Analysis of Runoff Impact by Land Use Change Scenarios in an Urbanizing Watershed Using SWAT Model

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Soil & Water Assessment Tool | SWAT

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- Introduction
- Land Use Change model, CLUE-s
- The Future Land Use scenarios
- SWAT Calibration and Validation
- The Impact on Watershed Hydrology
- Conclusion

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Urban Role in World Mess

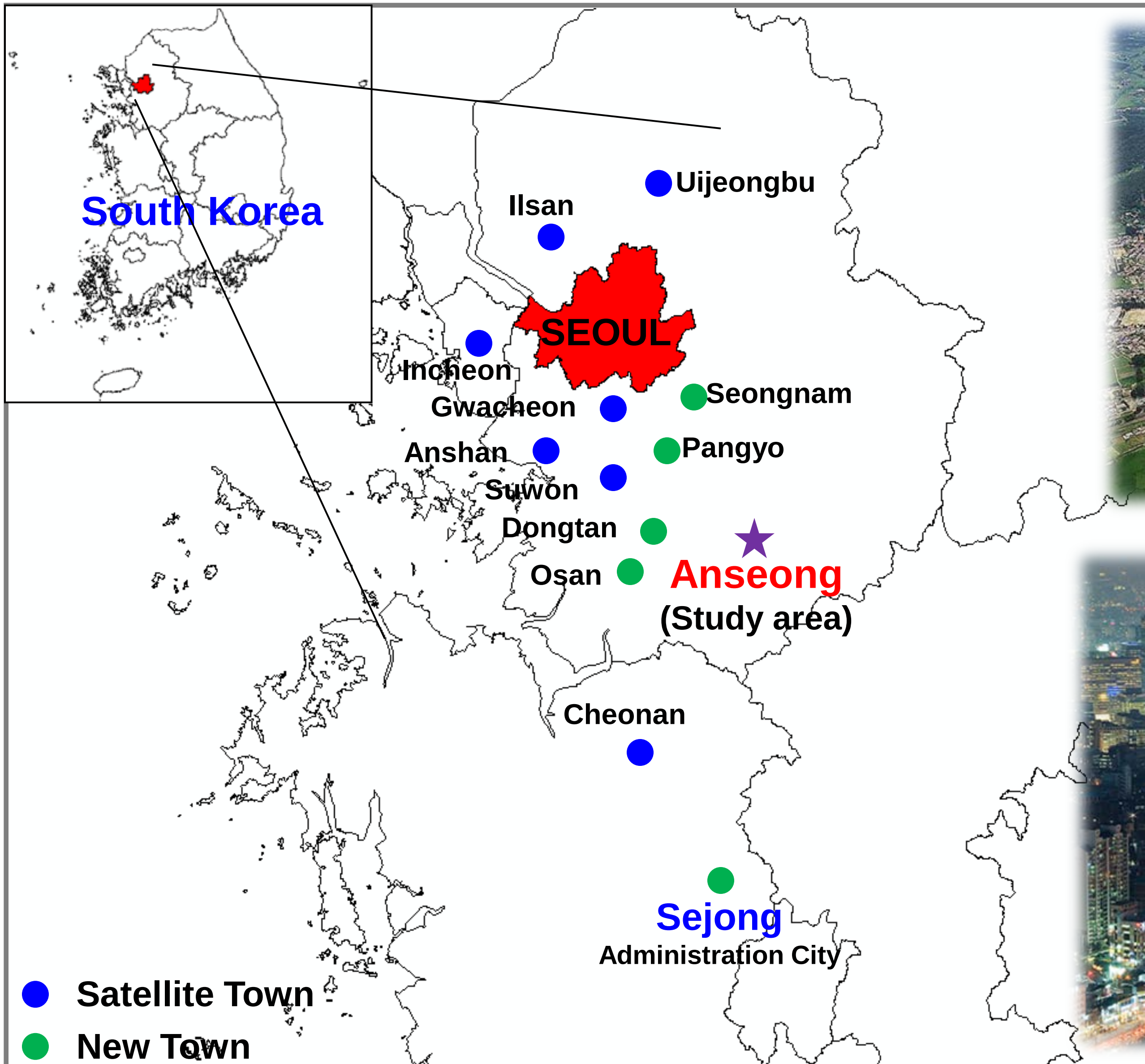
2%

- 2 % of world's surface area is made up by cities.
- 80 % of world's economic output is produced by cities.
- Cities are responsible for more than 70% of global greenhouse gas emissions.
- Cities account for 60-80 % of the world's energy consumption.
- 200 yrs ago, just 3 of 100 lived in cities.
- In 2020, 80 % of the population in developed counties and 51 % in developing counties will live in cities.

80%

THE TIMES OF INDIA NEW DELHI WEDNESDAY, JULY 18, 2012

The cities, Seoul & others



Purpose of this Study

- In South Korea, half of the populations (25 million) lives in and near around Seoul metropolitan area. For decades, the urbanization has been progressed with Seoul as the center of politics, economy, culture, and education etc.

- As Seoul has been already saturated, the government has tried to build new cities as a satellite function. Notwithstanding those efforts, because there are still many problems to be solved, recently the government determined to move the administration function to other place (Sejong) from Seoul by the political decision.

- Seoul has been expanding mainly to the South direction. The study area, Anseong is located between Seoul and Sejong.

- We try the possible land use changes of future Anseong and evaluate the hydrologic impacts of the area.

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Flowchart of this study

Study Watershed

Anseong-Cheon
Urbanizing watershed (5.7 % of 371.1 km^2) (urban of the total area)

Meteorological Data

1990-2010
Weather Data
AWS Rainfall Data

Observed Data

2000-2005
Streamflow (Gongdo)
Outflow (2 reservoirs)

GIS Data

DEM (30m) NGIS
Land use (30m) ME
1:50,000
Soil (30m) KRDA
1:25,000

SWAT Model Setup

Calibration(2000-2002) / Validation(2003-2005)

Future Land use change Impact Assessment

Hydrological responses
- evapotranspiration, streamflow, groundwater, surface runoff

Comparison of impacts between subwatersheds

Landsat Landuse data

1975, 1980, 1985,
1990, 1995, 2000

CLUE-s model

Driving Factors
Aspect, DEM, Distance to highway, Distance to local road, Distance to national road, Slope, Soil depth, Soil group, Soil type

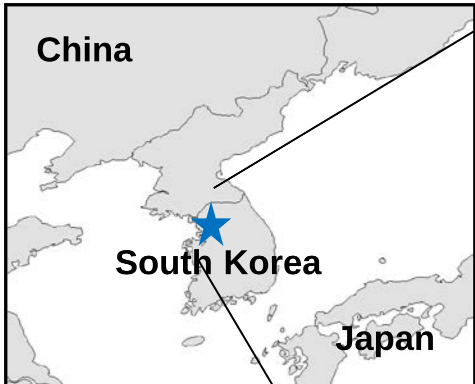
Land use Demand
Prediction of Land use

Statistical Analysis

Prediction of Future Land use

2040s, 2080s

Study Area



Suwon
Icheon
Weonsam
Gosam
Yangseong
Anseong
Geumgwang
Seoun
Cheonan

Water level Gong-Do Station / Outlet

- ✓ Watershed area : 371.1 km^2
- ✓ Annual average precipitation : 1,231 mm
- ✓ Annual average temperature : 11.7℃
- ✓ Urban area : 5.7 % (20.4 km^2)

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Study Area 2020 LU plan by LC

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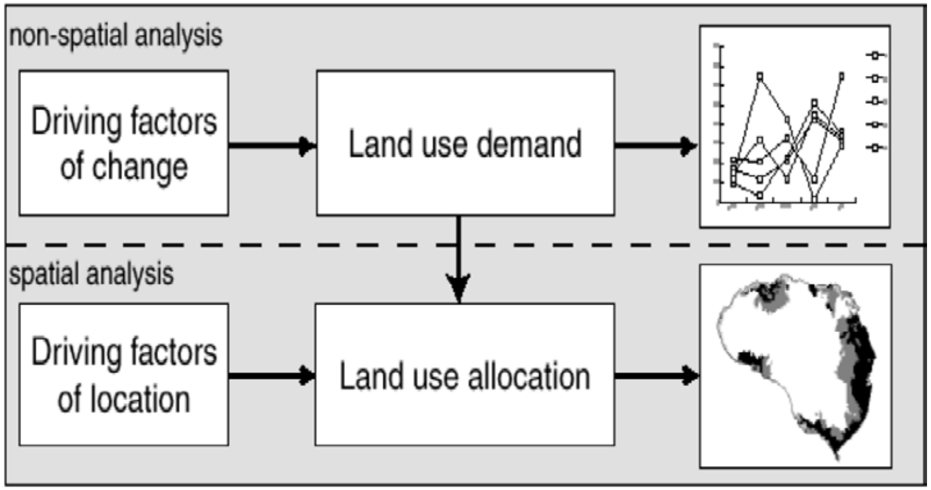
Land Use Change Prediction Model

◻ CLUE-s (Conversion of Land Use and its Effects)

- The Conversion of Land Use and its Effects at Small regional extent(CLUE-s) was developed to simulate land use change.

