EVALUATION OF SPATIAL SOIL LOSS USING THE LAND USE INFORMATION OF QUICKBIRD SATELLITE IMAGERY

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ABSTRACT: This study is to estimate the spatial distribution of soil loss using the land use data produced from QuickBird satellite imagery. For a small agricultural watershed (1.16 km^2) located in the upstream of Gyeongan-cheon watershed, a precise agricultural land use map were prepared using QuickBird satellite image of April 5 of 2003. RUSLE (Revised Universal Soil Loss Equation) was adopted for soil loss estimation. The data (DEM, soil and land use) for the RUSLE were prepared for 5 m and 30 m spatial resolution. The results were compared with each other and the result of 30 m Landsat land use data.

KEY WORDS: Spatial Soil Loss, Land Use Information, QuickBird Satellite Imagery, RUSLE

1. INTRODUCTION

Soil loss is caused on the topsoil. Thus the reduction of soil productivity can be originated by the occurrence. It loses soil contained organic matter and nutrient eventually causing water pollution as they move into a stream.

Therefore, the prediction of soil loss from a watershed is important. RUSLE (Revised Universal Soil Loss Equation), improved from USLE (USDA, 1997), is the well known and generalized soil loss prediction tool of a watershed. It considers land cover-management and the practice. To calculate and predict soil loss accurately of a watershed, a precise land use that is classified as USGS (United States Geological Survey) Level IV (0.25 - 1.0 m spatial resolution) will become a critical spatial data for improving spatially distributed soil loss and the amount.

KOMPSAT (KOrea Multi-Purpose SATellite)-3 that will have spatial resolutions of 0.8 m panchromatic and 2.8 m multi-spectral images is scheduled to launch in 2008. KOMPSAT-3 image can produce USGS Level IV land use data. This data can be used to identify detail hydrological cycle, soil erosion process, sediment and pollutant transport mechanism (Kim et al., 2007).

This study is to estimate the spatial distribution of soil loss using the land use data produced from QuickBird satellite imagery which is resemble with the spatial resolution and spectral characteristics of KOMPSAT-3. and compare the result with the result of 30 m Landsat land use data. Figure 1 shows the flow chart of this study.

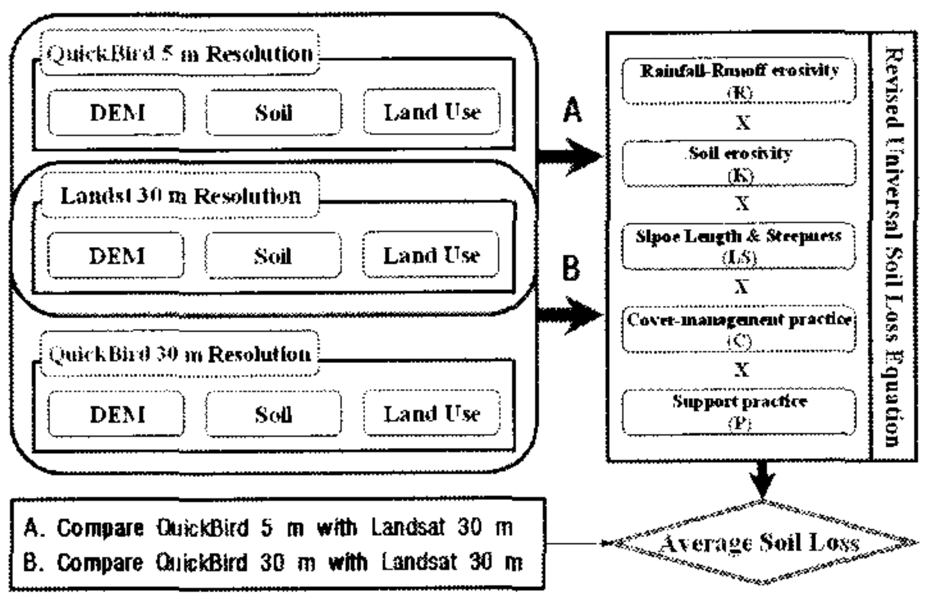


Figure 1. Flow chart of this study.

2. MATERIAL AND METHODS

2.1 The Study Watershed

A small agricultural watershed (1.16 km^2) located in the upstream of Gyeongan-cheon watershed which is located in Haegok-Dong, Yongin-Si, of Gyeonggi-Do Province in South Korea. (Figure 2). The Gyeongan-Cheon is the main tributary of Han river basin which is directly linked to the Paldang lake.

