The Spatial Analysis between SWAT Simulated Soil Moisture, and MODIS LST and NDVI Products

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Contents

Introduction

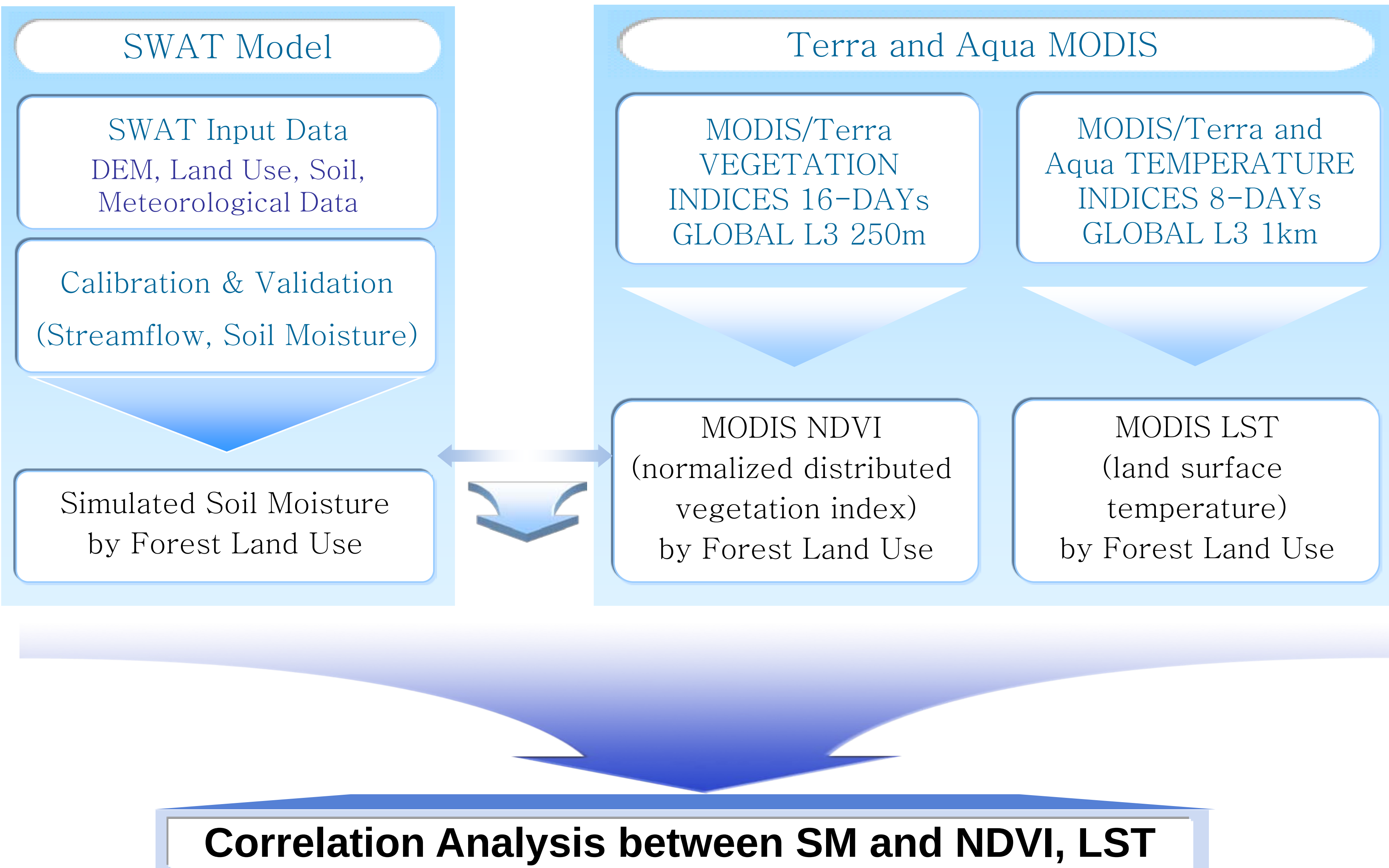
- ***Soil moisture*** is an important hydrologic component of water balance, and highly dependent on the ***surface temperature*** and its ***vegetation vitality*** under the spatial land cover condition.

- Recently, researches to evaluate the watershed scale soil moisture have been attempted by using ***satellite products*** to overcome the limited information of field scale soil moisture. The monitoring and modelling of land surface and/or vegetation processes by using satellite images viz. NOAA AVHRR and ***Terra and Aqua MODIS*** is now popular.

- MODIS NDVI and LST can be a useful indicator to analyze the soil moisture during the active growing of crop or plant, and to determine the soil moisture condition for drought monitoring (Narasimhan et al., 2005).

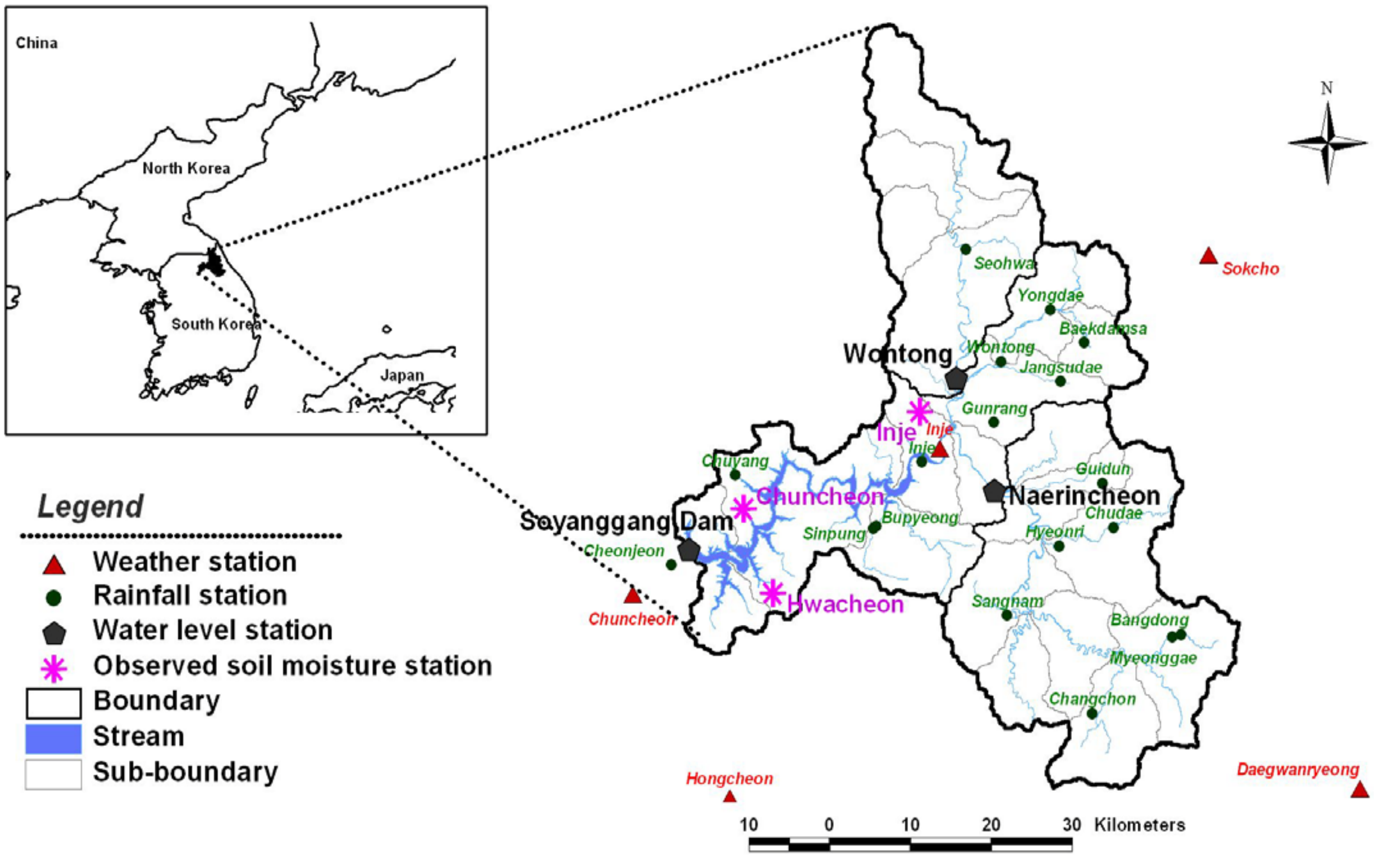
- This study is to identify how much MODIS NDVI and LST products can explain soil moisture of forest area by using ***SWAT simulated soil moisture*** results.

Process of This Study



Material and Method

❖ *Study Watershed*



- Study area: 2,694.4 km^2 forest-dominant (93 %) watershed
- The watershed was subdivided into 3 sub-watersheds, which the division locations are <u>Wontong</u>, <u>Naerincheon</u>, and <u>SoyanggangDam</u> water level gauging stations.
- The annual average precipitation is <u>1,359.5 mm</u>, and the mean temperature is <u>9.4 ℃</u> over the last 30 years (1977 - 2006).
- In the watershed, three measured soil moisture stations(<u>Inje</u>, <u>Chuncheon</u>, <u>Hwacheon</u>) was located.