- The model is subdivided into two distinct modules, namely a non-spatial demand module and a spatially explicit allocation procedure.
    - The non-spatial module calculates the area change for all and use types
    - The spatial module are translated in to land use changes at different locations with in the study region



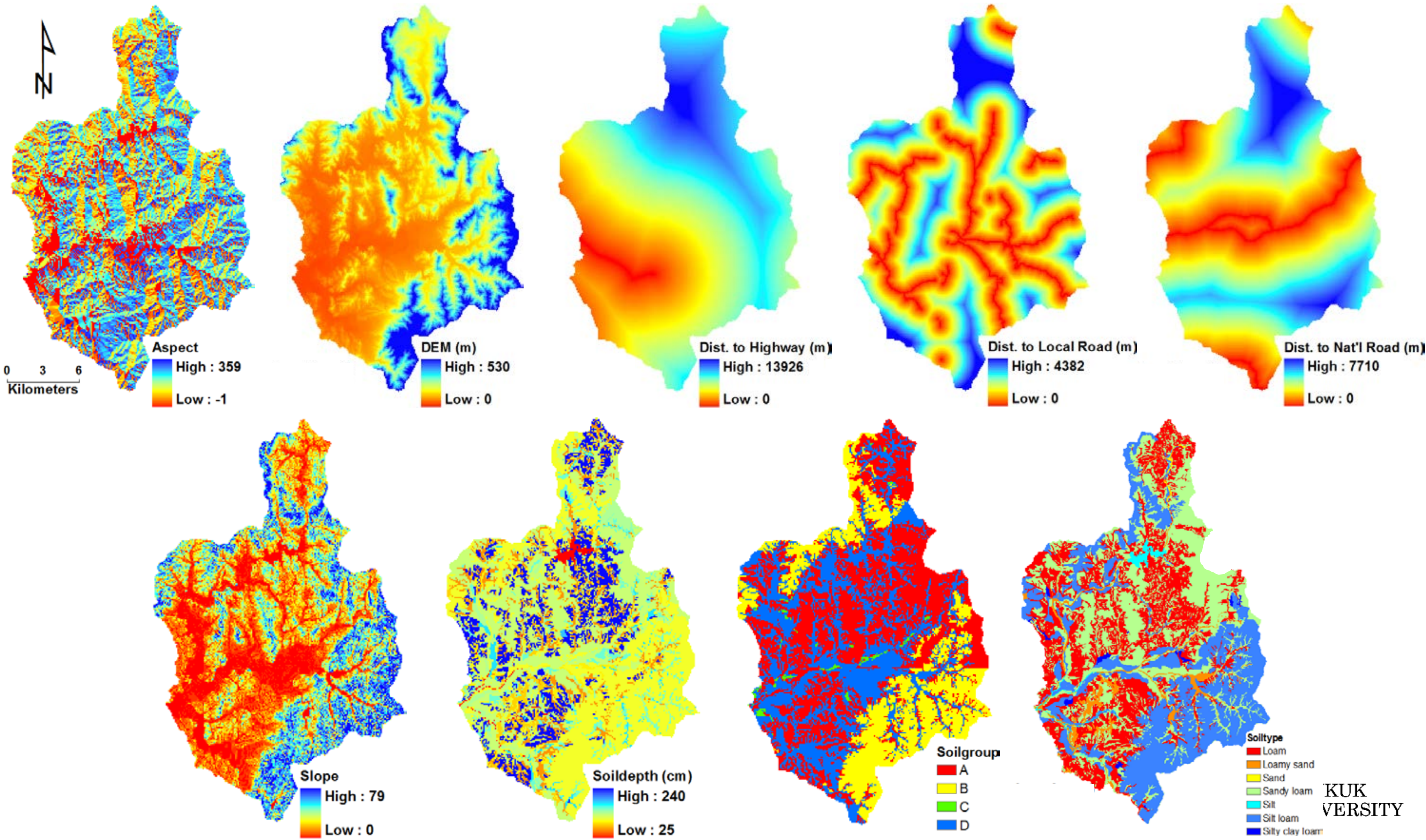
<case study>

- Oh et al. (2010)
: Prediction of paddy field change based on climate change scenarios using the CLUE model, *Paddy and Water Envion.*

- Park et al. (2011)
: Assessment of MIROC3.2 Hires climate and CLUE-S land use change impacts on watershed hydrology using SWAT, *Trans. ASABE*

CLUE-s data

- **Driving Factors**

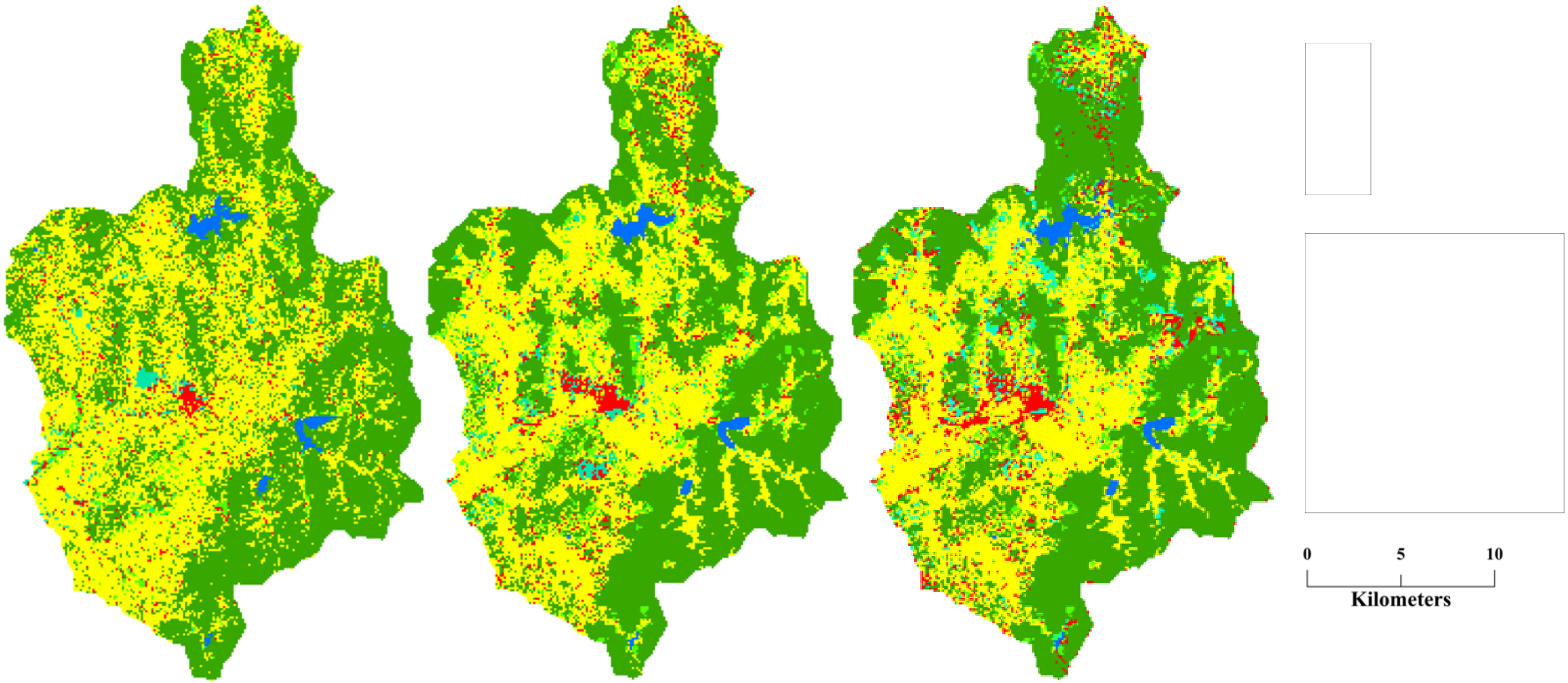


CLUE-s regression results

- The probability maps of each land use type were prepared from the logistic regression results.
- Forward stepwise logistics regression and relative operating characteristics analysis between 6 land use types and 9 driving factors.

