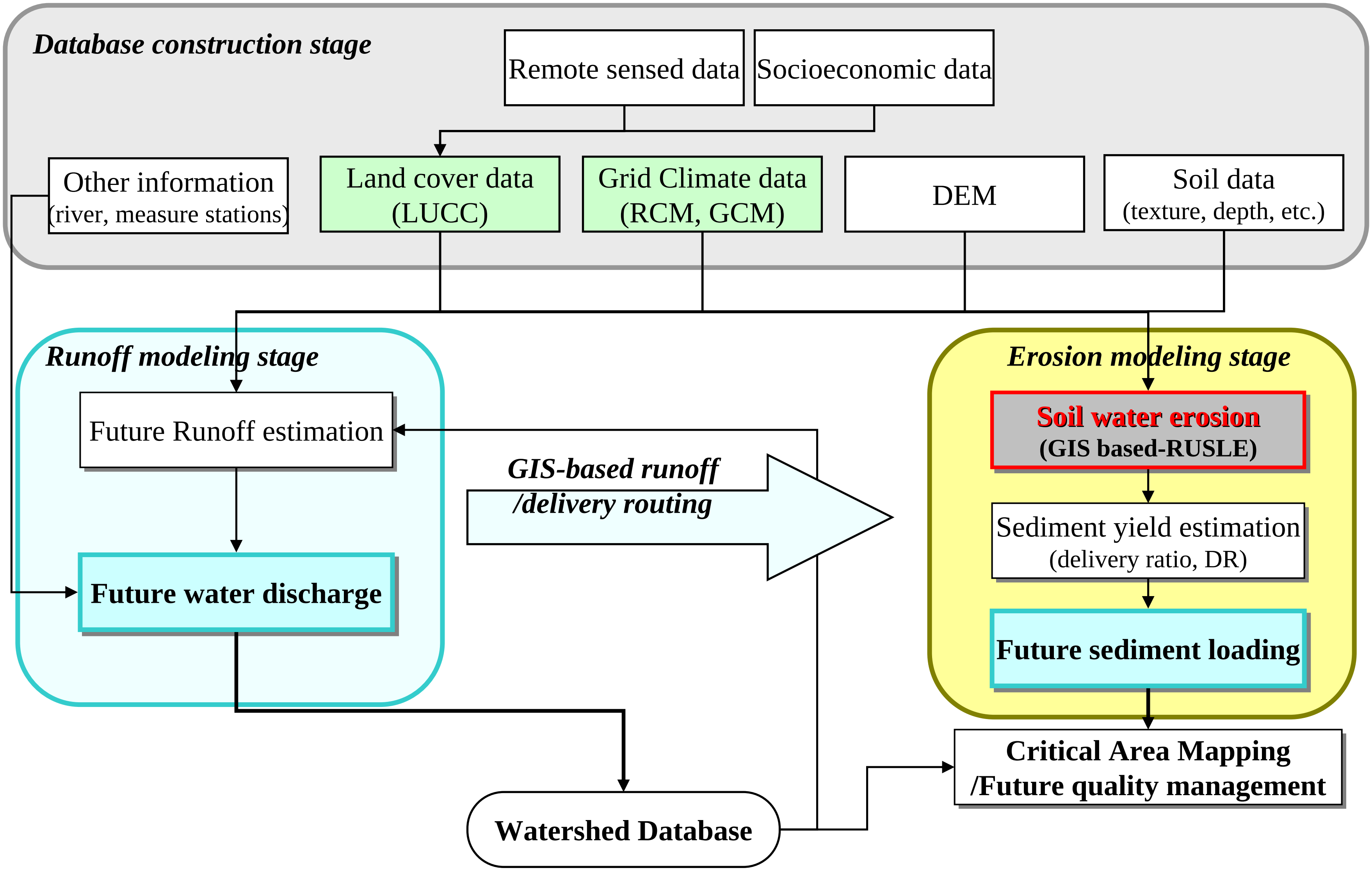
# Development of soil water erosion module using GIS and RUSLE

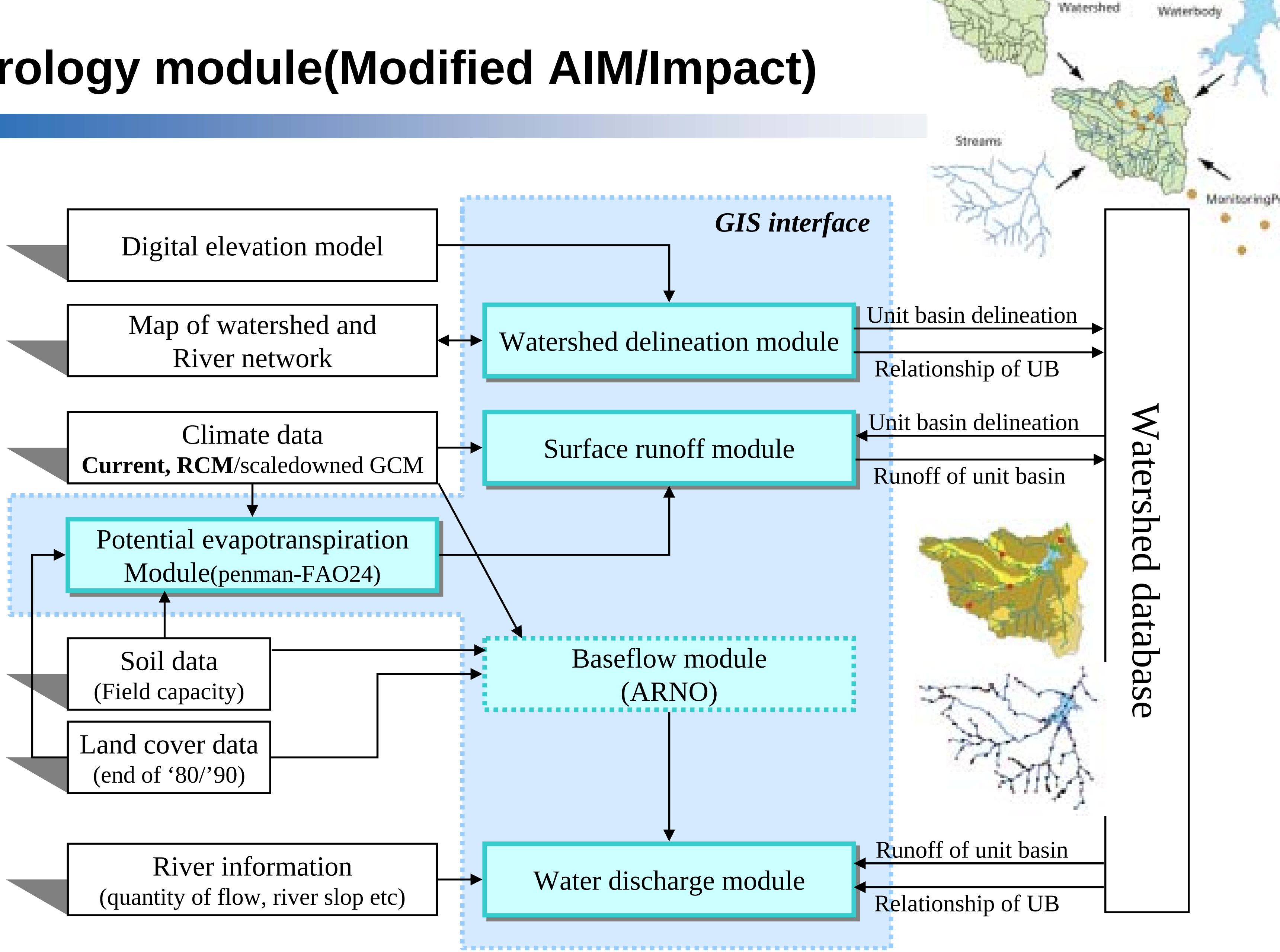
**AIM Korea team**

**Hui Cheul JUNG(KEI)**
**Seong Woo JEON(KEI)**
**Dong Kun LEE(SNU)**

# Outline of Sediment loading analysis



# Hydrology module(Modified AIM/Impact)



# Soil Water Erosion Module(RUSLE)

1. The RUSLE shows rill/interrill erosion and dosen’t consider the deposition of soil, it means RUSLE results are not real erosion but erosion potential.