Material and Method

❖ SWAT Model Description

- **Soil and Water Assessment Tool** **(SWAT, developed by Arnold et al. in 1998)**

$$SW_t = SW_0 + \sum_{i=1}^{t} (R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw})$$

SW_t = Final soil water content (mm)

SW_0 = Initial soil water content on day i (mm)

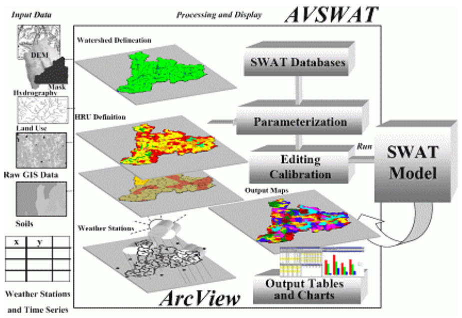
R_{day} = Amount of precipitation on day i (mm)

Q_{surf} = Amount of surface runoff on day i (mm)

E_a = Amount of evapotranspiration on day i (mm)

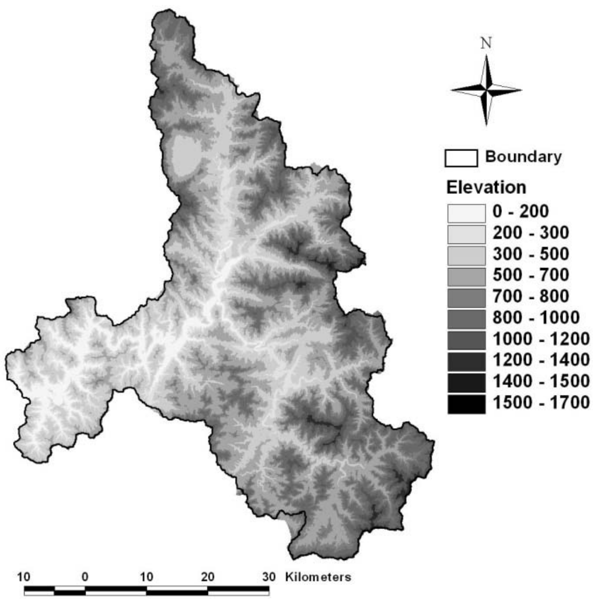
W_{seep} = Amount of water entering the vadose zone from the soil profile on day i (mm)

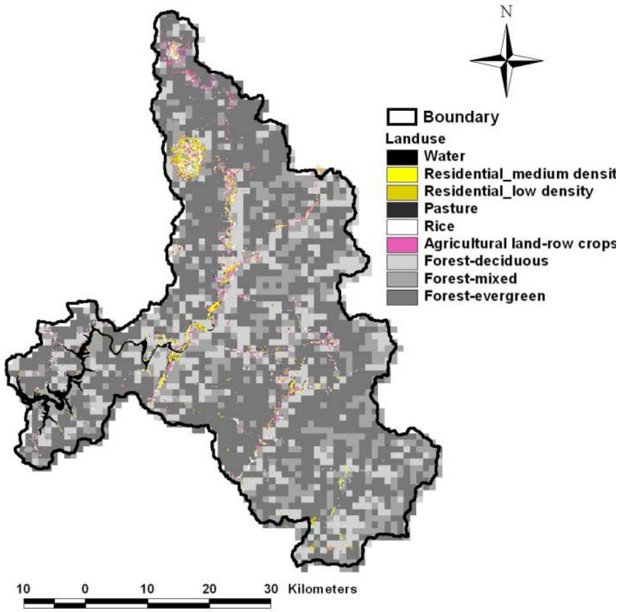
Q_{gw} = Amount of return flow on day i (mm)

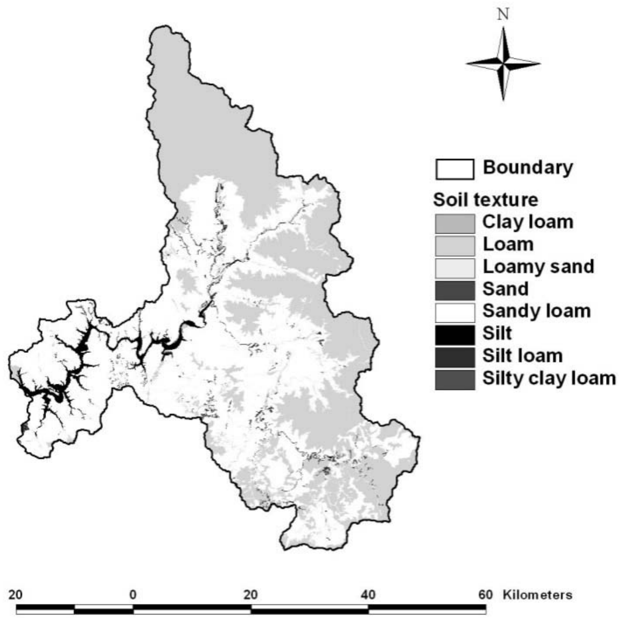


Material and Method

❖ *Input Datasets for Calibration and Validation of the SWAT Model*







Elevation

- range : 155 - 1,639 m
- average : 643.9 m

Land use

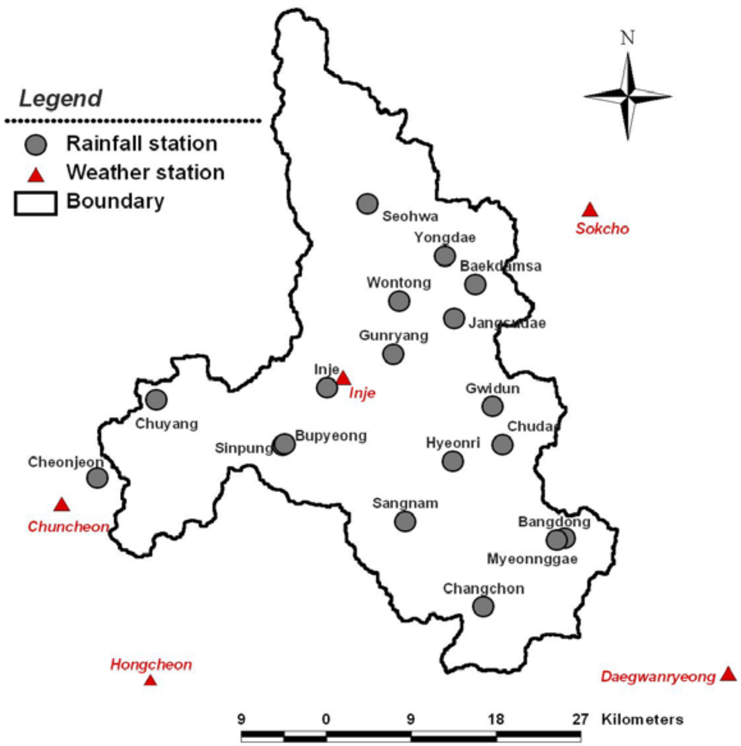
- the 9 categories
- prepared by 2000 Landsat TM (Thematic Mapper) supervised classification with NOAA NDVI

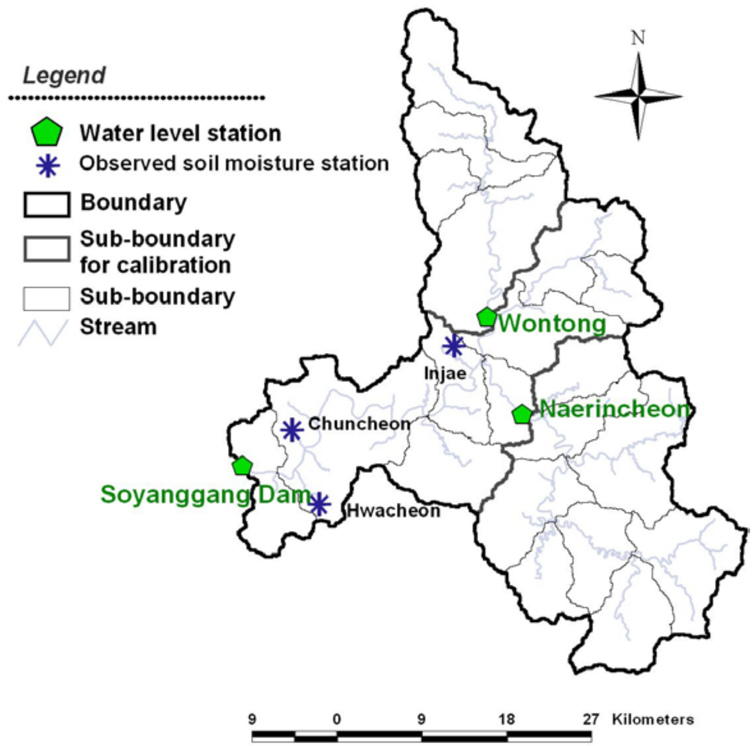
Soil

- loam (52.4 %), and loamy sand (42.4 %)

Material and Method

❖ *Input Datasets for Calibration and Validation of the SWAT Model*





Meteorological data

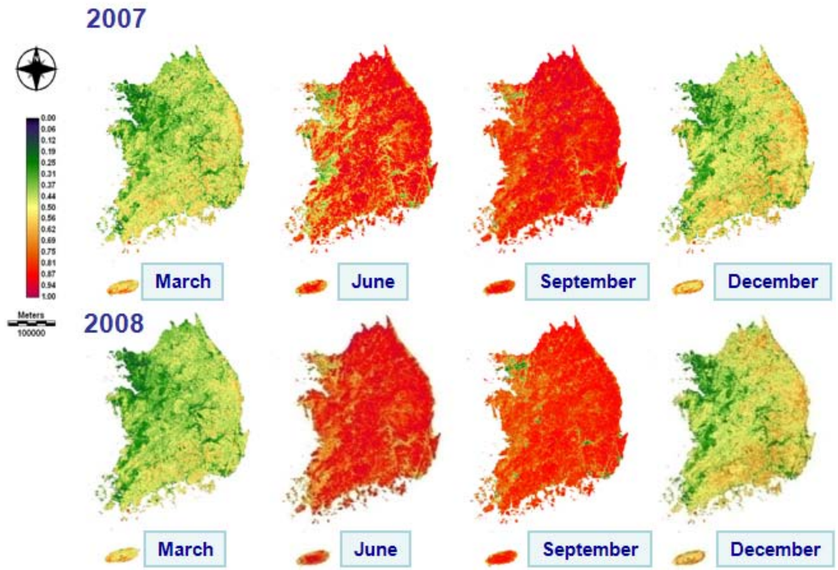
- Daily weather data (temperature, relative humidity, wind speed, sunshine hour) were collected from five stations (1998-2008)
- Daily rainfall data were collected from eighteen stations (1998-2008)