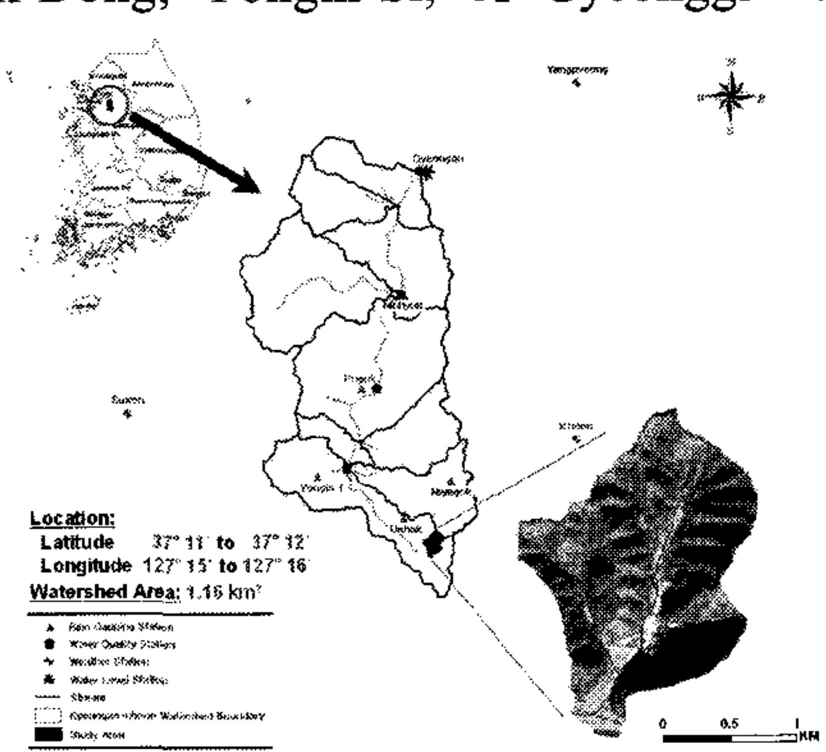


Figure 2. The Study Watershed

2.2 Land Use Data Preparation Using QuickBird Satellite Image

KOMPSAT-3 has similar spectral characteristics with QuickBird image. QuickBird-2 satellite data can get the image of the spatial resolution of 0.61 m at perpendicular, 0.73 m at angle of 30 degrees in the case of panchromatic, and 2.44 m at perpendicular, 2.9 m at angle of 30 degrees in the case of multispectrum.

In this study, 1st May 2006 QuickBird image was used. It lies between the coordinates of latitude N 37° 11' 5" to N 37° 12' 0" and longitude E 127° 15' 46" to E 127° 16' 36". The mean spatial resolution of two images is each by 0.635 m in panchromatic, and 2.538 m in multispectrum.

The image was ortho-rectified and geometrically corrected using 2 m DEM (Digital Elevation Model) from NGIS (National Geographic Information System) 1:5,000 digital map and 30 GCPs (Ground Control Points) acquired from SOKKIA GPS (Global Positioning System) equipment. The land use was produced by on-screen digitizing method with GPS field investigation data. The land use was classified with more than 23 categories.

2.3 The Revised Universal Soil Loss Equation

RUSLE (Revised Universal Soil Loss Equation) model was adopted to estimate soil loss of the watershed. The RUSLE can be expressed as Equation 1 (Renard et al., 1997). The RUSLE was integrated within a GIS framework to calculate soil loss spatially. In this module, algorithms and procedures were developed to derive the slope length factor (L) and steepness factor (S) from a DEM (Digital Elevation Model), then integrated with the R, K, C, and P factors to develop homogeneous patches within each field or river basin (FU et. al., 2005).

$$A = 2.24\,R \times K \times LS \times C \times P \qquad (1)$$

where A = estimated average soil loss (kg/m^2/year), R = rainfall-runoff erosivity factor(10^7J/ha·mm/ha), K = soil erodibility factor (kg/m^2/R), L = slope length factor (dimensionless), S = slope steepness factor (dimensionless), C = cover-management factor (dimensionless), P = support practice factor (dimensionless), Every data was calculated by GIS.

2.4 GIS Data Preparation

Two kinds of spatial resolution (5 m and 30 m) for elevation, land use and detailed soil map were prepared using 1:5,000, 1:25,000 scale of NGIS digital map respectively.

