1st ~2nd age-class	491,716	141,308,755	611,404,976	1,244	8.8
	Broadleaf Forest	Over 5th age-class	53	17,119	57,577	1,086	0.0
		3rd ~4th age-class	38,402	10,461,664	45,255,138	1,179	0.6
		1st ~2nd age-class	56,156	15,462,425	66,903,907	1,191	1.0
Total			5,647,834	1,612,731,465	6,978,042,894	1,235	100.0

Natural Capital Valuation Support System

NCVSS

- Supporting to decide for the place expected development by NCVSS
- Supporting select easy the target area and use query result
- Supporting the result of valuation of forest types, CO_2 absorption, O_2 supply , preventing soil erosion, water recharge.

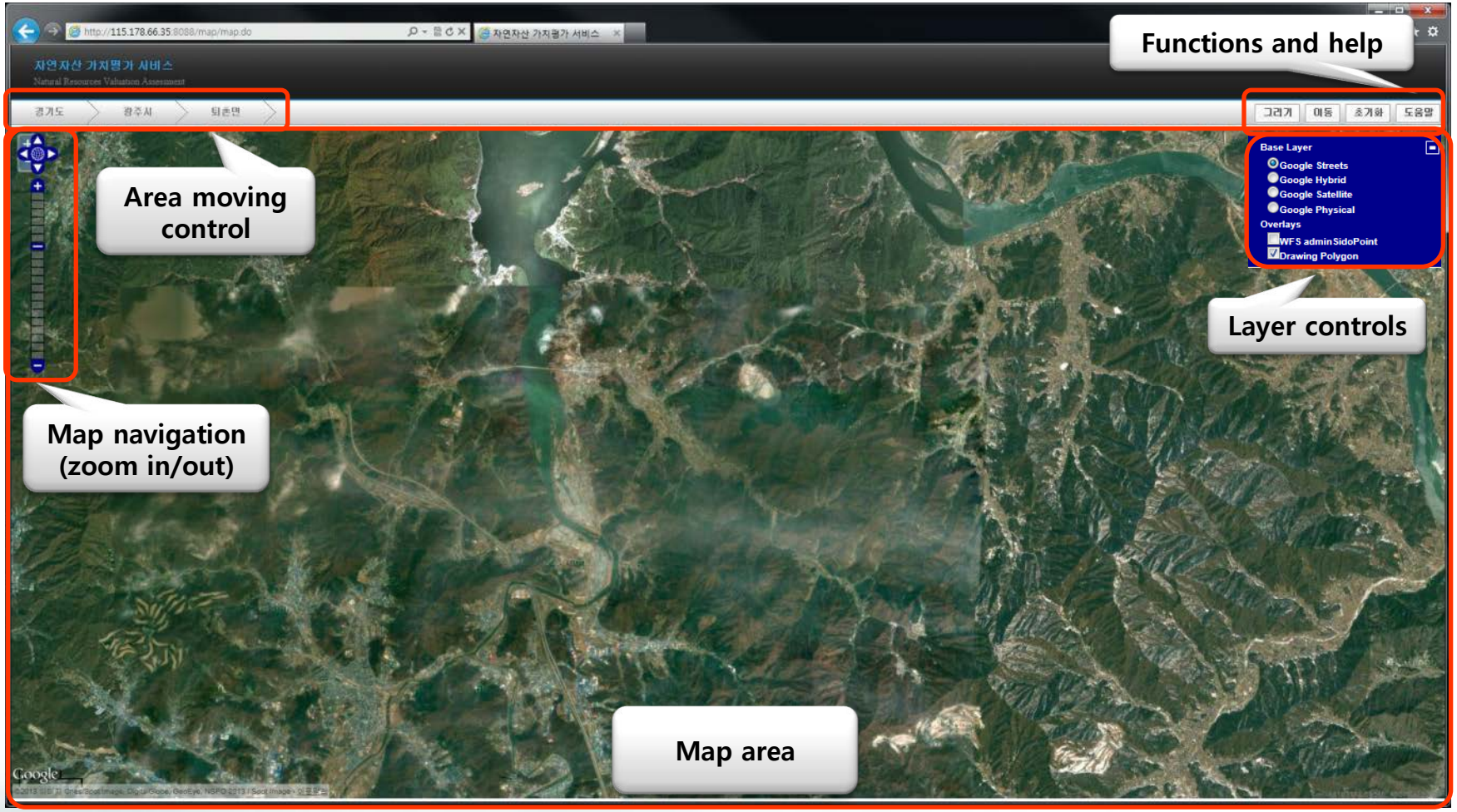


Business planning and examine the development place

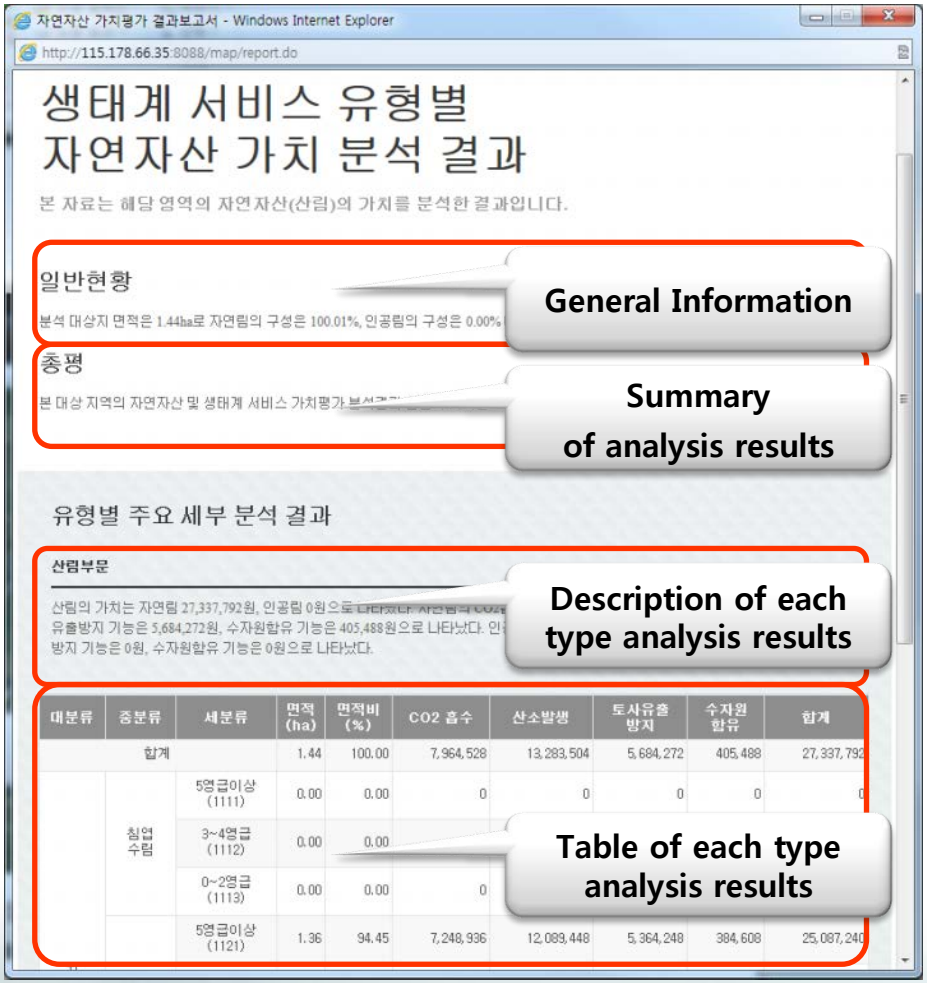
NCVSS Provides a decision support system