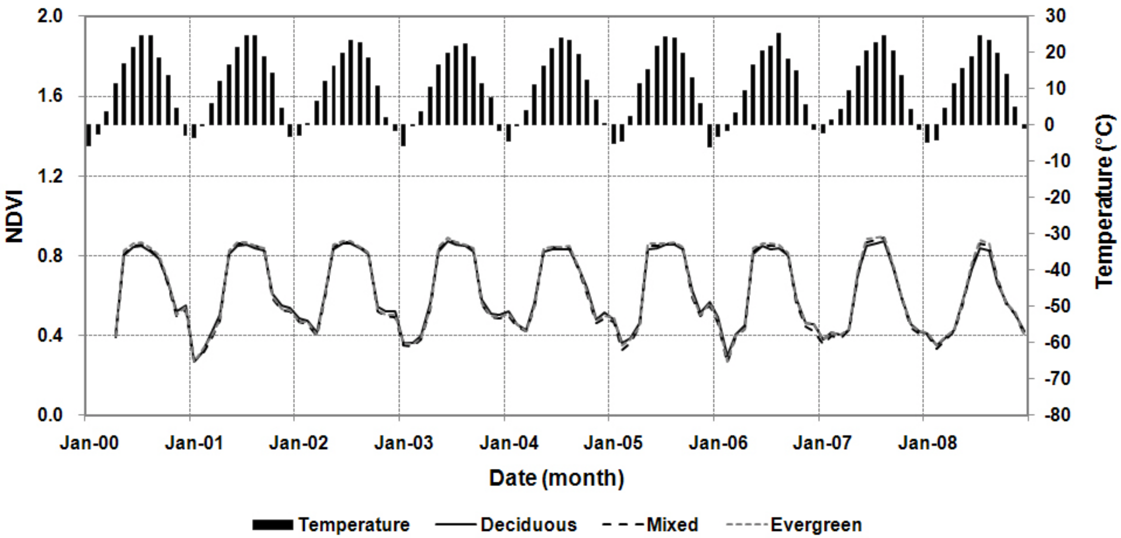
Streamflow and soil moisture data

- Daily streamflow data at the three water level stations were obtained (1998-2008) from the Ministry of Construction and Transportation.
- Daily soil moisture data were obtained from Agricultural Information System (2003-2008)

Material and Method

❖ *MODIS NDVI for the Correlation Analysis*





MODIS NDVI

- Spatial resolution: 250 m
- Temporal resolution: 16 days
- Wave length:

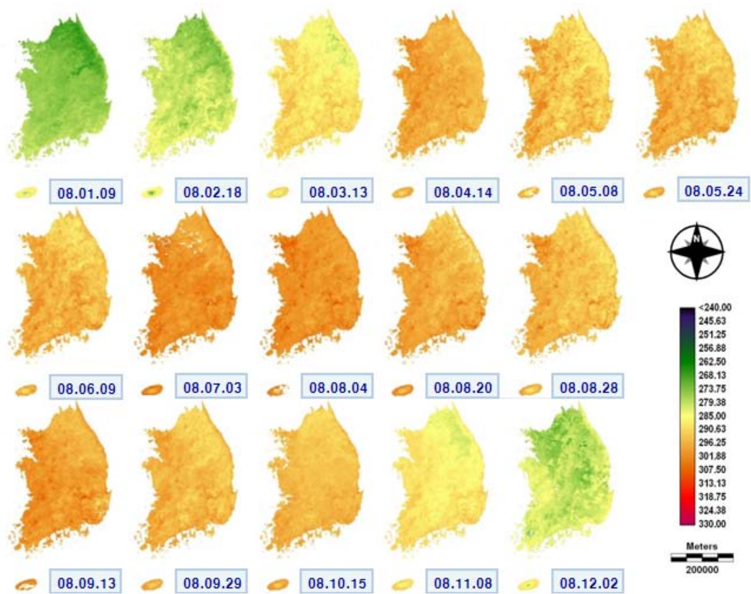
  Band1(0.62-0.67 ㎛)

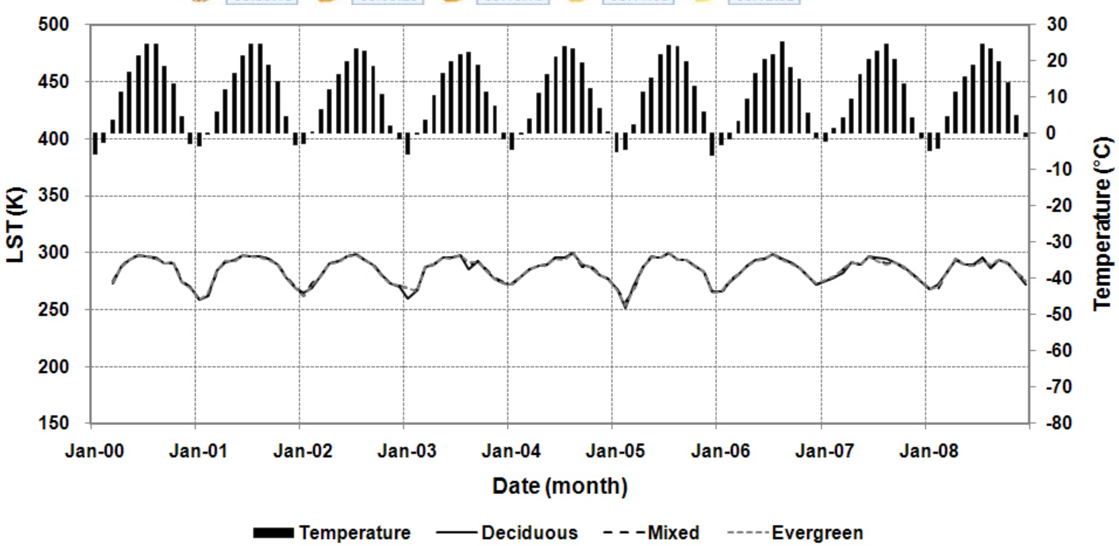
  Band2(0.84-0.88 ㎛)
- NDVI:

  (Band2-Band1)/(Band2+Band1)
- The value of NDVI: 0.27-0.90
- NDVI of June, July and August is mainly high.

Material and Method

❖ *MODIS LST for the Correlation Analysis*





MODIS LST

- Spatial resolution: 1 km
- Temporal resolution: 8 days
- Wave length:

  Band31(10.78-11.28 ㎛)

  Band32(11.77-12.27 ㎛)
- Unit: Kelvin
- The value of LST: 252-300
- LST of May, June, July and August is mainly high.

Result and Discussion

❖ *Model Calibration and Validation for the Streamflow*

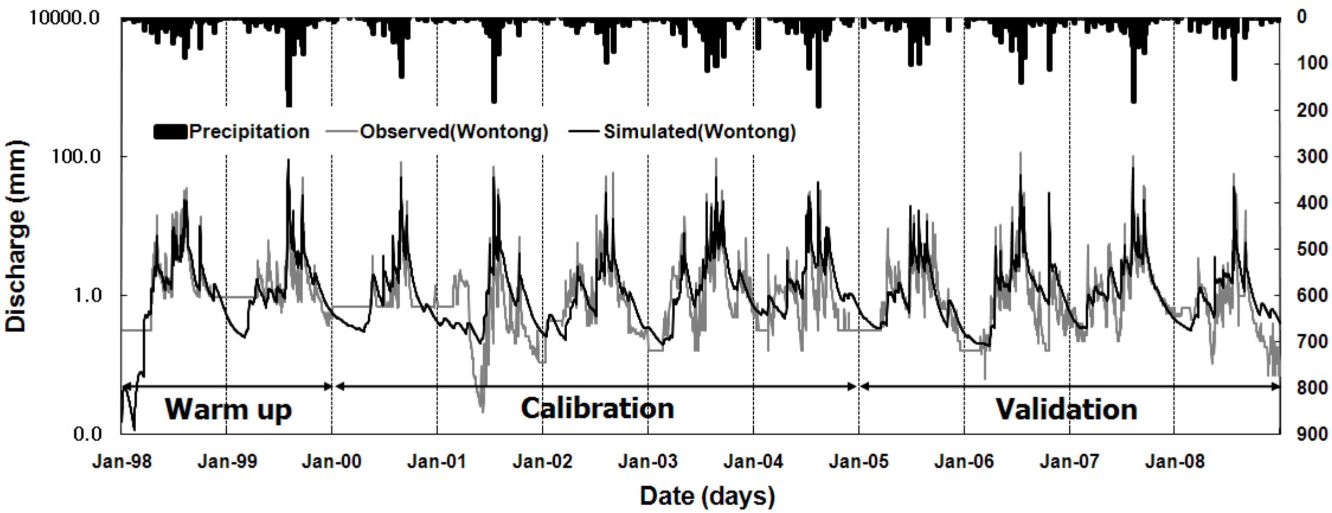
- SWAT model setup process
  - ✓ No. of Subbasin : 20
  - ✓ No. of HRU : 348