DEM (Digital Elevation Model) for the study area were prepared as input data. Two spatial resolution (5 m and 30 m) of DEM were produced through TIN (Triangular Irregular Network) and lattice transformation process using the 1:5,000 NGIS (National Geographic Information System) digital map. Figure 3a shows the 5 m resolution DEM.

Soil data were rasterized from a vector map that was supplied by the Korea Rural Development Administration (Figure 3b).

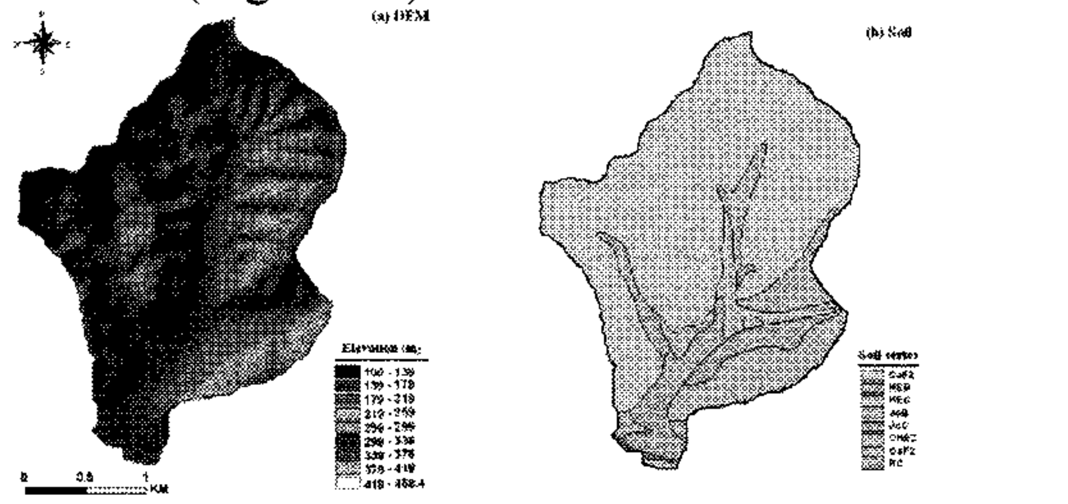
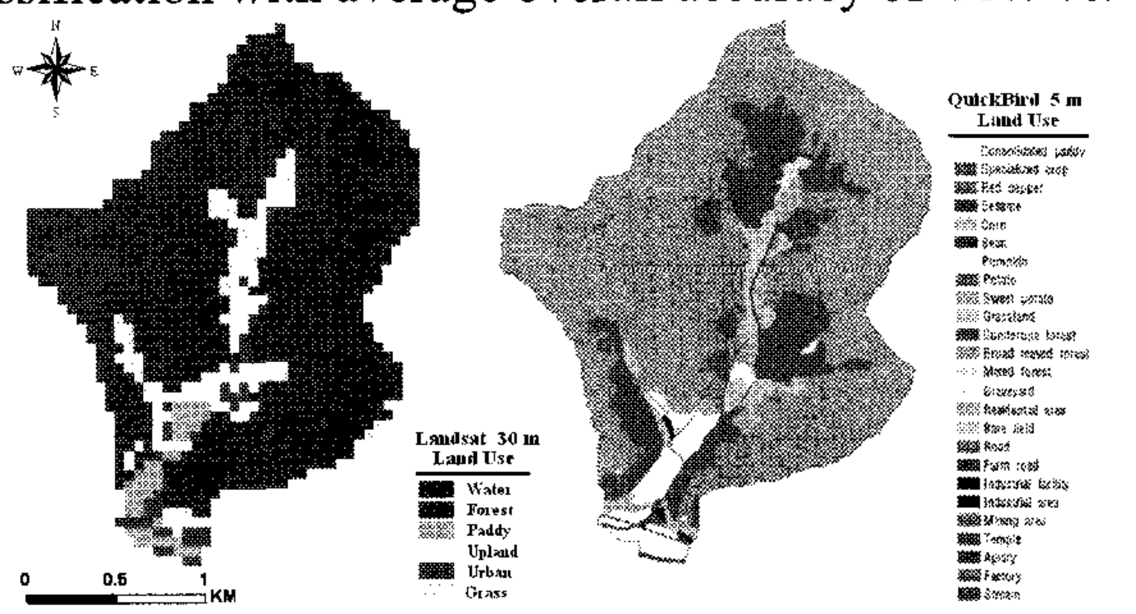


Figure 3. DEM (a) and Soil (b).