Driving Factor	Land Use Type					
	Water	Urban	Bare Field	Grass	Forest	Agriculture
Aspect	-0.0016	--	0.0007	--	--	--
DEM	0.0053	-0.0002	--	--	--	0.0004
Distance to Highway	0.0002	-0.0003	-0.0002	--	0.0001	-0.0001
Distance to Local road	-0.0009	-0.0003	--	0.0003	0.0004	-0.0004
Distance to Nat'l road	0.0002	-0.0091	-0.0001	-0.0001	0.0001	-0.0001
Slope	-0.0223	0.0025	--	--	--	--
Soil depth	-0.0034	0.1883	0.0033	--	-0.0069	0.006
Soil group	0.3488	--	--	--	-0.4275	0.3842
Soil type	-0.0004	--	0.0002	--	-0.0001	0.0001
Constant	-6.5259	-1.2974	-2.8541	-4.2096	0.19	-1.2488

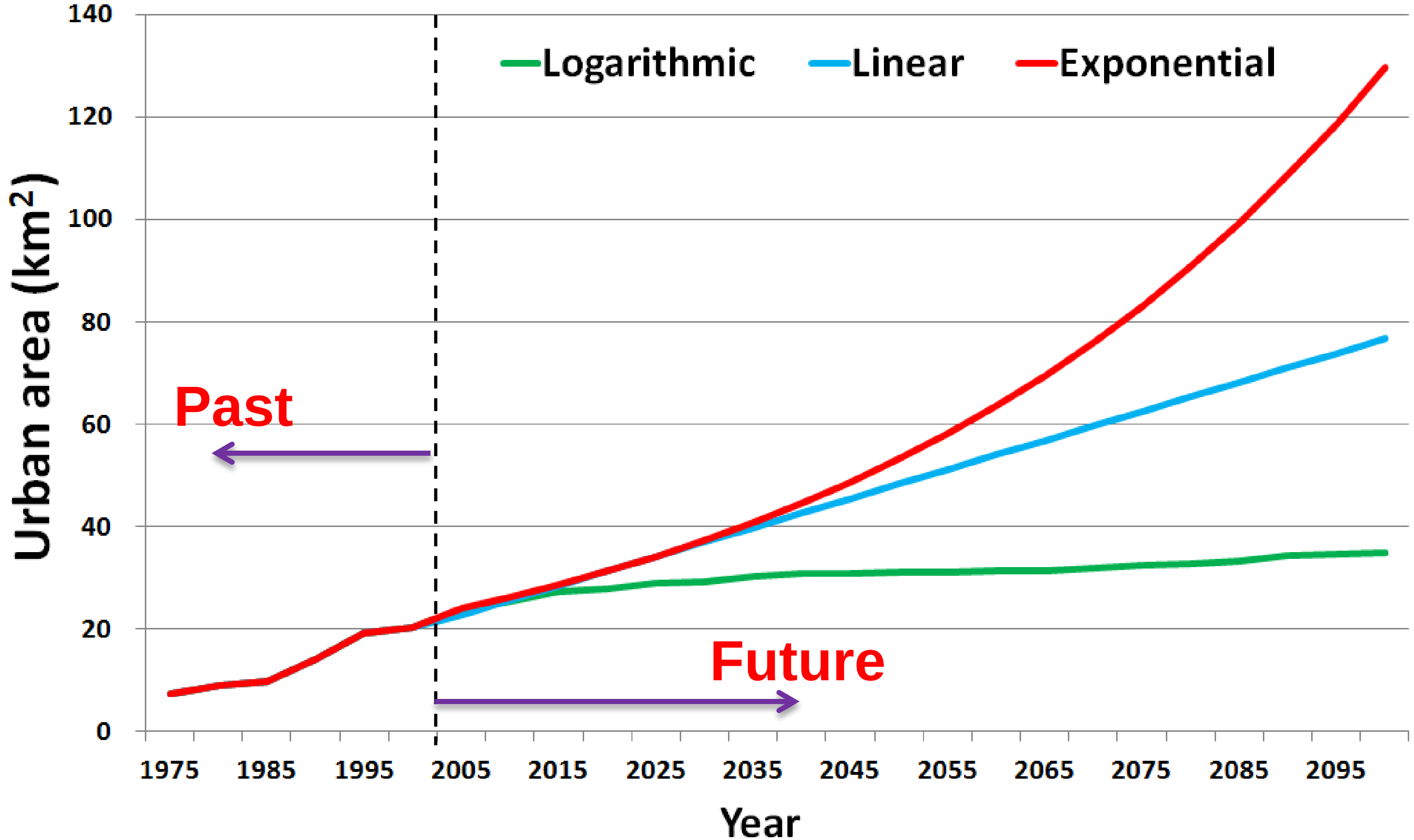
The past land uses



1980 **1990** **2000**
(Baseline)

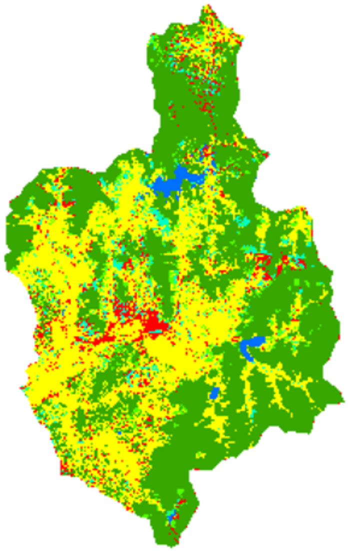
- The past land use changes by suing Landsat image classification
- The expanding urban area (red color)