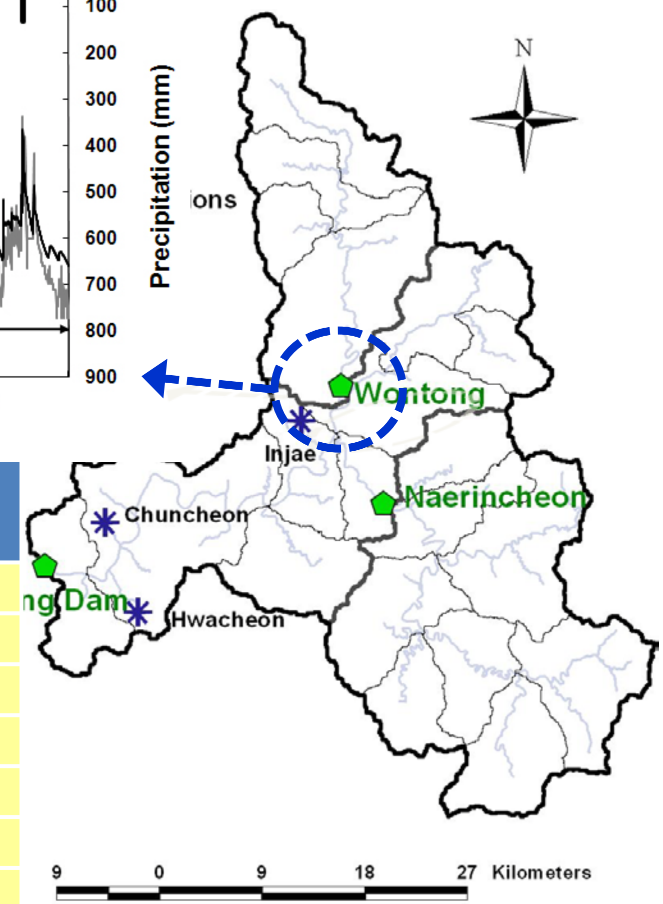
- The calibrated model parameters at 3 sub-watersheds

Parameter	Description	Calibration Range	Wontong Optimal value	Naerincheon Optimal value	Soyanggang Dam Optimal value
CN2	Curve number adjustment ratio	± 20%	0	10	10
ESCO	Soil evaporation compensation	0.01 - 1	0.5	0.3	0.02
SOL_AWC	Available water capacity	± 20%	10	- 10	5
SFTMP	Snowfall temperature (℃)	- 5 - 5	1	1	1
SMTMP	Snow melt base temperature (℃)	- 5 - 5	0.5	0.5	0.5
SMFMX	Maximum snow melt factor (mm H2O/ºC-day)	0 - 10	4.5	4.5	4.5
SMFMN	Minimum snow melt factor (mm H2O/ºC-day)	0 - 10	4.5	4.5	4.5
TIMP	Snow pack temperature lag factor	0 - 1	1	1	1
LAT_TTIME	Lateral flow travel time (days)	-	3	3	2
GW_DELAY	Groundwater delay time (days)	0 - 500	180	150	180
CH_K2	Effective hydraulic conductivity of main channel	0 - 150	70	20	20

Result and Discussion

❖ *Model Calibration and Validation for the Streamflow*

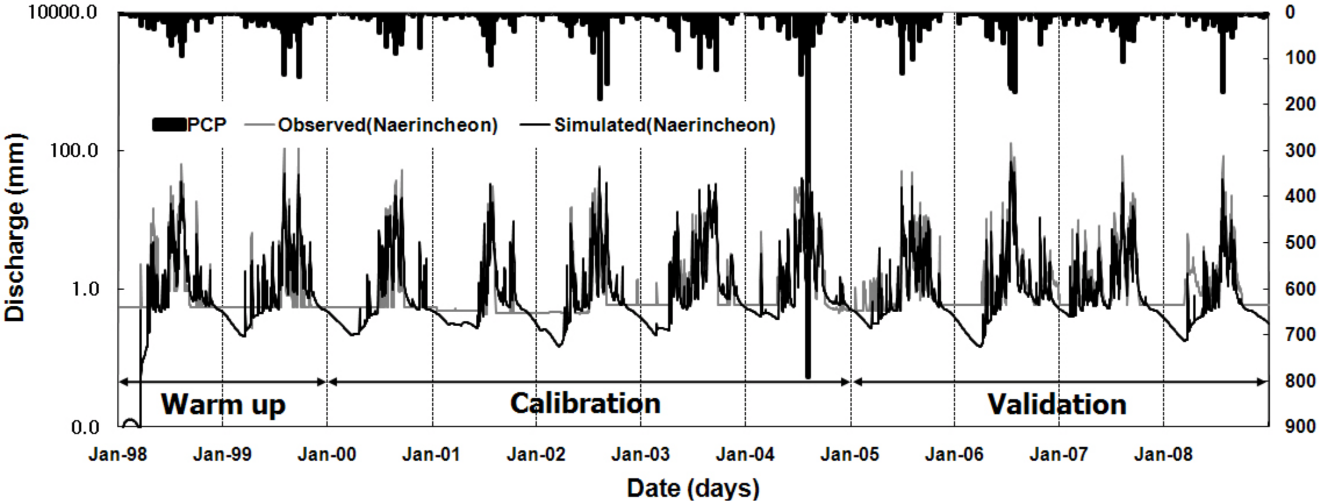


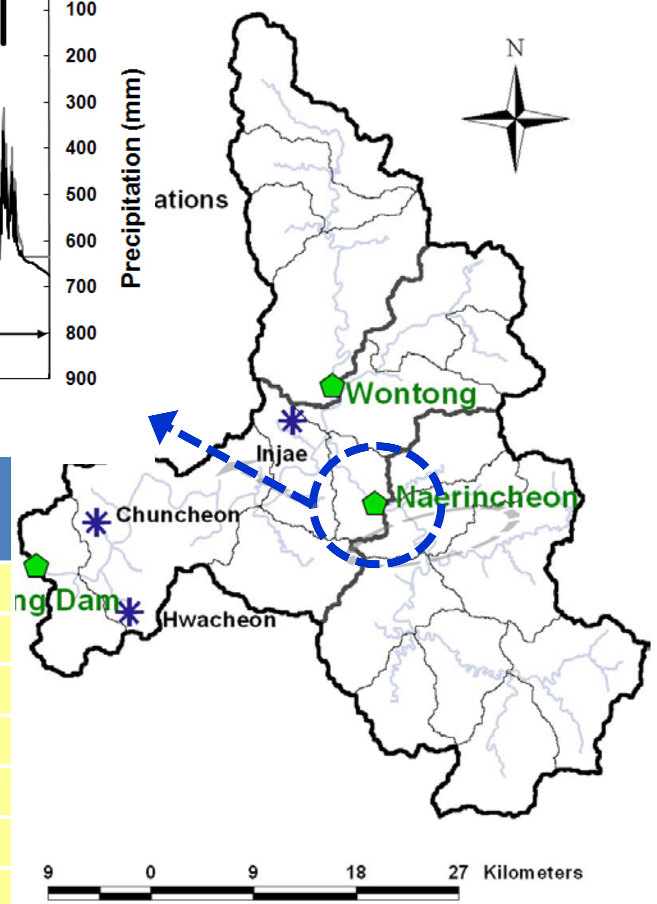


Year		R^2	RMSE (mm/day)	NSE
Calibration	2000	0.83	2.25	0.80
	2001	0.88	1.68	0.86
	2002	0.68	3.04	0.60
	2003	0.78	3.15	0.76
	2004	0.45	3.07	0.56
Validation	2005	0.56	1.48	0.62
	2006	0.88	2.40	0.74
	2007	0.72	2.80	0.70
	2008	0.74	2.27	0.73
Average		0.72	2.46	0.71