2. LS factor from the DEM will consider upslope contribution area using GIS. (Flow accumulation concept)

| Climate data (**RCM rainfall**) | DEM (slop,aspect) | Soil data (texture) | Land cover data (LUCC) |
|---|---|---|---|

$$A(i,j) = R(i,j) \times LS(i,j) \times K(i,j) \times C(i,j) \times P(i,j)$$

where

A is the average annual potential soil erosion ( ton ha-1 year-1) of grid (x,y)

R is the average rainfall erosivity factor (MJ mm ha-1 h-1 year-1)

LS is the average topographical parameter

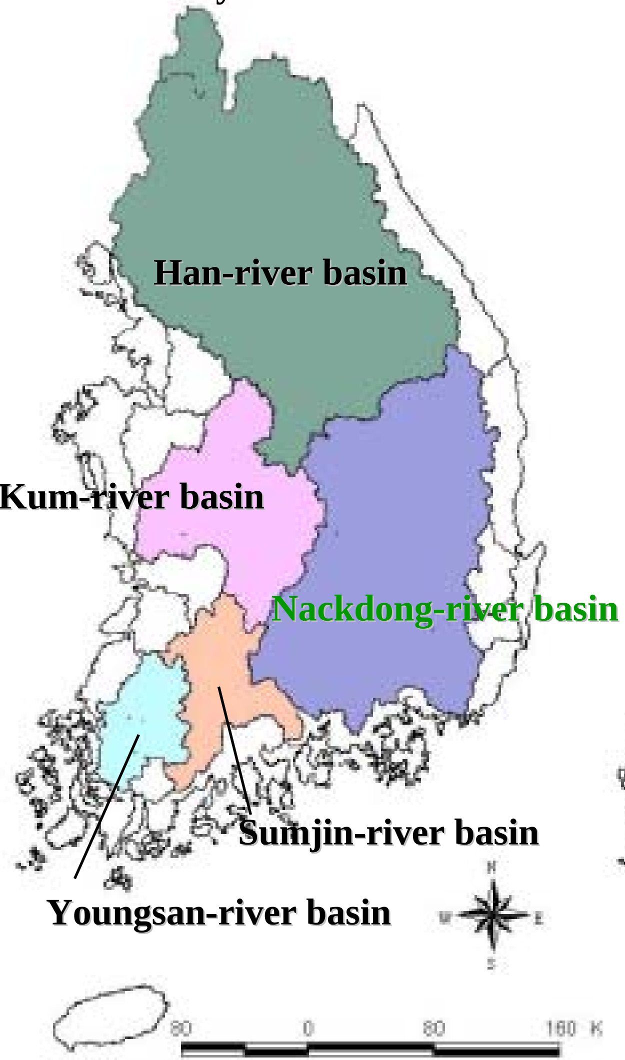
K is the average soil erodibility factor (ton ha h ha-1 MJ-1 mm-1)

C is the average land cover and management factor

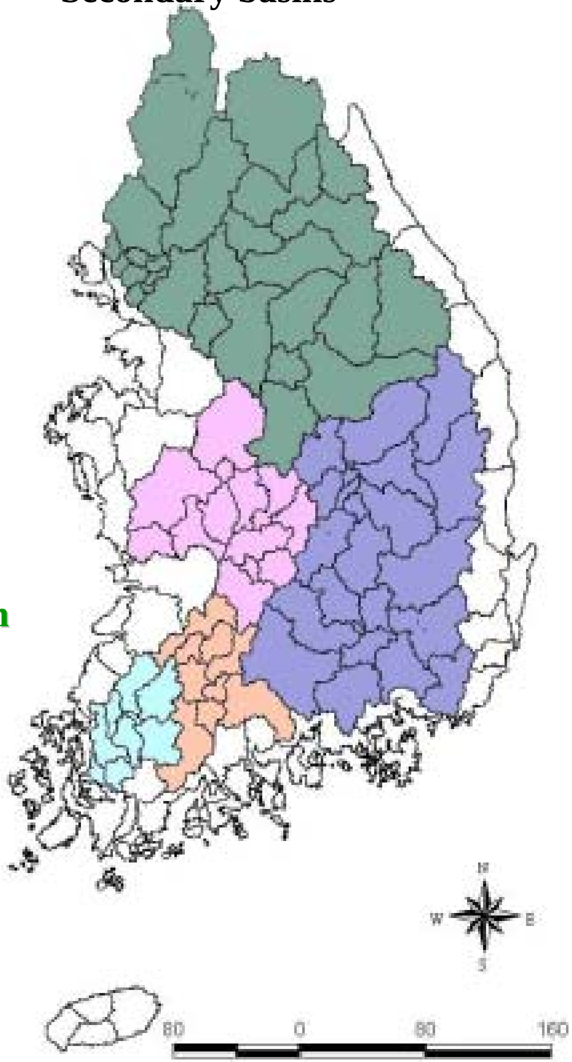
P is the average conservation practice factor