Three Land use Change Scenarios

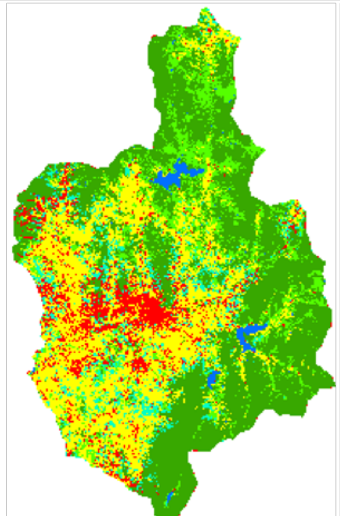
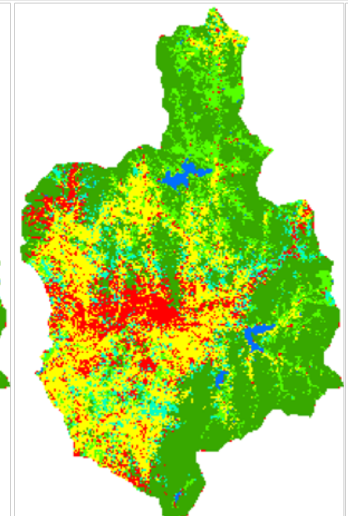
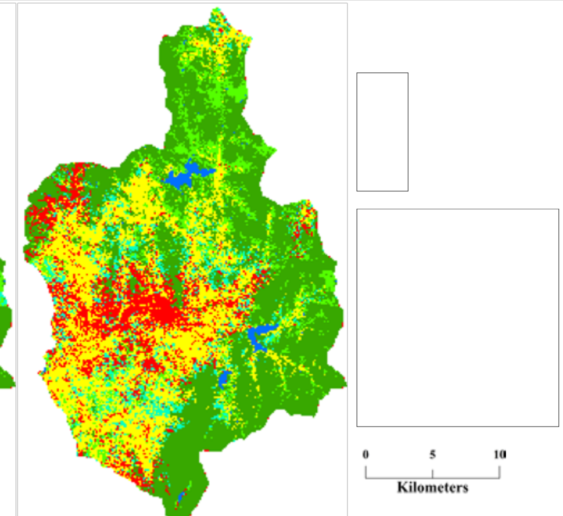
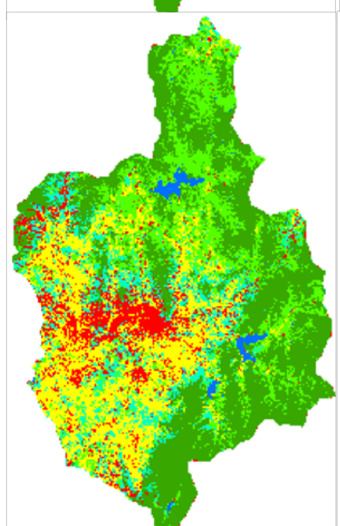
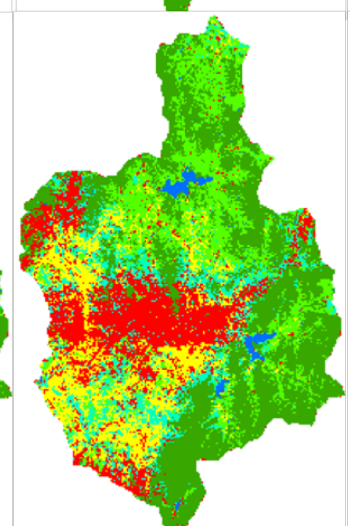
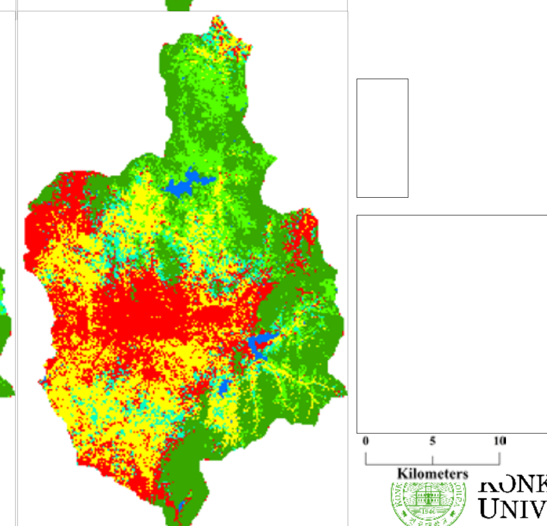


❖ Predict future land use changes Using 3 possible scenarios (Logarithmic, Linear, Exponential)

2040s & 2080s spatial land uses



2000
(Baseline)

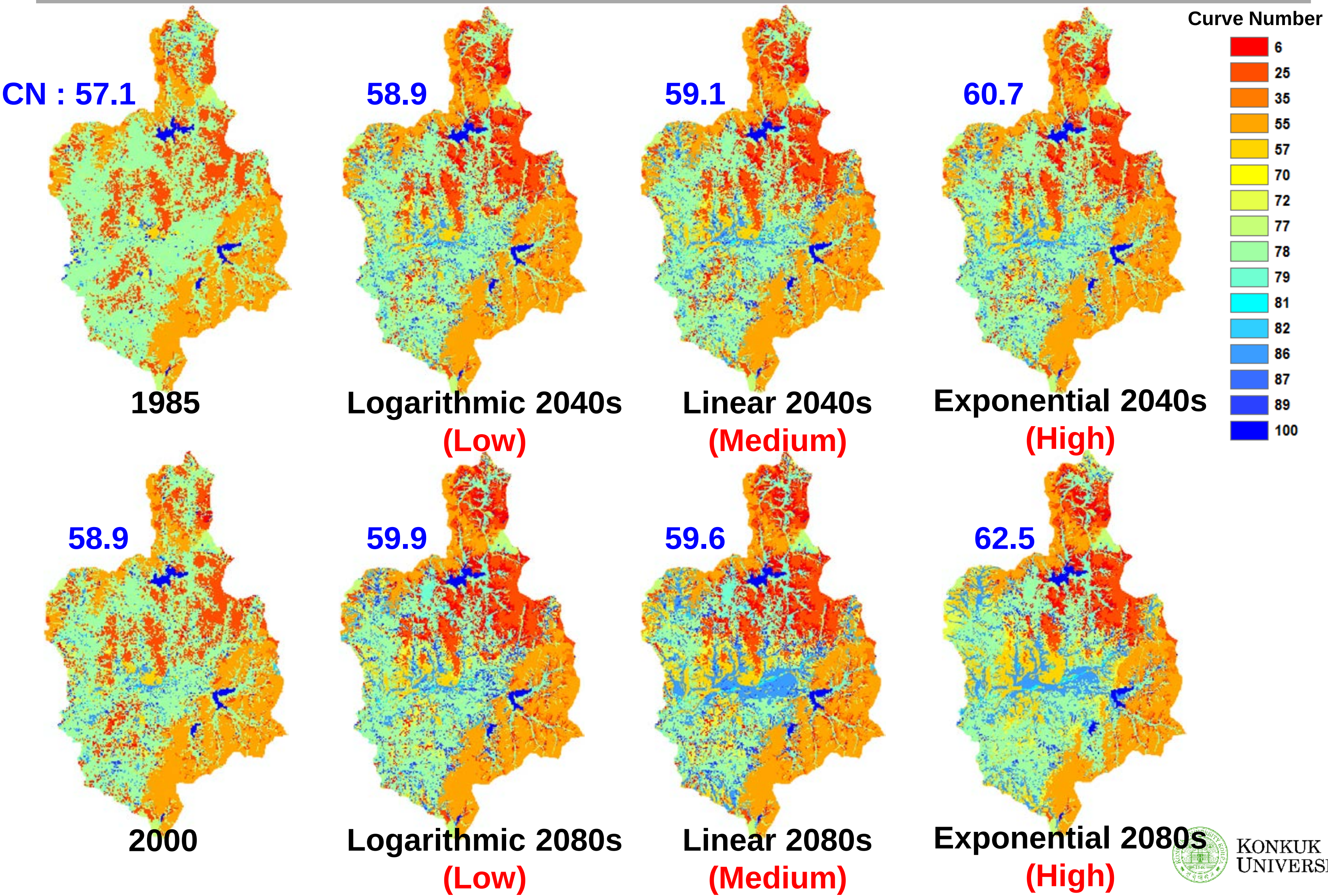
Year	Logarithmic (Low)	Linear (Medium)	Exponential (High)
2040s			
2080s			

2040s & 2080s Land uses summary

km² (%)

Scenarios		Water	Urban	Bare field	Grass	Forest	Agricul-ture
Past	1985	4.7 (-2.1)	9.9 (-51.5)	2.6 (-70.2)	6.2 (-62.9)	181.5 (+3.0)	152.0 (+28.5)
Baseline	2000	4.8	20.4	12.2	16.7	176.3	127.6
Logarithmic (Low)	2040	4.8 (+0.0)	30.9 (+51.4)	24.6 (+101.5)	46.9 (+180.4)	148.4 (-15.8)	102.4 (-19.7)
	2080	4.8 (+0.0)	32.9 (+61.2)	40.0 (+227.6)	73.8 (+341.1)	127.8 (-27.5)	78.8 (-38.3)
Linear (Medium)	2040	4.8 (+0.0)	42.7 (+109.0)	24.6 (+101.5)	46.9 (+180.4)	150.4 (-14.7)	88.7 (-30.5)
	2080	4.8 (+0.0)	65.4 (+220.1)	40.0 (+227.6)	73.8 (+341.1)	123.7 (-29.8)	50.4 (-60.5)
Exponential (High)	2040	4.8 (+0.0)	44.6 (+118.5)	24.6 (+101.5)	36.9 (+120.6)	148.4 (-15.8)	98.7 (-22.6)
	2080	4.8 (+0.0)	90.8 (+344.7)	25.0 (+104.8)	43.8 (+161.7)	103.9 (-41.0)	89.7 (-29.7)

2040s & 2080s SCS Curve Number



SWAT Model

SWAT (Soil and Water Assessment Tool)