Result and Discussion

❖ *Model Calibration and Validation for the Streamflow*

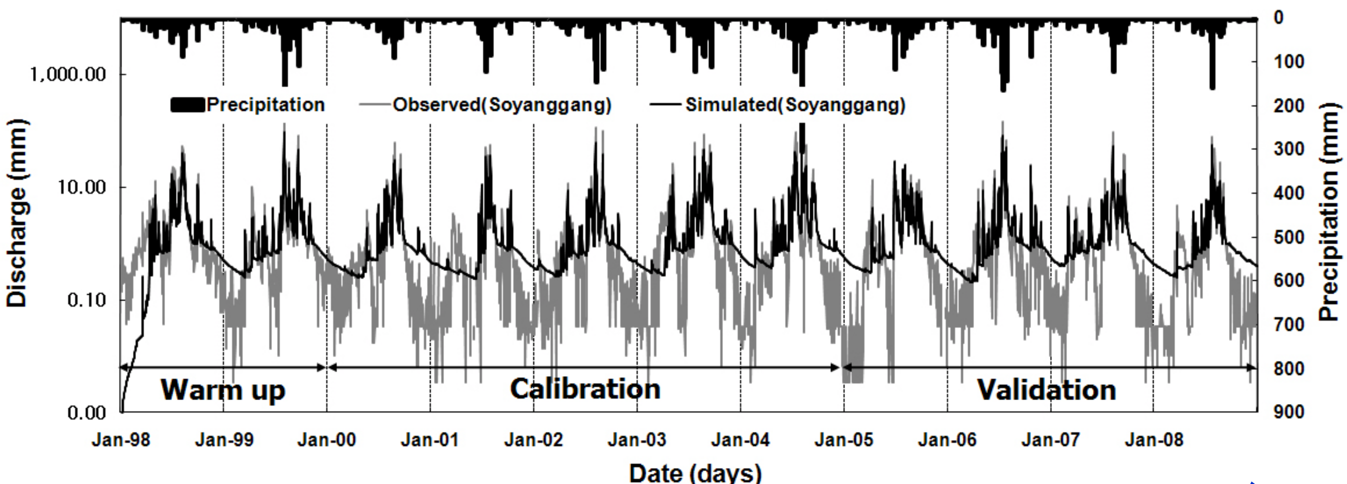


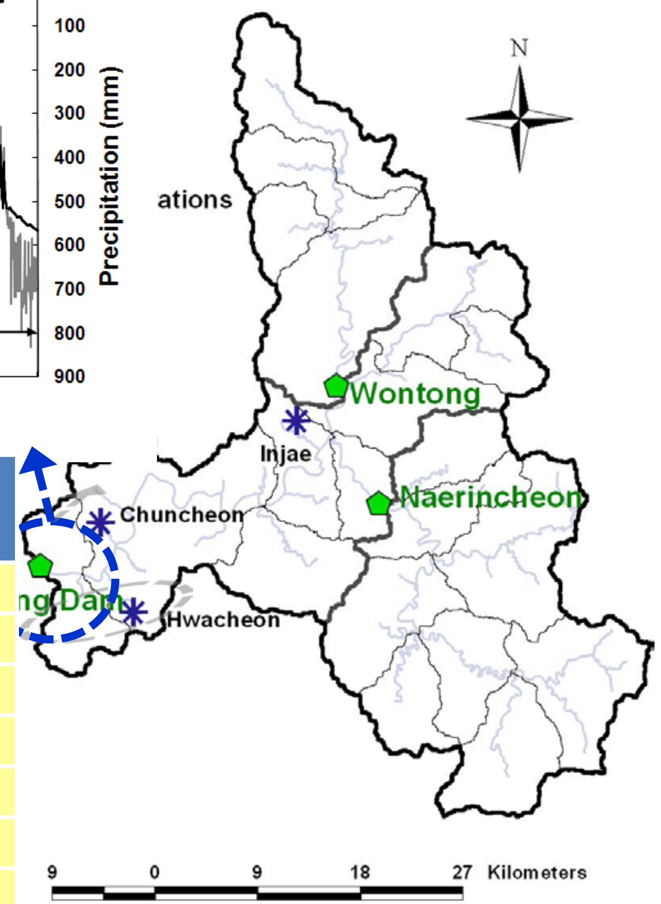


Year		R^2	RMSE (mm/day)	NSE
Calibration	2000	0.82	2.68	0.74
	2001	0.66	1.78	0.65
	2002	0.70	3.52	0.70
	2003	0.70	2.72	0.54
	2004	0.94	3.13	0.94
Validation	2005	0.64	2.91	0.63
	2006	0.84	3.44	0.78
	2007	0.82	2.08	0.75
	2008	0.78	3.53	0.72
Average		0.77	2.87	0.72

Result and Discussion

❖ *Model Calibration and Validation for the Streamflow*

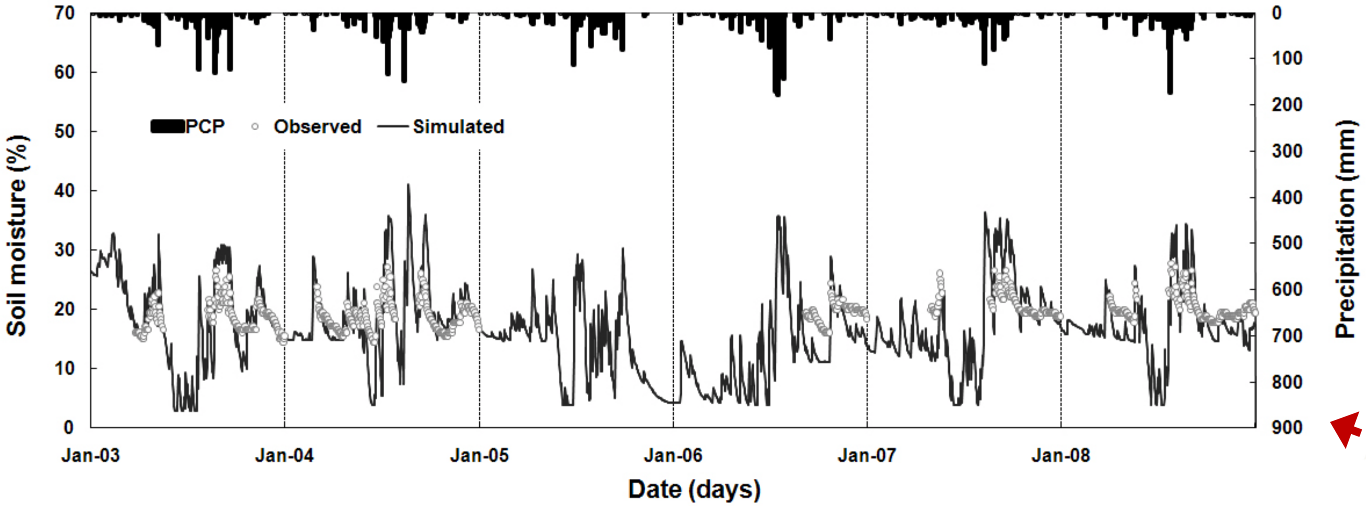


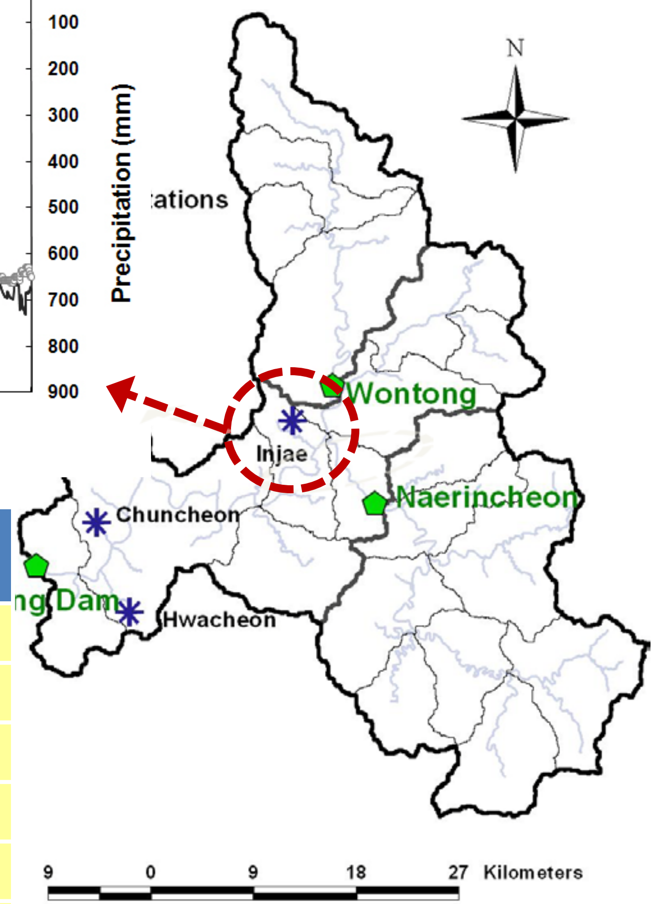


Year		R^2	RMSE (mm/day)	NSE
Calibration	2000	0.70	1.91	0.68
	2001	0.86	3.06	0.77
	2002	0.82	2.09	0.70
	2003	0.80	2.72	0.71
	2004	0.70	1.91	0.68
Validation	2005	0.70	1.91	0.68
	2006	0.86	3.06	0.77
	2007	0.82	2.09	0.70
	2008	0.80	2.72	0.71
Average		0.78	2.39	0.71