# Database Construction(Map of basin)

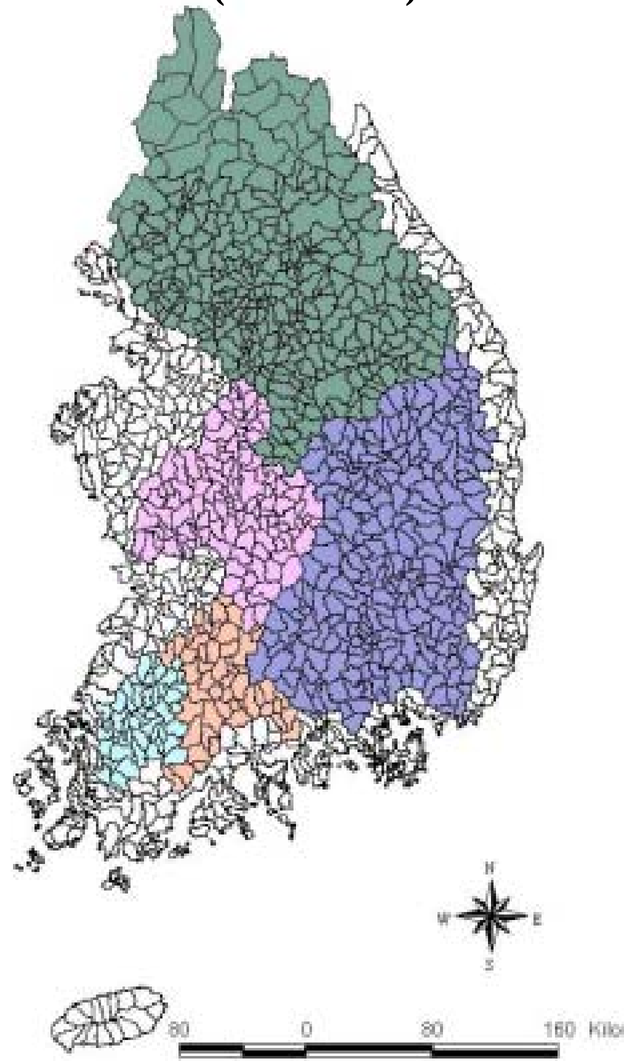
**Primary basins**




**Secondary basins**



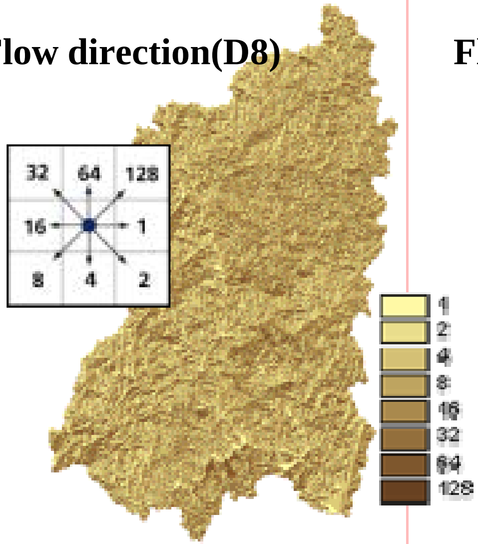

**unit basins(catchments)**



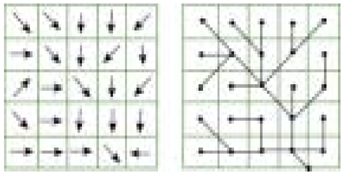
# Database Construction(Building HydroGIS )

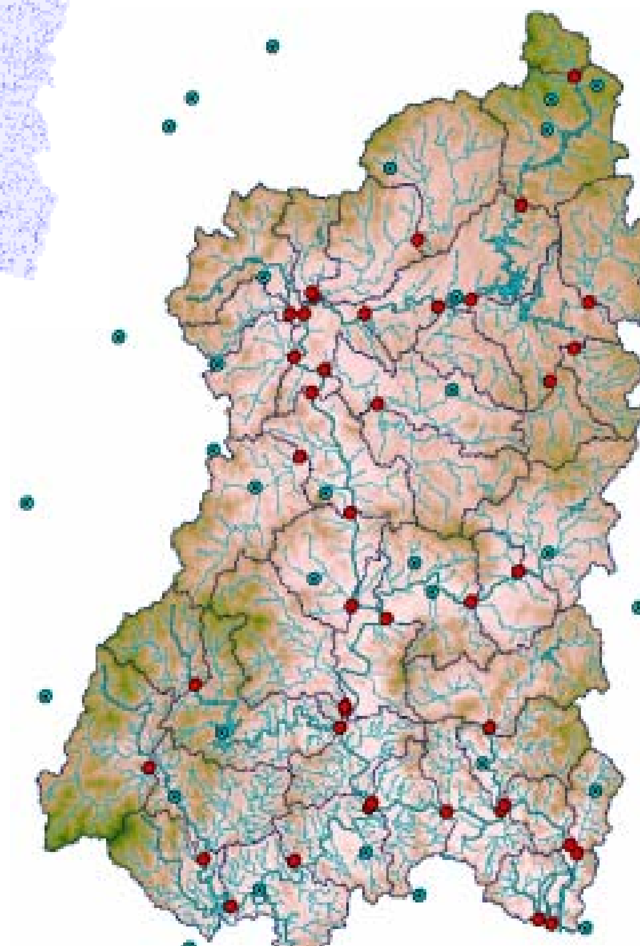
DEM

Flow direction(D8)