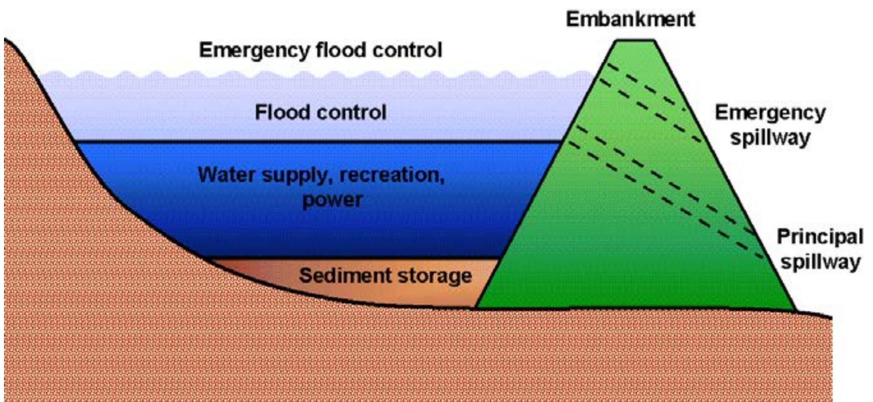
- SWAT is a continuous, long-term, and distributed-parameter model designed to predict the impact of land management practices on the hydrology.
- SWAT subdivides a watershed into sub-basin connected by a stream network, and further delineates HRUs (hydrologic Response Unit) Consisting of unique combinations of land cover and soils within each sub-basins

Reservoir water balance

$$\boxed{V = V_{stored} + V_{flowin} - V_{flowout} + V_{pcp} - V_{evap} - V_{seep}}$$

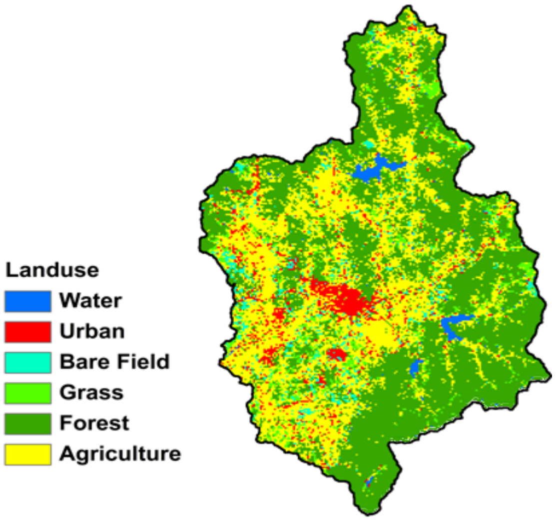
$$V_{flowout} = 86400 \cdot q_{out} [runoff\ ratio,\ m^3/s]\ (m^3 H_2O)$$

Soil & Water Assessment Tool SWAT

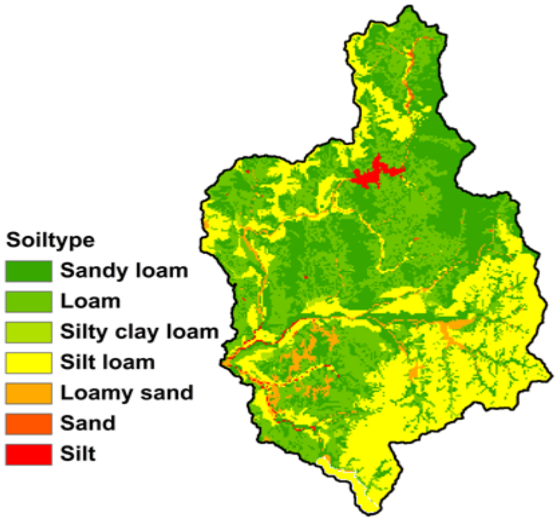


Preparation of input data

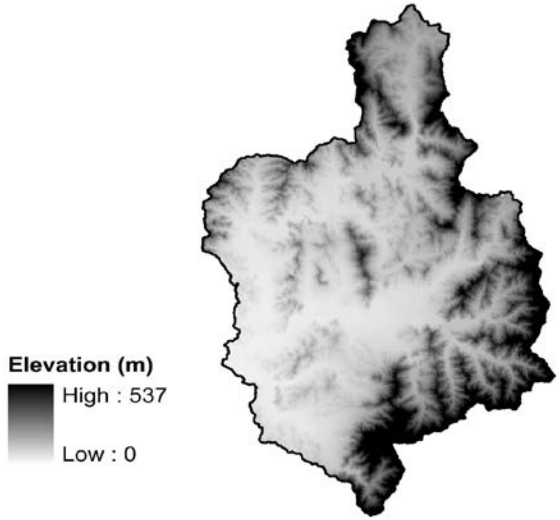
Data Set	Source	Scale	Properties
DEM	Korea National Geography Institute	1/5,000	**Digital Elevation Model (DEM) ; 100 X 100 m**
Soil	Korea Rural Development Administration	1/25,000	**Soil classifications and physical properties such as bulk density, texture, and saturated conductivity.**
Land use	Landsat TM Satellite Image in 2000	30m	**Land use classifications such as paddy, grass, and forest.**



Land Use



Soil type



DEM

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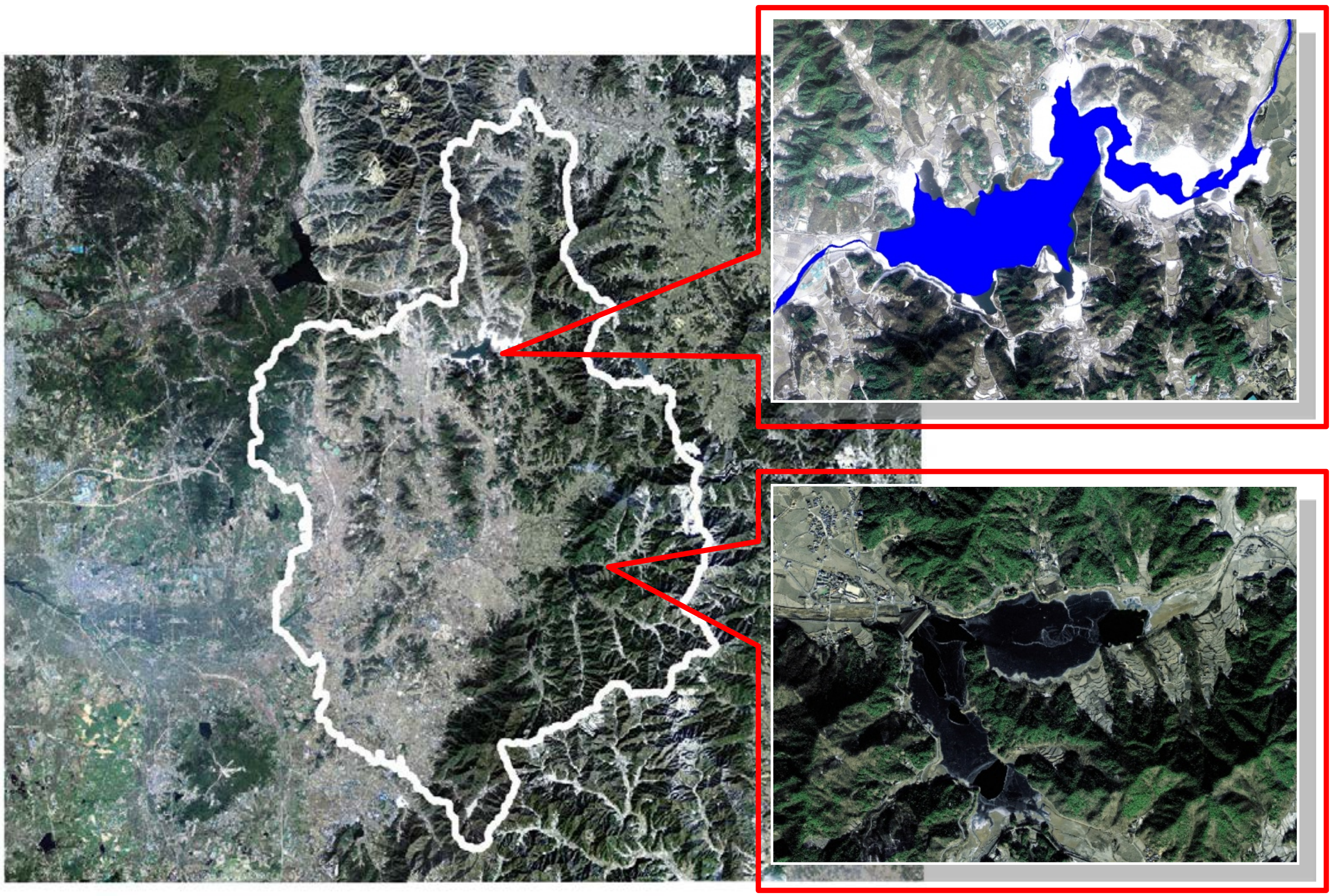
Two agricultural reservoirs included in SWAT