Result and Discussion

❖ *Model Calibration and Validation for the Soil Moisture*

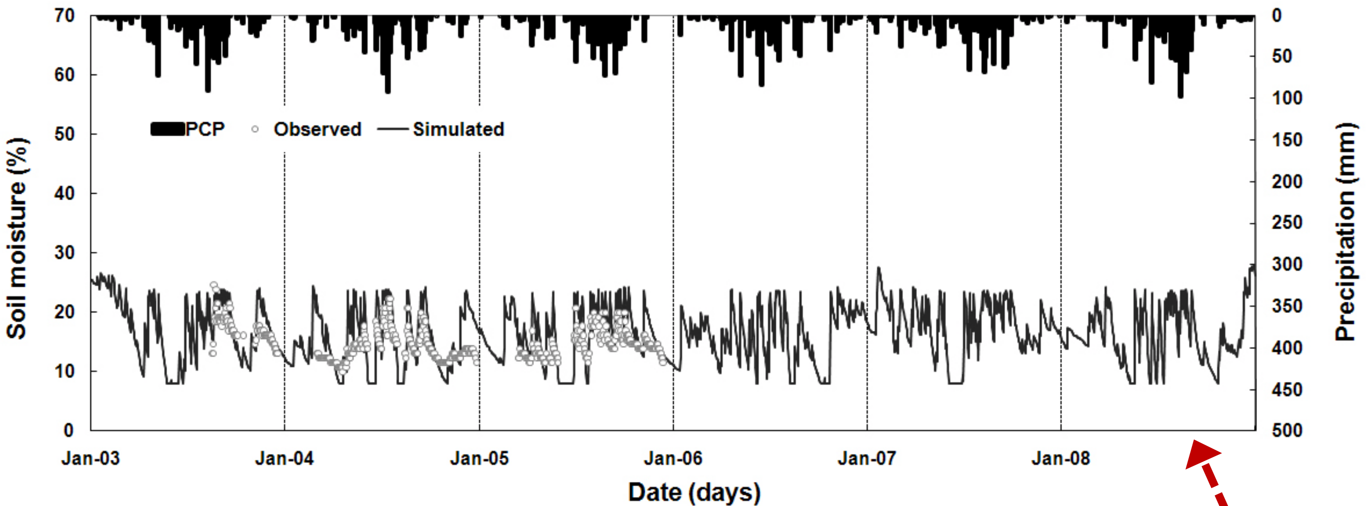


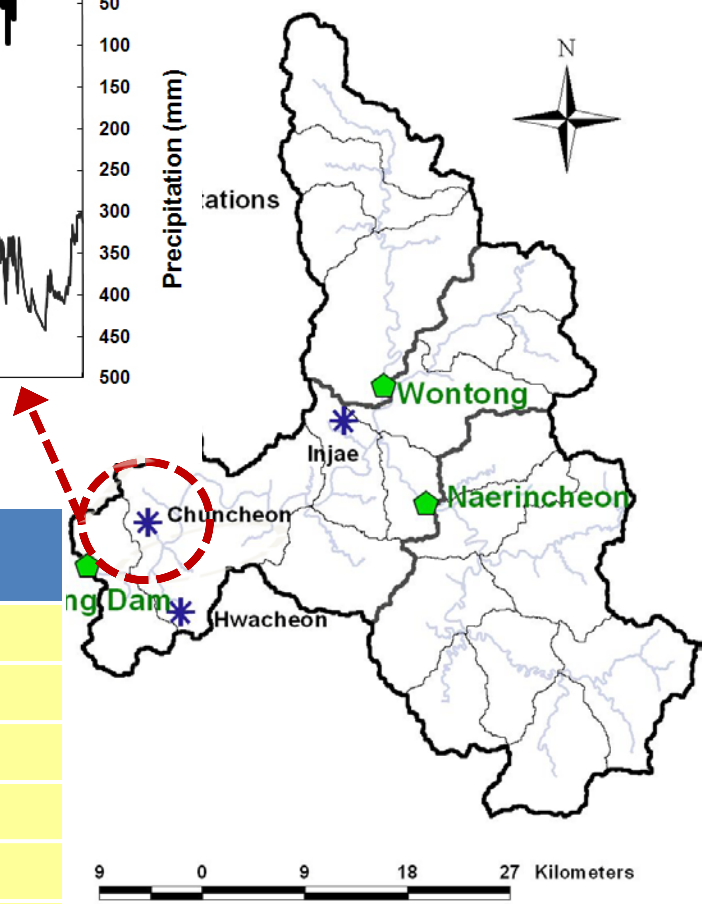


Year		Observed (%)	Simulated (%)	R^2
Calibration	2003	17.3	18.7	0.60
	2004	15.6	19.0	0.60
Validation	2005	-	-	-
	2006	14.4	12.8	0.72
	2007	19.8	17.5	0.60
	2008	18.9	17.4	0.64
Average		17.2	17.0	0.63

Result and Discussion

❖ *Model Calibration and Validation for the Soil Moisture*

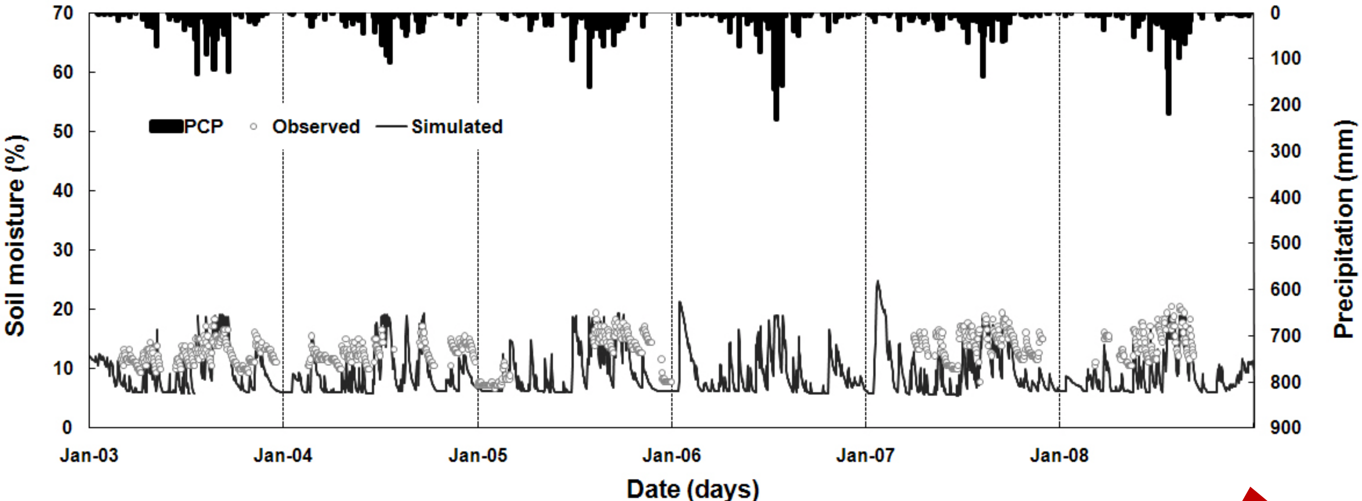


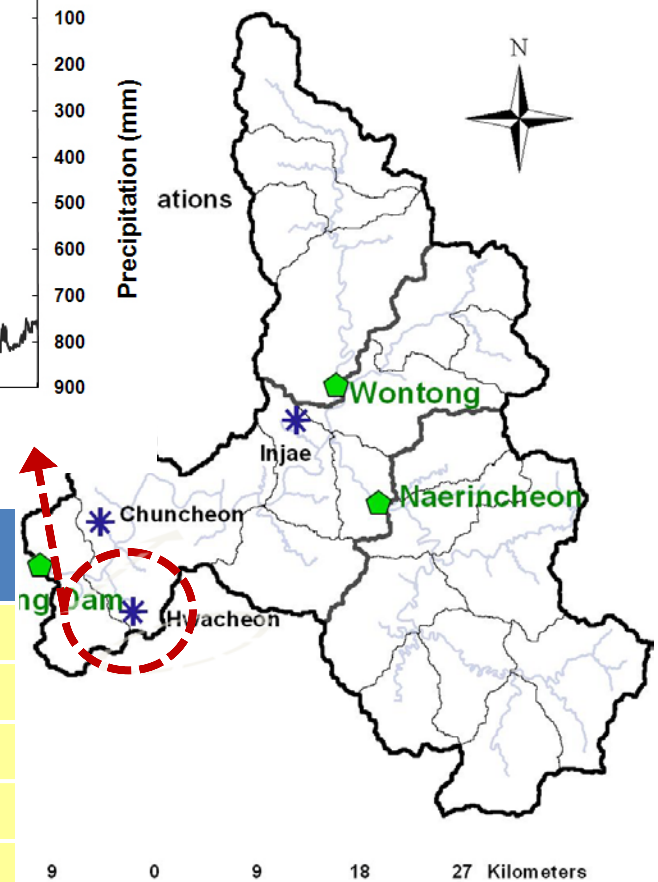


Year		Observed (%)	Simulated (%)	R^2
Calibration	2003	6.6	17.6	0.55
	2004	12.5	15.3	0.51
Validation	2005	11.8	16.1	0.61
	2006	-	-	-
	2007	-	-	-
	2008	-	-	-
Average		10.3	16.3	0.56

Result and Discussion

❖ *Model Calibration and Validation for the Soil Moisture*



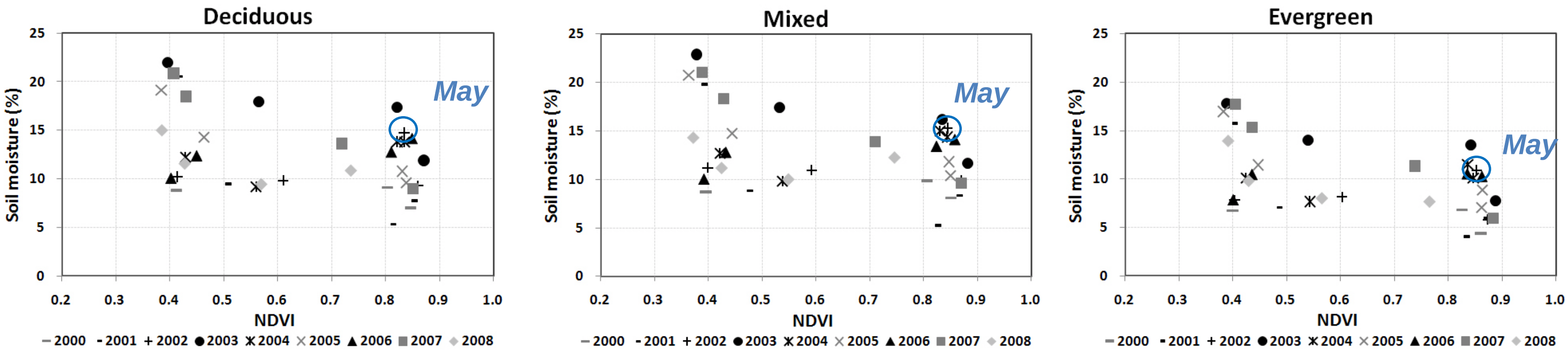


Year		Observed (%)	Simulated (%)	R^2
Calibration	2003	10.6	9.6	0.61
	2004	9.0	9.0	0.56
Validation	2005	7.1	9.4	0.62
	2006	-	-	-
	2007	13.4	10.0	0.65
	2008	8.4	8.9	0.56
Average		9.7	9.4	0.60

Result and Discussion

❖ *The Correlation Analysis between SWAT Soil Moisture and MODIS NDVI*

Forest leaf growing period (March – June)