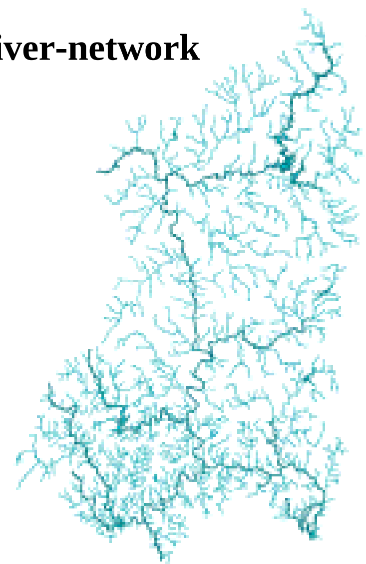



Flow accumulation

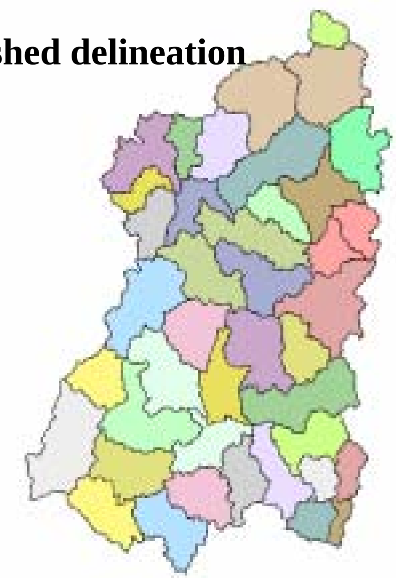




River-network

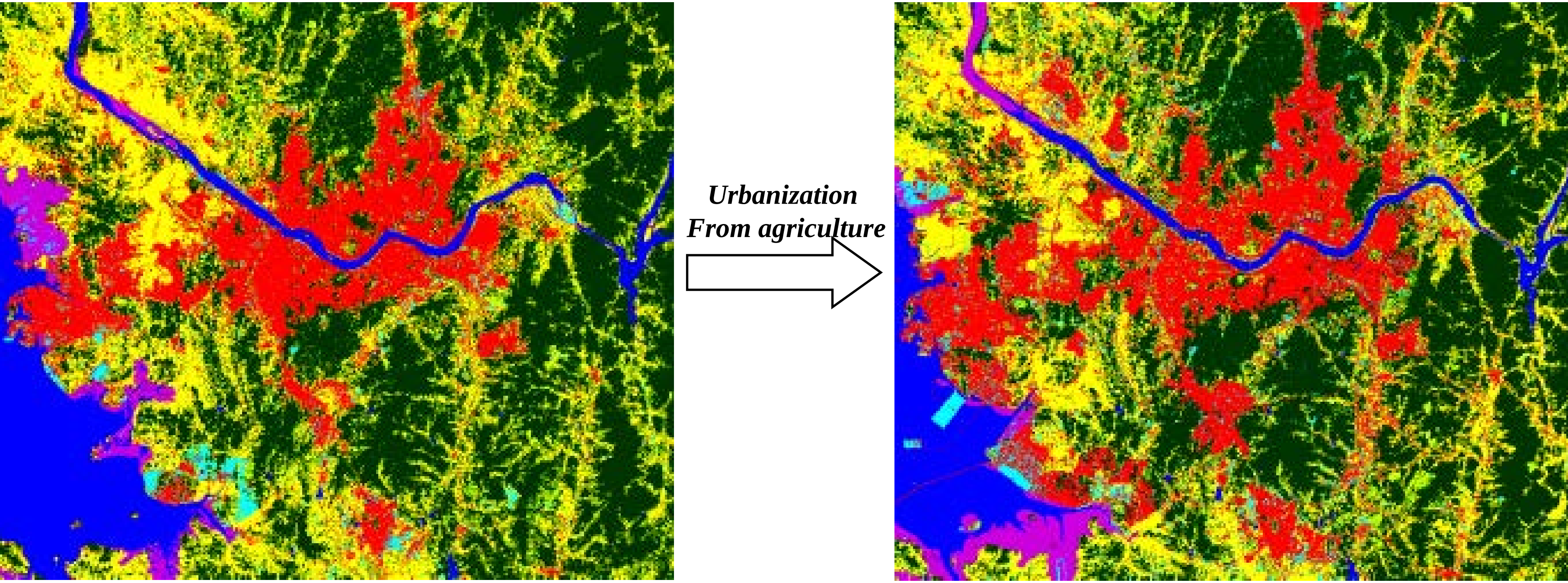


Watershed delineation

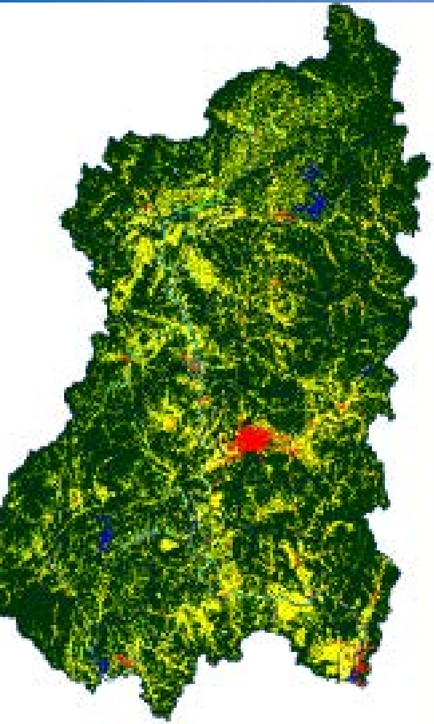


# Database Construction(Land cover database)

| | South Korea | | | | | North Korea | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Surfaces 1980s | | Surfaces 1990s | | change rate | Surfaces 1980s | | Surfaces 1990s | | change rate |
| classes | ha | % | ha | % | | nk(ha) | % | nk(ha) | % | |
| Water bodies | 161325.3 | 1.6 | 165538.9 | 1.7 | 2.61 | 139997.2 | 1.1 | 147107.3 | 1.2 | 5.08 |
| **Urban fabric** | **195988.4** | **2.0** | **321199.0** | 3.2 | 63.89 | **126947.3** | **1.0** | **190691.0** | 1.6 | 50.21 |
| Barrens | 106831.7 | 1.1 | 142496.0 | 1.4 | 33.38 | 83886.8 | 0.7 | 141950.1 | 1.2 | 69.22 |
| Wetlands | 61752.8 | 0.6 | 35071.4 | 0.3 | -43.21 | 43731.9 | 0.4 | 28618.9 | 0.2 | -34.56 |
| Grasslands | 280564.6 | 2.8 | 365821.9 | 3.6 | 30.39 | 377535.3 | 3.1 | 492604.7 | 4.0 | 30.48 |
| **Forest** | **6775526.9** | **67.6** | **6748725.6** | 67.3 | -0.40 | **9287767.0** | **75.7** | **8789543.3** | 71.7 | -5.36 |
| **Agriculture** | **2442389.8** | **24.4** | **2245671.5** | 22.4 | -8.05 | **2203895.0** | **18.0** | **2472288.5** | 20.2 | 12.18 |
| Etc. | 1513.9 | 0.0 | 1368.9 | 0.0 | -9.58 | 2601.7 | 0.0 | 3558.3 | 0.0 | 36.77 |
| Area(ha) | 10025893.3 | 100.0 | 10025893.3 | 100.0 | - | 12266362.2 | 100.0 | 12266362.2 | 100.0 | - |

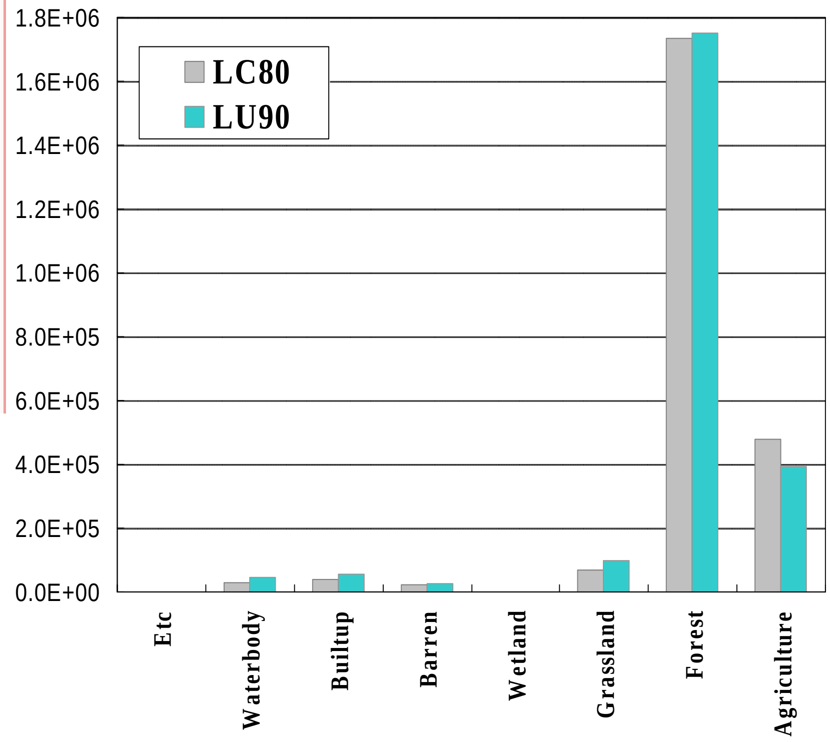


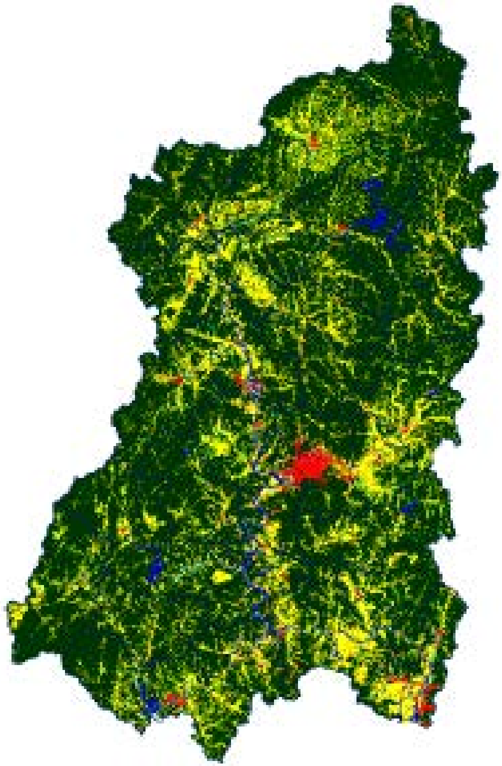
# Database Construction(Land cover database)