- **SWAT reservoir operation**
- **Daily release data for the two reservoirs were used . (1998-2006)**



Gosam reservoir

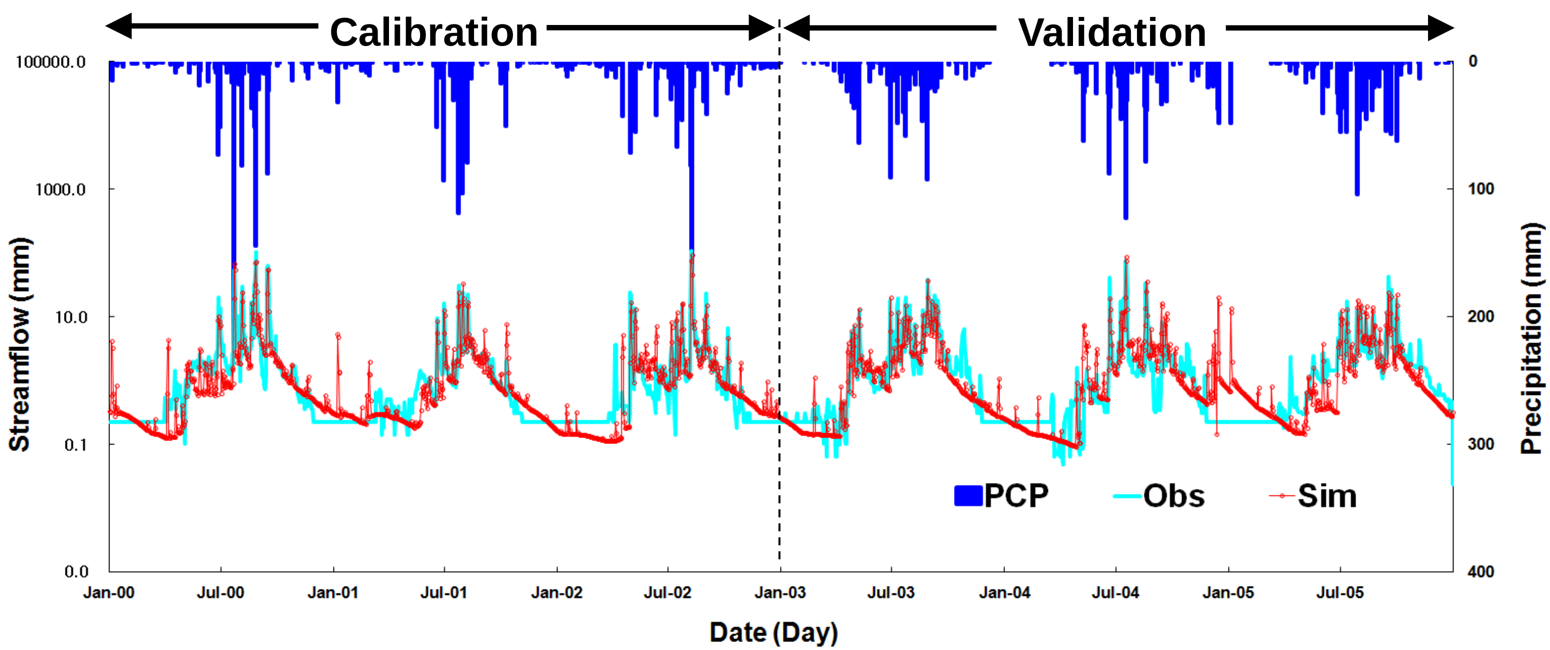
Total storage	: 16,105 10^3 m^3
Usable storage	: 15,217 10^3 m^3
Area of full water	: 2.79 km^2
Benefit area	: 29.8 km^2

Geumgwang reservoir

Total storage	: 12,095 10^3 m^3
Usable storage	: 12,047 10^3 m^3
Area of full water	: 1.51 km^2
Benefit area	: 19.3 km^2

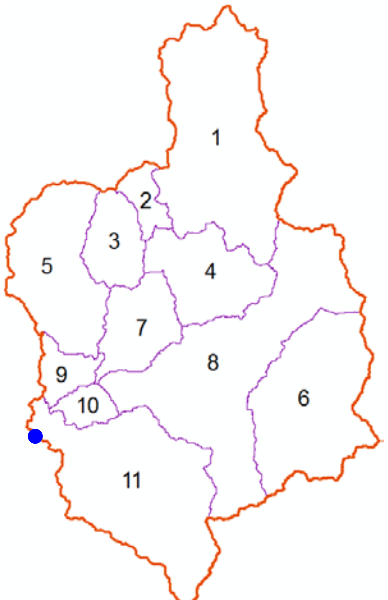
SWAT Calibration and Validation

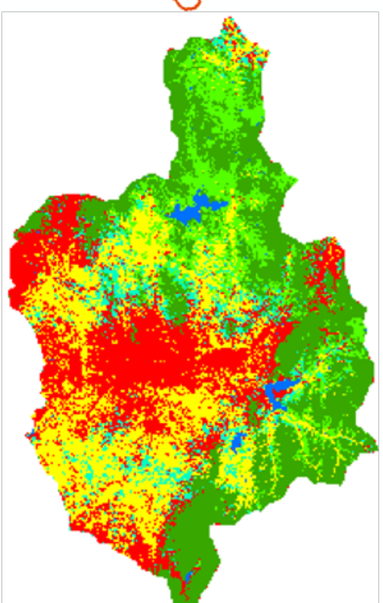
❖ Calibration period : 2000-2002 / Validation period : 2003-2005



Statistic		Calibration			Validation			Avg.
		2000	2001	2002	2003	2004	2005	
Evaluation criteria	RMSE (mm/d)	3.97	1.53	2.27	1.43	3.15	2.39	2.46
	R^2	0.80	0.77	0.94	0.83	0.80	0.64	0.80
	NSE	0.79	0.71	0.92	0.87	0.78	0.61	0.78