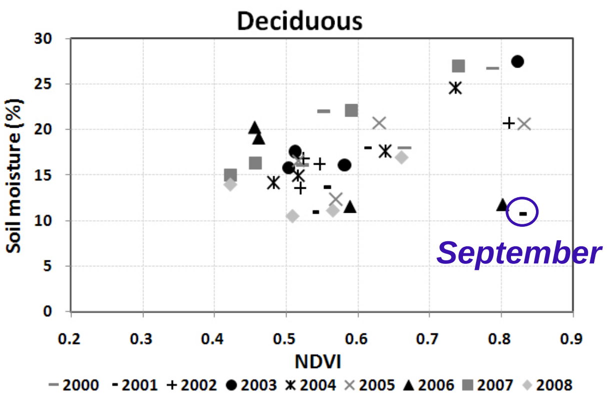
Year	Rainfall (mm)	Temperature (°C)	Equation (y = Soil Moisture, x = NDVI)			R^2		
			Deciduous	Mixed	Evergreen	Deciduous	Mixed	Evergreen
2000	235.3	13.4	y=-2.1393x+9.7736	y=+0.2865x+8.6856	y=-2.8548x+7.9764	0.21	0.01	0.28
2001	211.5	13.9	y=-25.223x+27.016	y=-20.147x+23.375	y=-17.178x+19.279	0.67	0.58	0.63
2002	286.1	13.7	y=+4.2162x+8.1402	y=+3.0535x+9.7578	y=+0.7755x+7.6458	0.12	0.08	0.01
2003	374.6	12.6	y=-16.213x+28.043	y=-17.309x+28.402	y=-14.574x+22.958	0.76	0.82	0.72
2004	356.6	13.1	y=+6.9717x+7.6368	y=+7.8776x+7.7714	y=+3.9831x+7.2158	0.41	0.51	0.28
2005	383.1	12.8	y=-16.709x+23.950	y=-15.855x+24.347	y=-14.713x+20.488	0.87	0.80	0.78
2006	405.7	12.5	y=+6.0098x+8.5721	y=+5.8201x+8.9483	y=+3.0951x+7.8093	0.68	0.65	0.36
2007	345.4	12.6	y=-23.683x+29.736	y=-21.503x+28.595	y=-21.457x+25.797	0.97	0.97	0.95
2008	290.4	12.6	y=-9.6834x+16.847	y=-3.1432x+13.596	y=-13.221x+16.962	0.42	0.08	0.61
Average	321.0	13.0	y=-4.8919x+17.7461	y=-6.7688x+17.0531	y=-8.4605x+15.1257	0.57	0.50	0.51

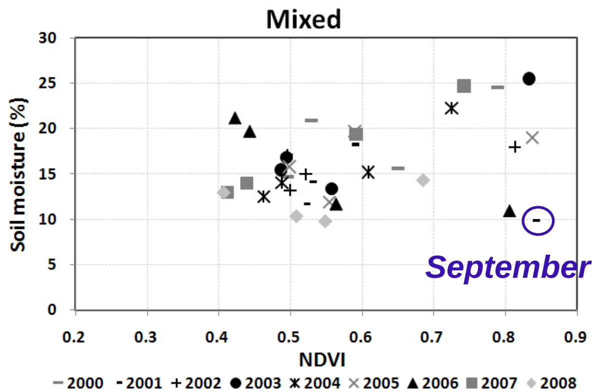
Average : 0.53

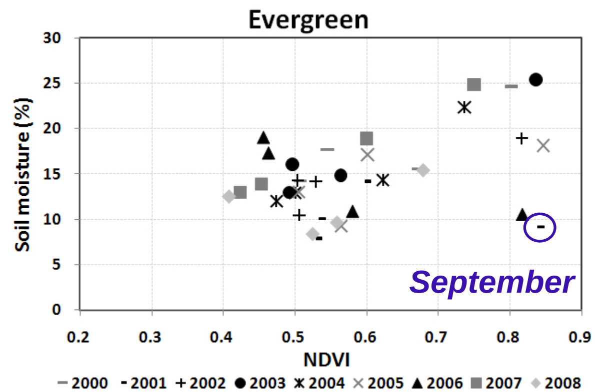
Result and Discussion

❖ *The Correlation Analysis between SWAT Soil Moisture and MODIS NDVI*

Forest leaf falling period (September – December)







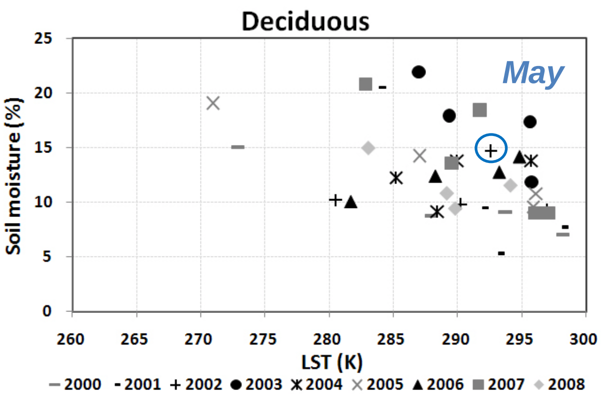
Year	Rainfall (mm)	Temperature (°C)	Equation (y = Soil Moisture, x = NDVI)			R^2		
			Deciduous	Mixed	Evergreen	Deciduous	Mixed	Evergreen
2000	251.6	8.5	y=+28.532x+2.6753	y=+22.524x+5.0682	y=+28.514x+0.0186	0.53	0.42	0.68
2001	157.4	8.7	y=-7.6178x+18.133	y=-12.189x+21.008	y=-1.522x+11.287	0.09	0.26	0.01
2002	167.9	7.5	y=+18.698x+5.6075	y=+9.1336x+10.486	y=+19.81x+2.7876	0.80	0.43	0.76
2003	452.3	9.0	y=+35.537x-2.2618	y=+29.42x+0.3436	y=+32.665x-2.1686	0.91	0.81	0.92
2004	272.2	9.7	y=+38.851x-5.2091	y=+33.517x-3.1374	y=+36.596x-5.9488	0.92	0.89	0.87
2005	192.6	8.2	y=+18.317x+5.9039	y=+12.434x+8.909	y=+18.333x+2.8593	0.40	0.27	0.46
2006	254.9	9.4	y=-23.788x+29.401	y=-26.003x+30.399	y=-21.302x+26.778	0.69	0.74	0.69
2007	303.2	9.3	y=+38.124x-0.9763	y=+35.385x-1.5646	y=+36.384x-2.5936	0.99	0.99	0.99
2008	142.9	9.4	y=+13.144x+6.031	y=+6.1203x+8.5509	y=+11.297x+5.3715	0.20	0.11	0.16
Average	243.9	8.9	y=+17.755x+6.5894	y=+12.260x+8.8959	y=+17.864x+4.2657	0.61	0.55	0.62

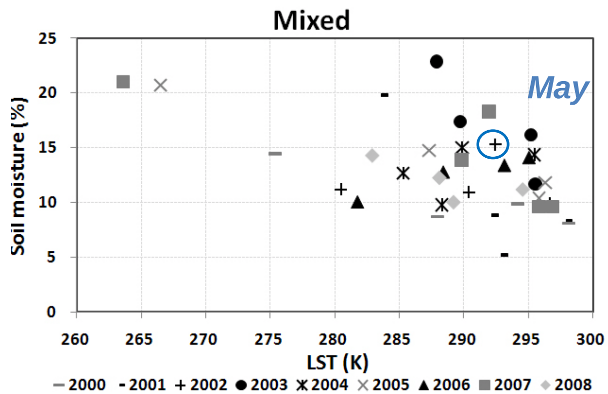
Average : 0.59

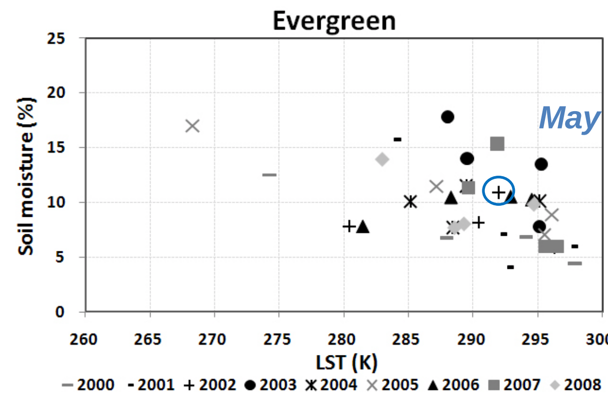
Result and Discussion

❖ *The Correlation Analysis between SWAT Soil Moisture and MODIS LST*

Forest leaf growing period (March – June)