End of 1980

**Basin area: 23,727.68km2**
**Length of longest river: 521.5km**

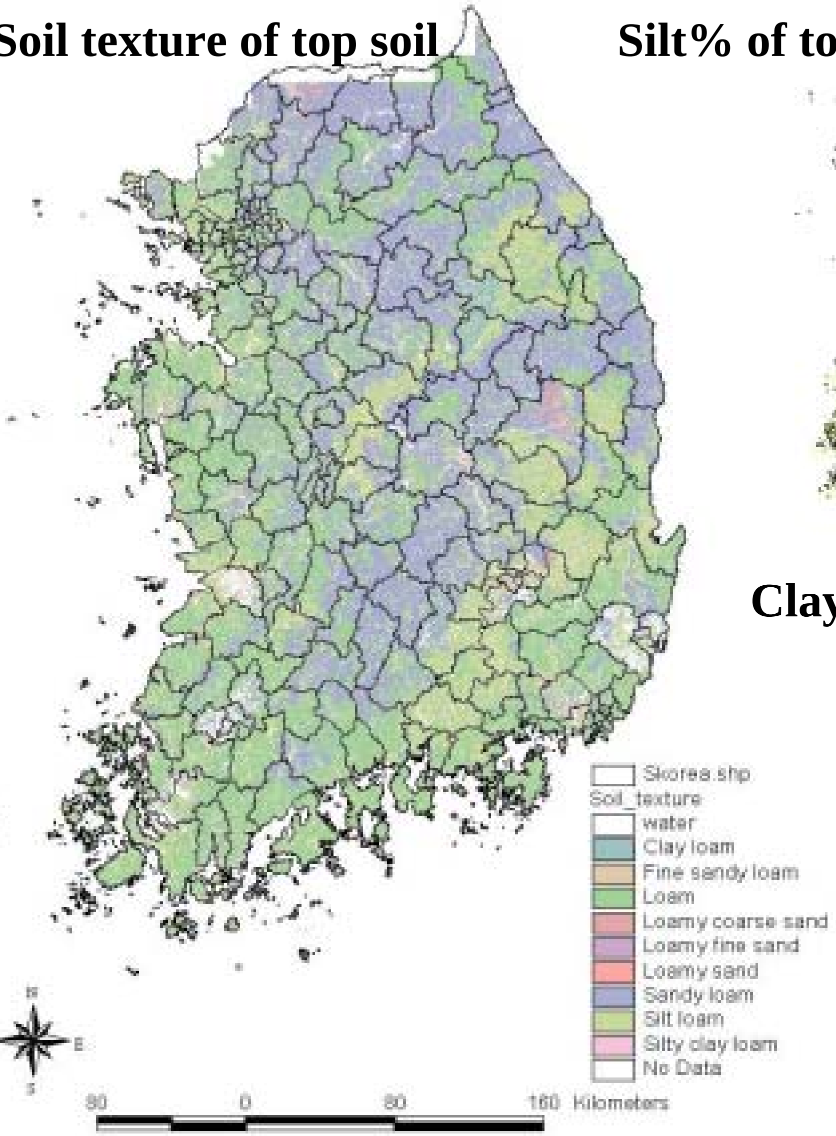


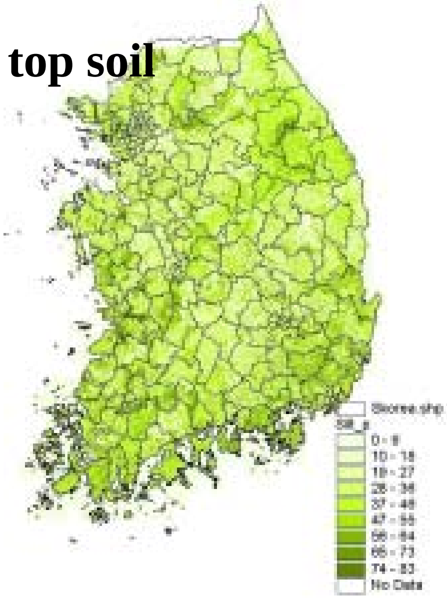
End of 1990

# Database Construction(detailed soil map;soil series)

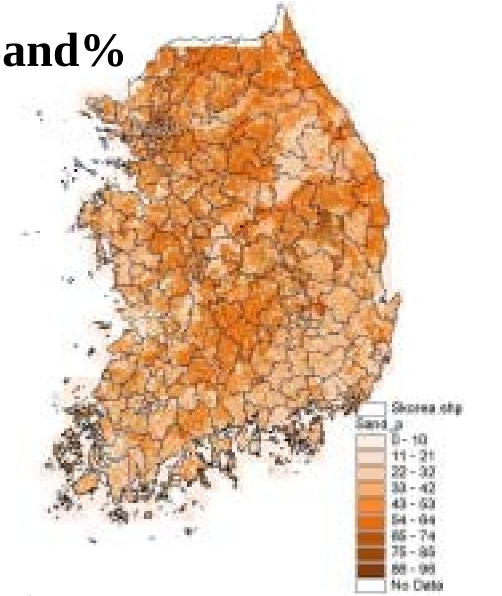
**Soil texture of top soil**



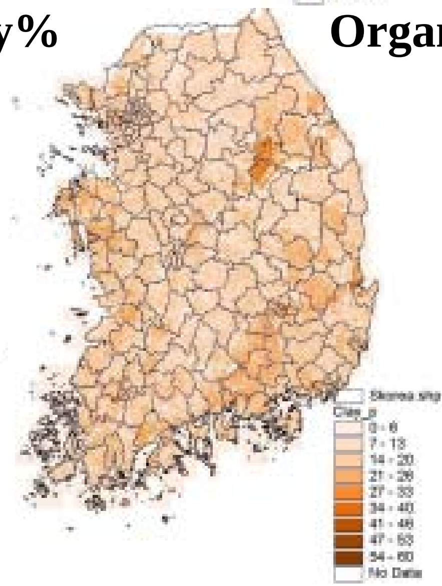

**Silt% of top soil**



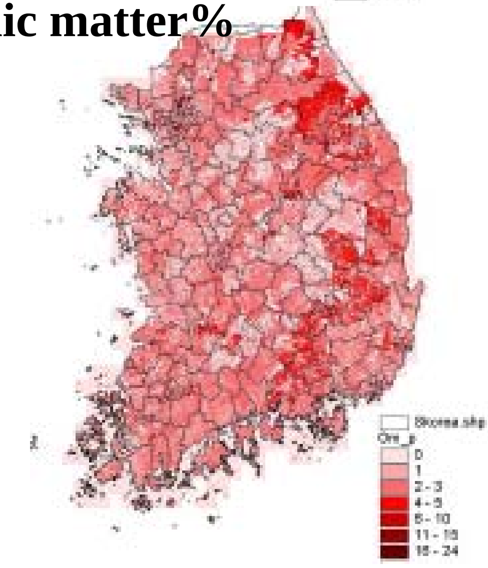

**Sand%**




**Clay%**




**Organic matter%**



# Slop length and steepness (LS factor)

the effect of topography on soil erosion in RUSLE, It has 2 components, the length factor (L) and the steepness factor (S)(Renard *et al.*, 1997)

- **L factor**: Where λ is the slop length (m), m is the slop length exponent and β is slop angle (%). Slop length is defined as the horizontal distance from the original of overland flow to the point where deposition begins or where runoff flows into a defined channel.

$$L = \left(\frac{\lambda}{22.13}\right)^m \qquad m = \frac{F}{(1+F)} \qquad F = \frac{\sin\beta / 0.0896}{3(\sin\beta)^{0.8} + 0.56}$$

*m = ((sin([slop] * 0.01745) / 0.0896) / (3 * pow( sin([slop] * 0.01745),0.8) + 0.56))*

- L factor with **upslope drainage contributing area** (Desmet & Govers, 1996)

$$L(i,j) = \frac{(A(i,j)+D^2)^{m+1} - A(i,j)^{m+1}}{x^m \cdot D^{m+2} \cdot (22.13)^m}$$

*L=(pow([Flowacc] + 10000,([m] + 1)) - pow([Flowacc],[m] + 1)) / (pow(100,[m] + 2) * pow(22.13,[m]))*

where $A(i,j)[m]$ is unit contributing area at the inlet of grid cell, $D$ is grid spacing and $x$ is shape correction factor

# Slop length and steepness (LS factor)

•**S factor**: Hill slop length λ is calculated as the grid area divided by the total length of streams in the same grid. Slop angle β is taken to be the mean angle of all sub-grids in the steepest direction. (McCool et al.(1987,1989))