Future Impact on Watershed Hydrology

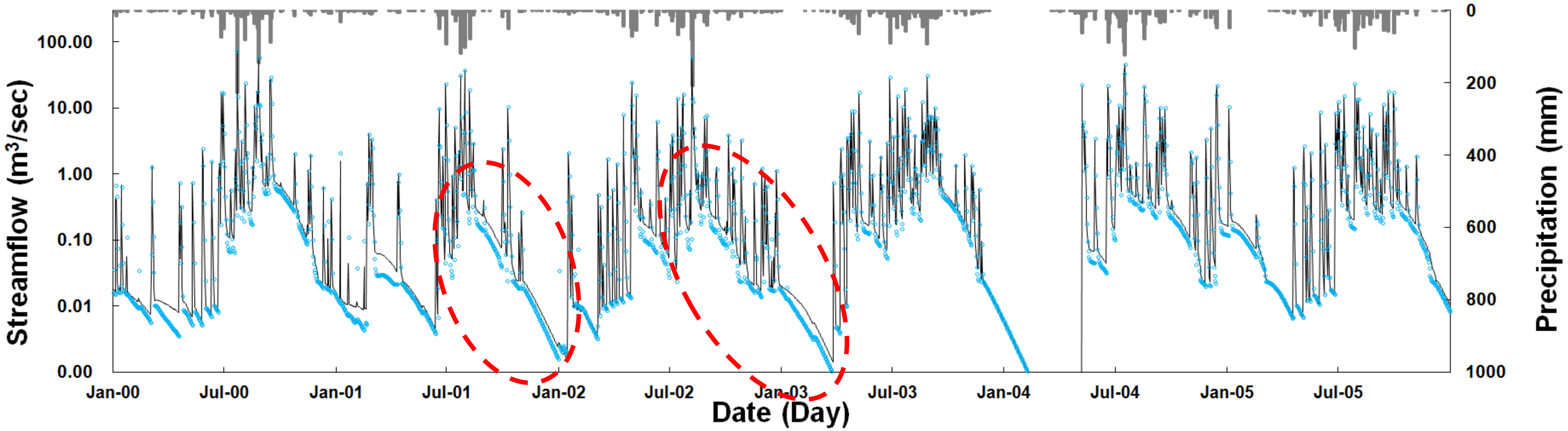




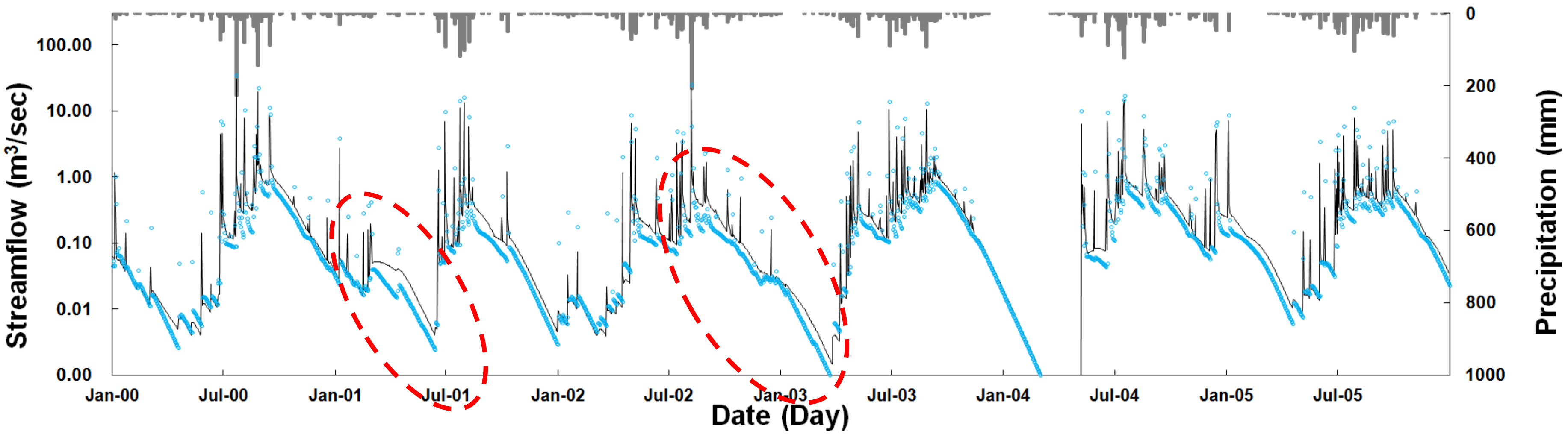
Sub Watershed (km²)	2000 (Baseline)	Curve Number Value					
		Logarithmic (Low)		Linear (Medium)		Exponential (High)	
		2040s	2080s	2040s	2080s	2040s	2080s
1 (66.2)	56.1	45.7 (-10.4)	45.0 (-11.1)	45.7 (-10.4)	42.9 (-13.2)	47.5 (-8.6)	45.2 (-10.9)
2 (6.3)	67.7	60.8 (-6.9)	57.4 (-10.3)	60.8 (-6.9)	56.5 (-11.2)	61.2 (-6.5)	60.2 (-7.5)
3 (13.9)	64.4	62.1 (-2.3)	59.4 (-5.0)	62.1 (-2.3)	59.3 (-5.1)	65.8 (+1.4)	68.8 (+4.4)
4 (24.9)	59.0	54.3 (-4.7)	50.5 (-8.5)	53.8 (-5.2)	50.2 (-8.8)	57.1 (-1.9)	58.3 (-0.7)
5 (36.3)	65.0	67.2 (+2.2)	68.7 (+3.7)	67.2 (+2.2)	68.7 (+3.7)	67.6 (+2.6)	71.6 (+6.6)
6 (47.2)	59.0	55.8 (-3.2)	54.1 (-4.9)	55.8 (-3.2)	54.4 (-4.6)	57.2 (-1.8)	57.5 (-1.5)
7 (17.8)	62.4	63.5 (+1.1)	64.5 (+2.1)	63.5 (+1.1)	64.8 (+2.4)	64.1 (+1.7)	66.9 (+4.5)
8 (74.4)	62.0	61.9 (-0.1)	61.4 (-0.6)	61.9 (-0.1)	63.0 (+1.0)	61.9 (-0.1)	66.2 (+4.2)
9 (7.4)	72.8	73.1 (+0.3)	74.1 (+1.3)	73.1 (+0.3)	72.4 (-0.4)	74.6 (+1.8)	73.4 (+0.6)
10 (5.6)	70.9	74.0 (+3.1)	75.0 (+4.1)	74.0 (+3.1)	74.2 (+3.3)	75.2 (+4.3)	76.3 (+5.4)
11 (60.4)	65.5	67.7 (+2.2)	68.8 (+3.3)	67.7 (+2.2)	68.7 (+3.2)	68.3 (+2.8)	71.7 (+6.2)
Average	58.9	58.9	59.9	59.1	59.6	60.7	62.5

Future Impact on Watershed Hydrology

Subwatershed 6 Runoff ratio : 2000 58.4%, Exponential 58.2%



Subwatershed 7 Runoff ratio : 2000 52.6%, Exponential 56.4%



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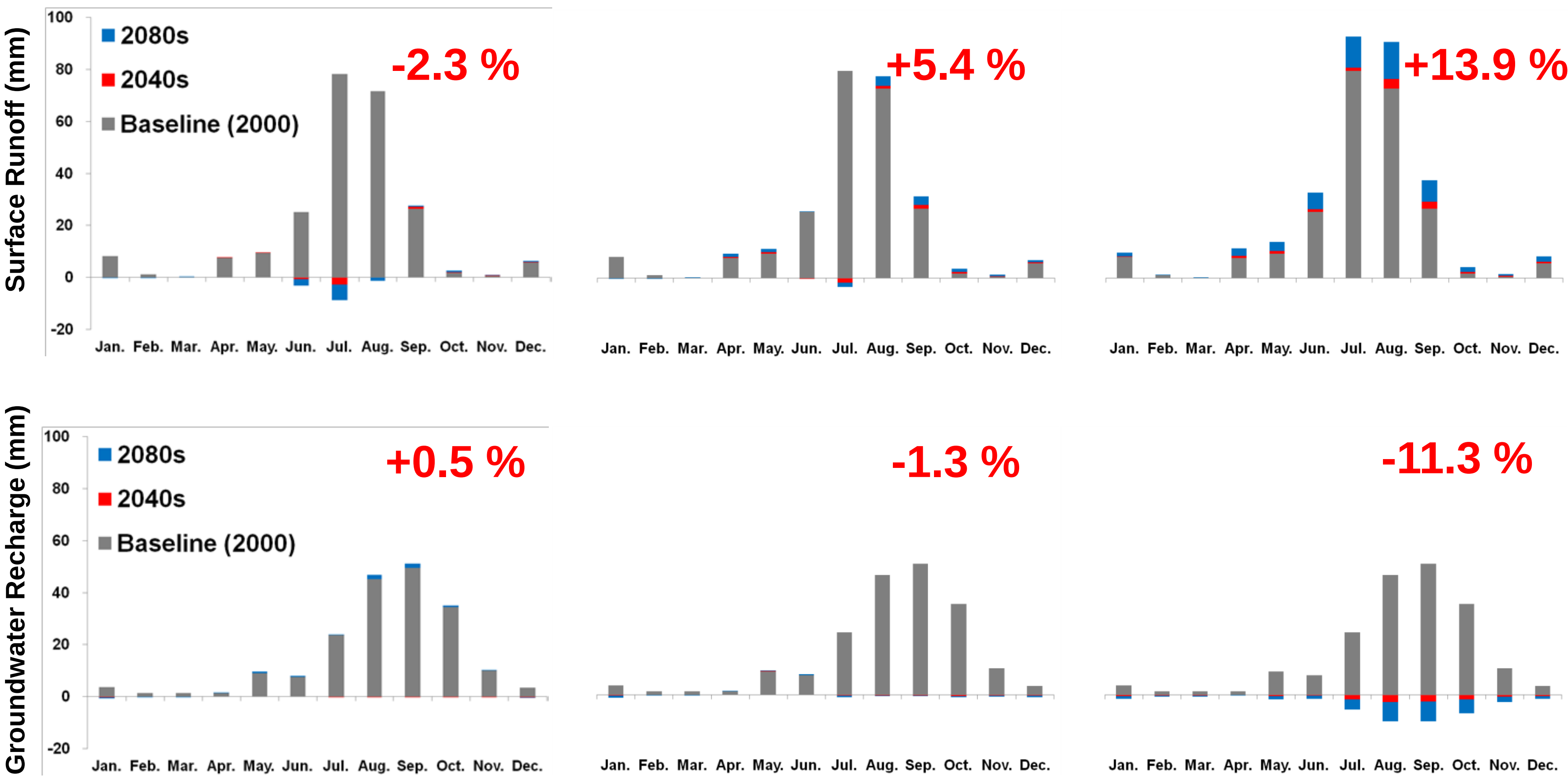
Future Impact on Watershed Hydrology