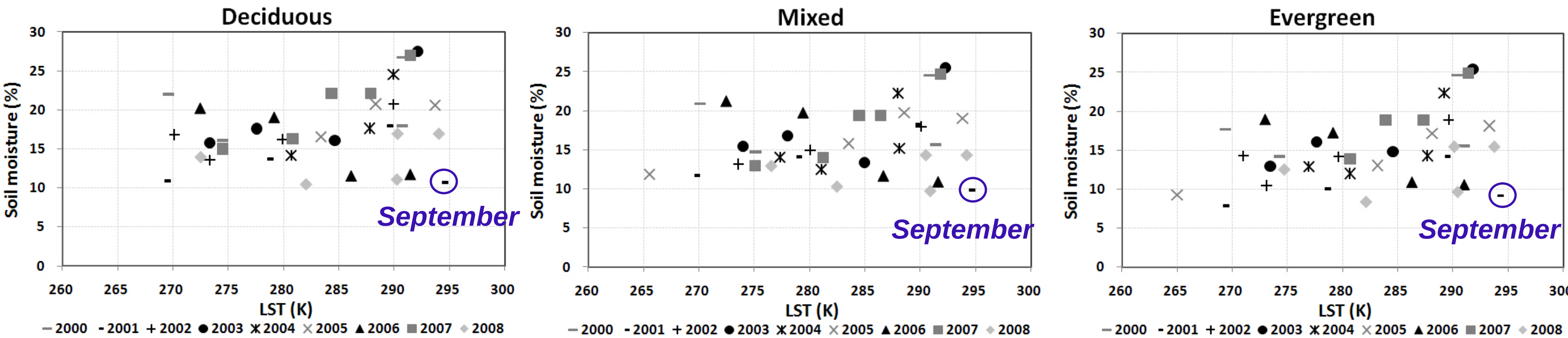
Year	Rainfall (mm)	Temperature (°C)	Equation (y = Soil Moisture, x =LST)			R^2		
			Deciduous	Mixed	Evergreen	Deciduous	Mixed	Evergreen
2000	235.3	13.4	y=-0.3067x+98.383	y=-0.259x+85.29	y=-0.3216x+100.42	0.93	0.81	0.94
2001	211.5	13.9	y=-0.9957x+301.32	y=-0.907x+275.08	y=-0.7868x+237.64	0.76	0.72	0.75
2002	286.1	13.7	y=+0.0334x+1.3174	y=+0.0087x+9.3033	y=-0.0446x+21.112	0.01	0.00	0.02
2003	374.6	12.6	y=-0.7597x+239.06	y=-1.036x+319.64	y=-0.8536x+262.53	0.67	0.75	0.60
2004	356.6	13.1	y=+0.2366x-56.321	y=+0.2586x-61.955	y=+0.0517x-5.1168	0.23	0.22	0.02
2005	383.1	12.8	y=-0.3572x+116.13	y=-0.3238x+107.17	y=-0.3257x+104.47	0.97	0.97	0.96
2006	405.7	12.5	y=+0.2779x-68.113	y=+0.2957x-73.039	y=+0.1918x-45.715	0.92	0.96	0.75
2007	345.4	12.6	y=-0.8283x+255.6	y=-0.3016x+101.23	y=-0.217x+73.14	0.77	0.65	0.57
2008	290.4	12.6	y=-0.3577x+115.1	y=-0.2812x+93.117	y=-0.3511x+111.27	0.48	0.55	0.35
Average	321.0	13.0	y=-0.3397x+111.39	y=-0.2828x+95.093	y=-0.2952x+95.528	0.64	0.63	0.55

Average : 0.61

Result and Discussion

❖ ***The Correlation Analysis between SWAT Soil Moisture and MODIS LST***

Forest leaf falling period (September – December)

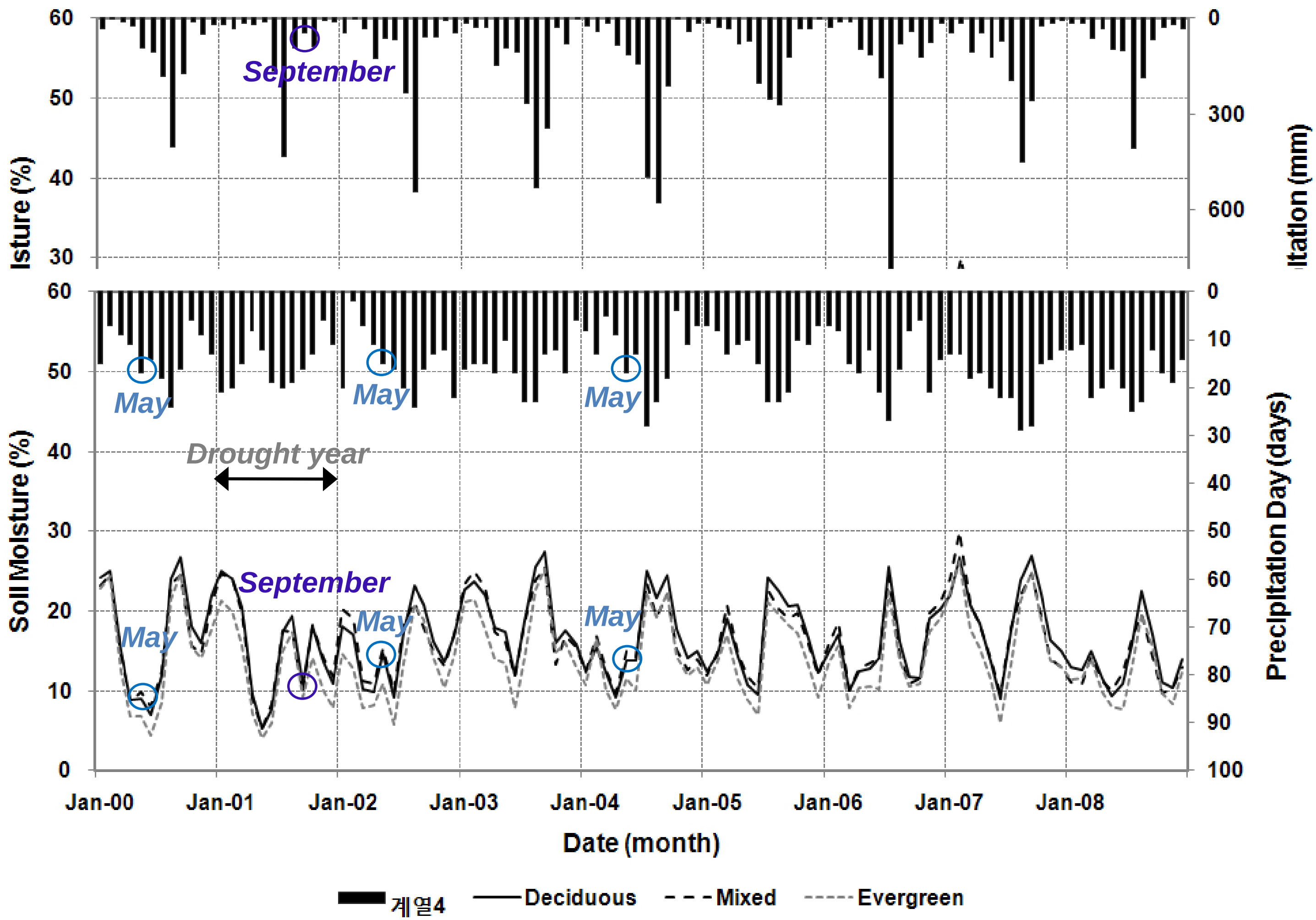


Year	Rainfall (mm)	Temperature (°C)	Equation (y = Soil Moisture, x =LST)			R^2		
			Deciduous	Mixed	Evergreen	Deciduous	Mixed	Evergreen
2000	251.6	8.5	y=+0.1306x-16.047	y=+0.0682x-0.2731	y=+0.182x-33.171	0.09	0.03	0.19
2001	157.4	8.7	y=+0.0839x-10.406	y=+0.0307x+4.7949	y=+0.124x-24.715	0.08	0.01	0.26
2002	167.9	7.5	y=+0.2633x-56.447	y=+0.1246x-18.914	y=+0.3427x-80.932	0.61	0.24	0.69
2003	452.3	9.0	y=+0.5498x-135.77	y=+0.4562x-111	y=+0.5928x-149.76	0.67	0.47	0.75
2004	272.2	9.7	y=+0.6502x-166.73	y=+0.5242x-132.68	y=+0.605x-156.21	0.69	0.42	0.55
2005	192.6	8.2	y=+0.312x-70.637	y=+0.277x-61.737	y=+0.3178x-75.354	0.92	0.90	0.93
2006	254.9	9.4	y=-0.5224x+163.16	y=-0.6088x+187.86	y=-0.5272x+163.28	0.87	0.91	0.93
2007	303.2	9.3	y=+0.7047x-179.51	y=+0.7278x-188.47	y=+0.7023x-181.27	0.90	0.91	0.88
2008	142.9	9.4	y=+0.1296x-23.155	y=+0.0665x-6.7377	y=+0.1592x-33.288	0.13	0.05	0.14
Average	243.9	8.9	y=-0.3397x+111.39	y=-0.2828x+95.093	y=-0.2952x+95.528	0.46	0.35	0.51

Average : 0.44

Result and Discussion

❖ *The Comparison of Correlation Analysis*



Result and Discussion

❖ ***The Comparison of Correlation Analysis***

Period	Case	Rainfall (mm)	Temperature (°C)	R^2		
				Deciduous	Mixed	Evergreen
Forest leaf growing	NDVI	321.0	13.0	0.57	0.50	0.51
	LST			0.64	0.63	0.55
Forest leaf falling	NDVI	243.9	8.9	0.61	0.55	0.62
	LST			0.46	0.35	0.51

➢ ***Based on period***

- ✓ **Forest leaf growing period : LST (61 %) > NDVI (53 %)**
- ✓ **Forest leaf falling period : NDVI (59 %) > LST (44 %)**

➢ ***Based on case***

- ✓ **NDVI : forest leaf falling period (59 %) > forest leaf growing period (53 %)**
- ✓ **LST : forest leaf growing period (61 %) > forest leaf falling period (44 %)**

Summary and Conclusions

- Due to the lack of soil moisture ground data, we need a pseudo indicator of soil moisture condition.
- This study was tried to investigate the correlations between SWAT simulated soil moisture (SM) and MODIS NDVI and LST how much the NDVI and LST can explain the soil moisture for the forest leaf growing and falling periods respectively.

- The soil moisture showed **high correlation** with the big inverse slope for NDVI and LST during the **forest leaf growing period** with the 9 years.

- The **low correlation** appeared **in case of dispersed storms** occurred during the period regardless of the leaf growing or falling periods.

- Yet, the study result include many uncertainty. So, in future, I will collect continuously MODIS data, and apply the other method.

Thank you for your attention!

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