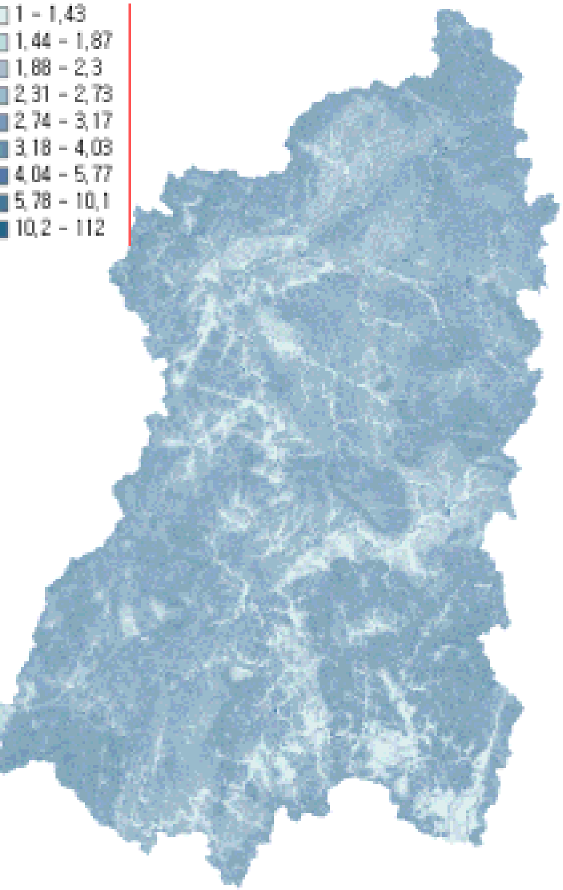
$$S(i,j)=\begin{cases}10.8\sin\beta(i,j)+0.03, & \tan\beta(i,j)<0.09\\ 16.8\sin\beta(i,j)-0.50, & \tan\beta(i,j)\geq 0.09\end{cases}$$

*S=con(tan([slop]  * 0.01745) < 0.09,(10.8 * sin([slop] * 0.01745) + 0.03),(16.8 * sin([slop] * 0.01745) - 0.5))*

# LS

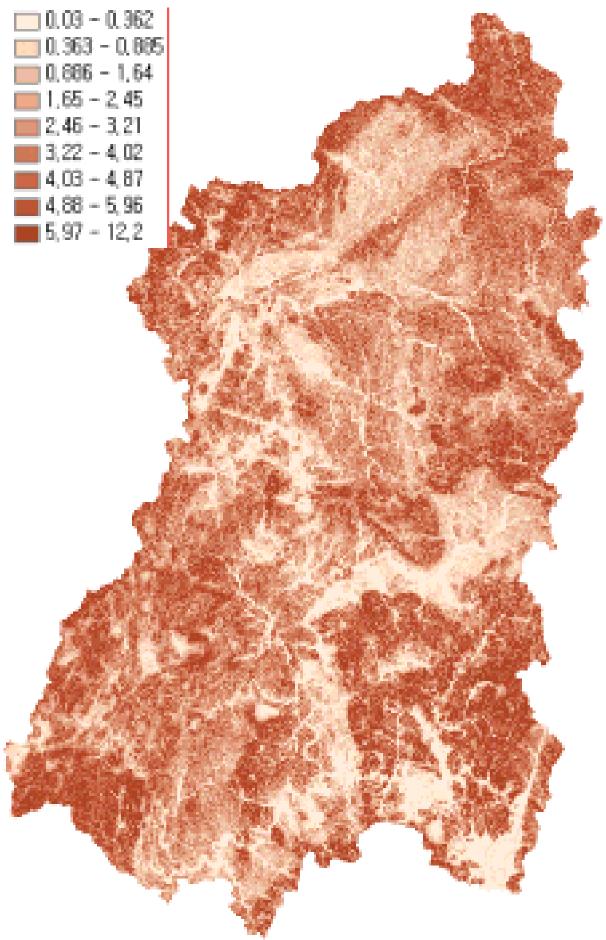
## L factor

**Desmet & Govers(1996)' equation**

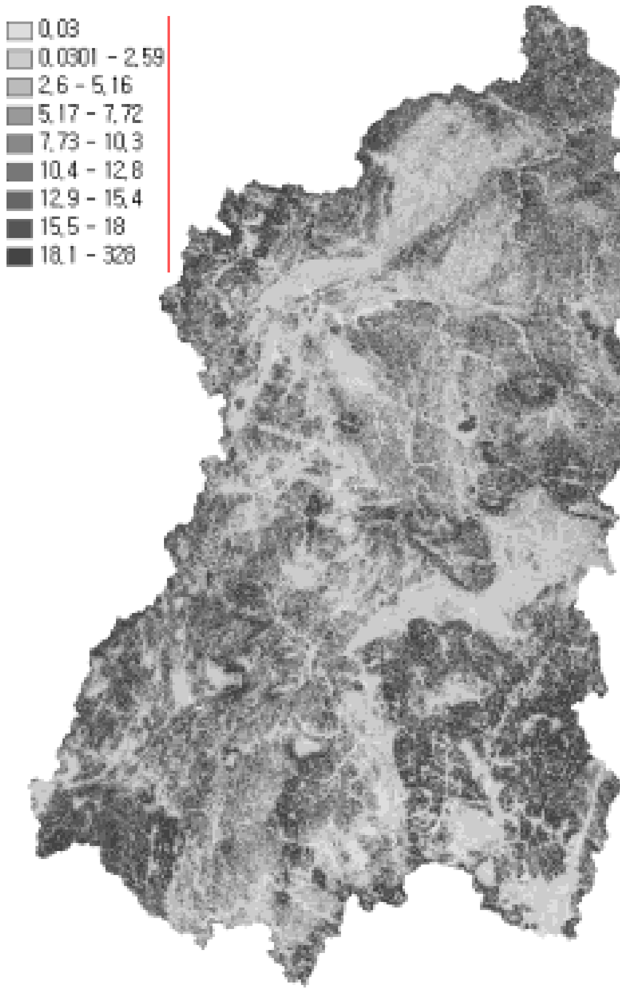



## S factor

**McCool et al.(1987,1989)' equation**




## LS factor



# Rainfall erosivity (R factor):

the R factor represents the **driving force of sheet and rill erosion by rainfall** and runoff and is computed originally from rainfall amount and intensity. Renard and Freimund(1994) has developed a regression equation between annual precipitation and the R factor has been drived based on 155 stations in the United States. And Hu *et al*.(2000) estimate the R factor with available precipitation data in Korea.

- **Renard and Freimund(1994)'s equation**

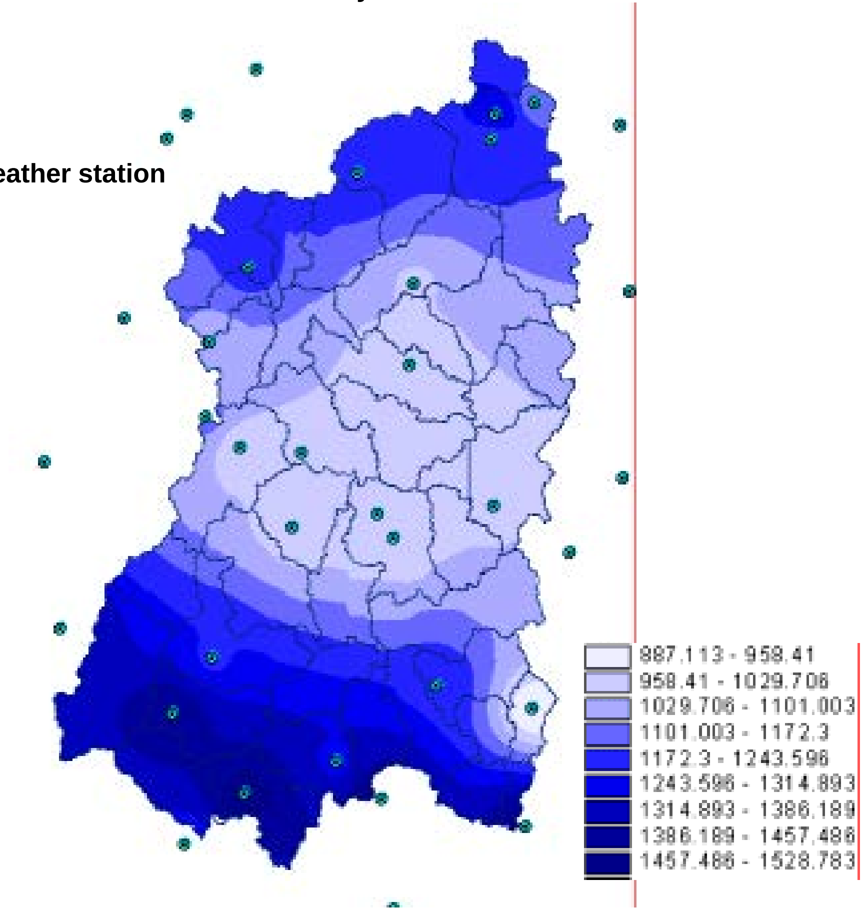
$$R = \begin{cases} 0.0483 P_a^{1.610}, & P_a \le 850mm \\ 587.8 - 1.249 P_a + 0.004105 P_a^2, & P_a > 850mm \end{cases}$$