- **Predicted hydrologic components – Surface Runoff, Groundwater Recharge**



Logarithmic (Low)	Linear (Medium)	Exponential (High)

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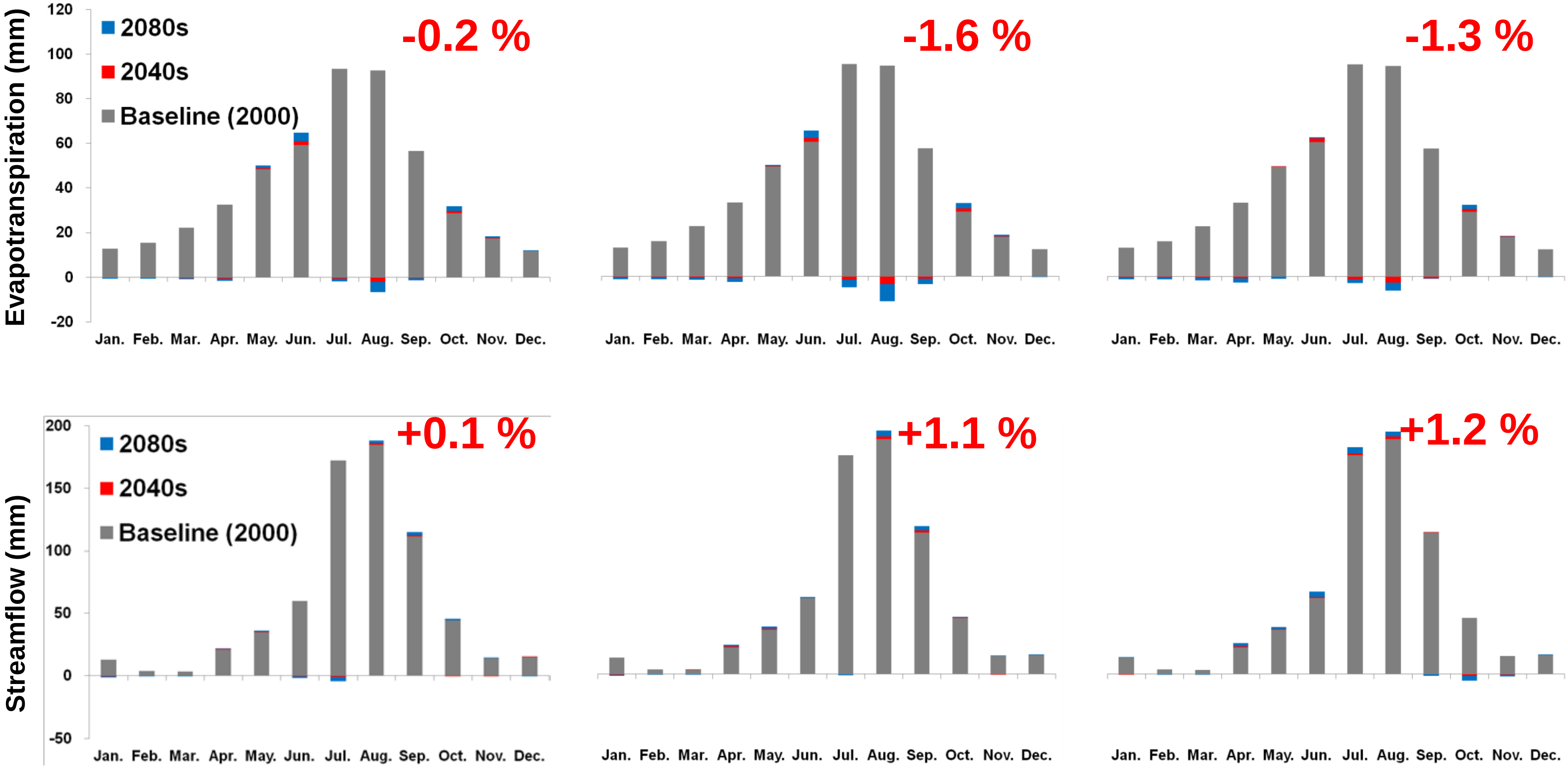
Future Impact on Watershed Hydrology

- **Predicted hydrologic components – Evapotrasspiration, Streamflow**



Logarithmic (Low)

Linear (Medium)

Exponential (High)

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Future Impact on Watershed Hydrology

Years		Curve number	ET (mm)	Surface Runoff (mm)	Groundwater Recharge (mm)	Streamflow (mm)
1985		57.1 (-1.8)	494.5 (+0.7)	233.7 (-0.5)	188.4 (-0.8)	674.4 (-0.5)
2000 (Baseline)		58.9	491.0	235.0	189.9	677.7
Logarithmic (Low)	2040s	58.9 (+0.0)	490.3 (-0.2)	232.8 (-0.9)	187.5 (-1.2)	678.4 (+0.1)
	2080s	59.9 (+1.0)	489.8 (-0.3)	226.2 (-3.7)	194.2 (+2.3)	678.4 (+0.1)
Linear (Medium)	2040s	59.1 (+0.2)	486.3 (-0.9)	237.4 (+1.0)	187.6 (-1.2)	682.4 (+0.7)
	2080s	59.6 (+0.7)	480.5 (-2.1)	245.2 (+4.3)	187.3 (-1.4)	688.0 (+1.5)
Exponential (High)	2040s	60.7 (+1.8)	487.6 (-0.7)	247.1 (+5.2)	178.5 (-6.0)	681.7 (+0.6)
	2080s	62.5 (+3.6)	481.9 (-1.9)	288.0 (+22.6)	158.4 (-16.6)	688.6 (+1.6)

Conclusion

- For the 3 scenarios of future land use, the followings are the key summaries for the study watershed.

Land Use Change Scenario		Curve Number	Urban Area (km^2)	Surface Runoff (mm)	Groundwater Recharge (mm)
2000 (Baseline)		58.9	20.4	235.0	189.9
Logarithmic (Low)	2040s	58.9 (+0.0)	30.9 (+51.4)	232.8 (-0.9)	187.5 (-1.2)
	2080s	59.9 (+1.0)	32.9 (+61.2)	226.2 (-3.7)	194.2 (+2.3)
Linear (Medium)	2040s	59.1 (+0.2)	42.7 (+109.0)	237.4 (+1.0)	187.6 (-1.2)
	2080s	59.6 (+0.7)	65.4 (+220.1)	245.2 (+4.3)	187.3 (-1.4)
Exponential (High)	2040s	60.7 (+1.8)	44.6 (+118.3)	247.1 (+5.2)	178.5 (-6.0)
	2080s	62.5 (+3.6)	90.8 (+344.7)	288.0 (+22.6)	158.4 (-16.6)

- For the whole watershed, the linear scenario seems marginal. The exponential scenario should be escaped.

- If we look at the subwatershed scale, even logarithmic, the sub-watersheds 5, 7, 10, 11 become more vulnerable for flood and stream baseflow.

“ Thank You ”

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