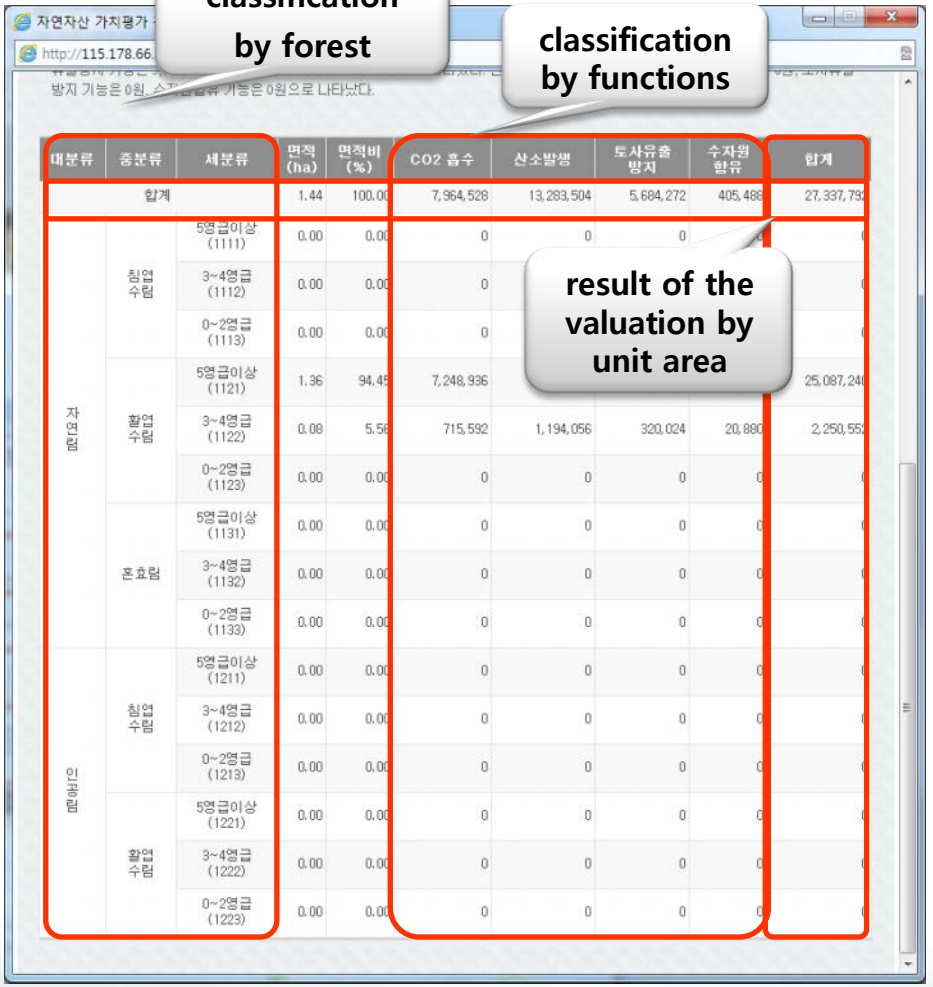
Environmental Impact Assessment And Development

Main screen of NCVSS



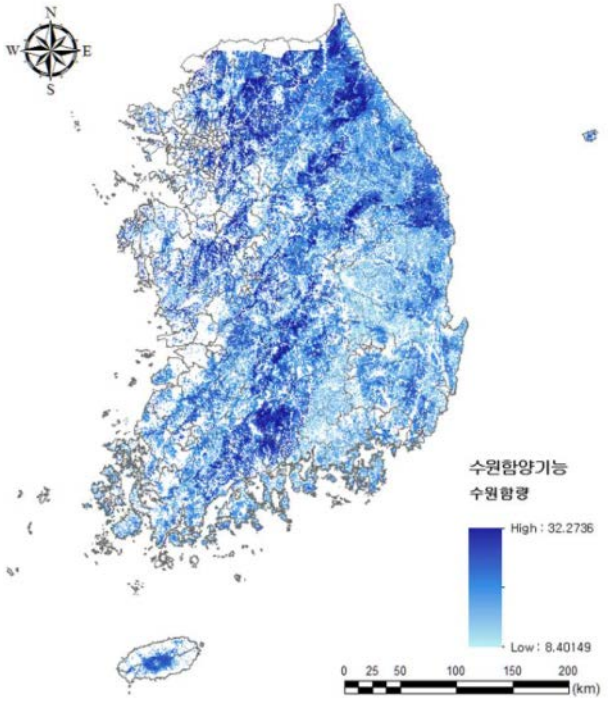
Reports of NCVSS





Next step

Ecosystem Services of forest to considering Climate change



Water availability

(KFRI statistic model, InVest Model)


Thanks!