where the R factor is in [MJ mm ha-1 h-1 year-1] and Pa is annual precipitation in [mm].

# R

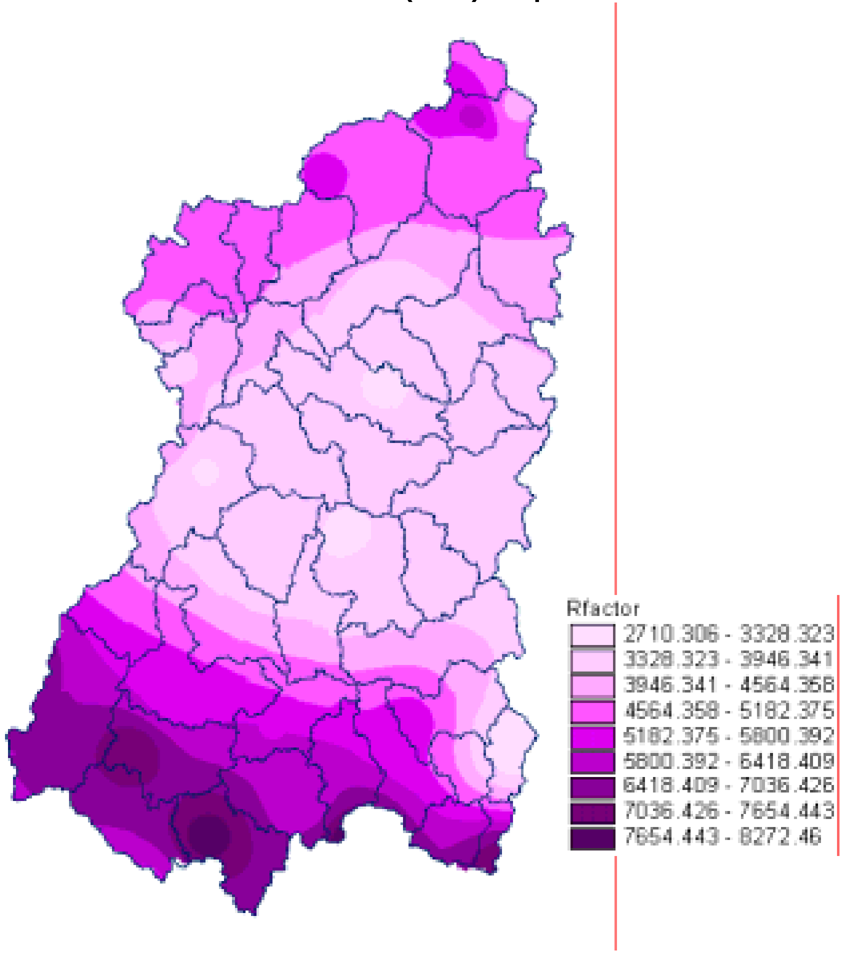
## Annual precipitation(mm/year)

-10 year mean-




## R factor(MJ mm/ ha h yr)

Renard and Freimund(1994)'s equation



# Soil erodibility (K factor)

Average long-term soil and soil profile response to the erosive power associated with rainfall and runoff. The RUSLE estimated the K factor using soil properties that are most closely correlated with soil erodibility and these soil properties are soil texture content of organic matter, soil structure and permeability. (Renard *et al.*, 1997)

- **Global erodibility** (Torri *et al.*, 1997) ($\gamma^2$=0.41, n=207)

$$K = 0.0293(0.65 - D_G + 0.24 D_G^2)\exp\left\{-0.0021\frac{OM}{f_{clay}} - 0.00037\left(\frac{OM}{f_{clay}}\right)^2 - 4.02 f_{clay} + 1.72 f_{clay}^2\right\}$$

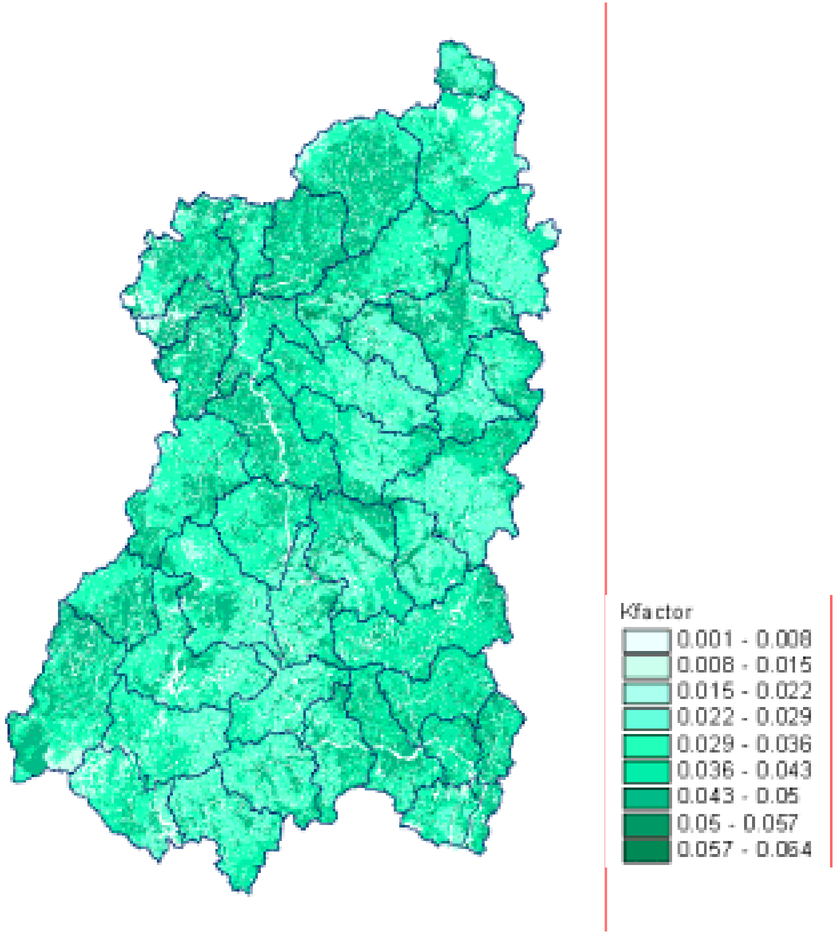
where the geometric mean of particle size, and K is in [ton ha h ha-1 MJ-1 mm-1], OM is percentage of organic matters, $f_{sand}$ is the fraction of sand( particle size of 0.05-2.0mm), $f_{silt}$ is the fraction of silt (particle size 0.002-0.05mm), $f_{clay}$ is the fraction of clay (particle size 0.00005-0.002mm).

$$D_G = -3.5 f_{clay} - 2.0 f_{silt} - 0.5 f_{sand}$$

# K

## K factor (ton ha h / ha MJ mm)

**Torri *et al*.(1997)' equation**



# Land use and conservation practice (C, P factor)

For representing the effect of land use and erosion conservation practice, RUSLE uses the C factor to express the effect of cropping and management and the P factor for support practices (Renard et al., 1997). The values of C and P factors are related to the land use identified by land cover types.

- **C factor** : average soil-loss ratio weighted by the distribution of rainfall during the year, The annual mean value of C factor is calculated from monthly precipitation-weighted value.
- **P factor** : the ratio of soil erosion with a specific support practice to the corresponding soil loss with straight-row upslope and down slop tillage.
- Both C, P factors are calculated based on the 100m resolution land use data and then averaged over each 1km grid.

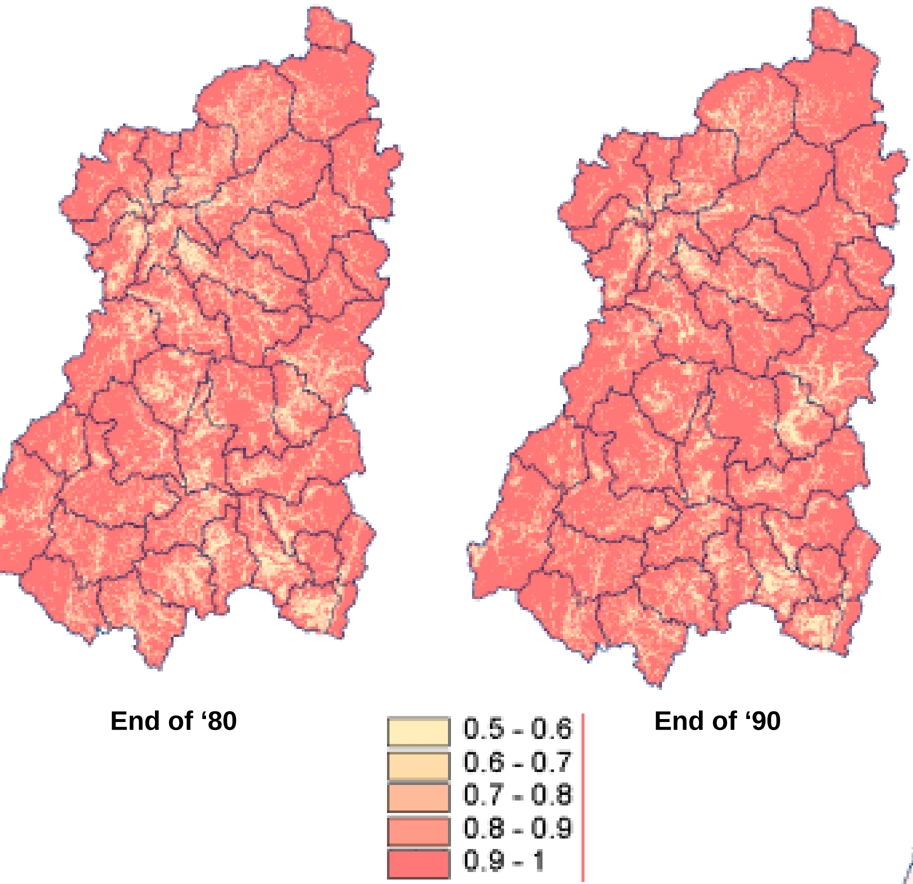
# Land use and conservation practice (C, P factor)

Table 1. Land cover classification and *C*, *P* factors

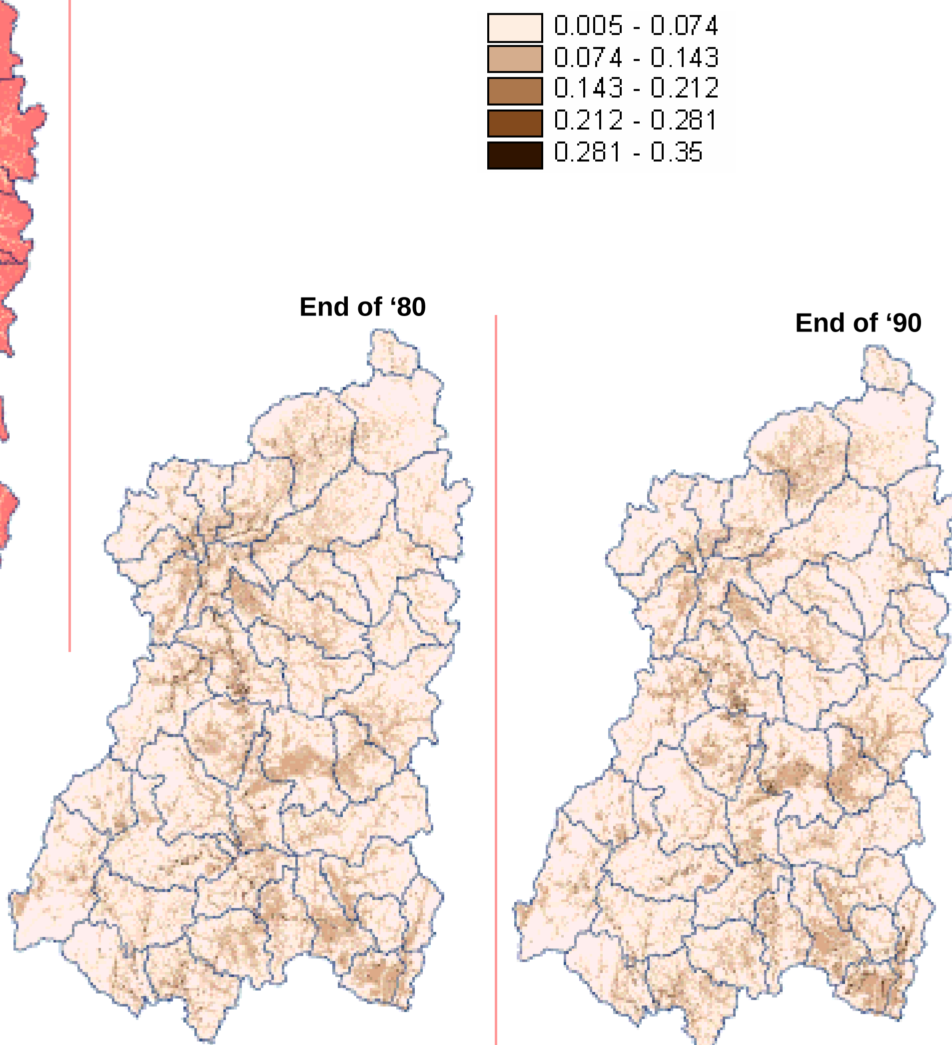
| Land cover types of RUSLE | *C* factor | *P* factor |
|---|---|---|
| Urban area | 0.1 | 1.0 |
| Bare land | 0.35 | 1.0 |
| Dense forest | 0.001 | 1.0 |
| Sparse forest | 0.01 | 1.0 |
| Mixed forest and cropland | 0.1 | 0.8 |
| Cropland | 0.5 | 0.5 |
| Paddy field | 0.1 | 0.5 |
| Dense grassland | 0.08 | 1.0 |
| Sparse grassland | 0.2 | 1.0 |
| Mixed grassland and cropland | 0.25 | 0.8 |
| Wetland | 0.05 | 1.0 |
| Water body | 0.01 | 1.0 |
| Permanent ice and snow | 0.001 | 1.0 |

# C,P

## P factor




## C factor



# Soil erosion potential

**Average annual potential soil erosion ( ton/ha)**