Land use from QuickBird image was produced by on-screen digitizing method with GPS field investigation data (Figure 4b). Land use data of 30 m resolution were generated from Landsat TM (Thematic Mapper) satellite imageries of 3 June 2004 (Figure 4a). Land cover analyses were achieved through a maximum likelihood classification with average overall accuracy of 95.7 %.



(a) Landsat Land use (b) QuickBird Land use

Figure 4. Land Use.

3. RESULTS AND DISCUSSION

3.1 RUSLE Spatial Soil Loss Using the QuickBird and Landsat Land Use Information

The R factor is the rainfall-runoff erosivity factor. It is the average annual summation (EI) values in a normal year's rain. The R factor according to 30-yr frequency and 24-hr duration is applied (Equation 2).

$$R = \frac{\sum EI_{30}}{100} \qquad (2)$$

where R is rainfall-runoff erosivity factor, E is total rainfall energy (kg·m/m^3·mm), I_{30} is maximum 30-minute rainfall intensity (mm/hr). However, it is difficult to apply Equation 2 where long term rainfall such as 30-yr frequency is hard to be calculated. Therefore, R value was calculated by Equation 3 (Toxopeus, 1998). P is the average annual rainfall (mm/year).

$$R = 3.85 + 0.35 \times P \qquad (3)$$

The K factor is soil erodibility factor which represents both susceptibility of soil to erosion and the rate of runoff, as measured under the standard unit plot condition. Table 1 shows the soil series and K factor for each soil series in the study area. Figure 5 shows the K factor calculated using a detailed soil map (1:25,000) and rasterized as 30 m and 5 m spatial resolution respectively.

Table 1. The K value for soil series

Soil series	Soil name	K Wischmeir
CaF2	CHEONGSAN	0.29
HEB	HOEGOG	0.23
HEC	HOEGOG	0.23
JoB	JIGOG	0.11
JoC	JIGOG	0.11
OnD2	OSAN	0.20
OnE2	OSAN	0.20
OsE2	OESAN	0.29
OsF2	OESAN	0.29
RC	RIVER INUNDATION ZONE	0.00
ScB	SACHON	0.26
SqD	SUAM	0.25

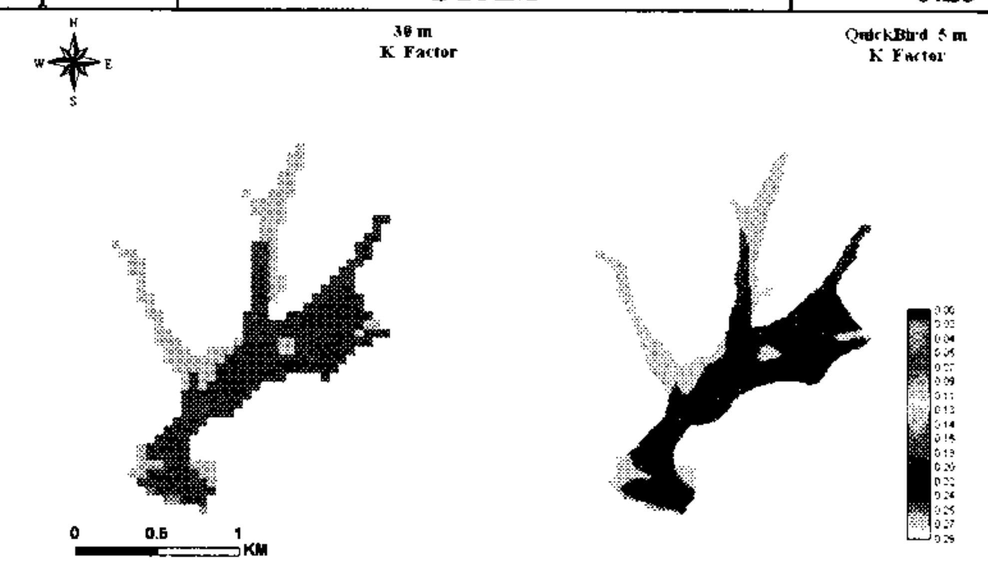


Figure 5. K Factor.

L is the slope length factor, representing the effect of slope length on erosion. S is the slope steepness which represents the effect of slope steepness on erosion. LS values were calculated for each resolution of DEM using Equation 4 (Wischmeier, 1974).

$$LS=\left(\frac{L}{22.13}\right)^{m}\left(\frac{65.4S^2}{S^2+10000}+\frac{4.6S^2}{\sqrt{S^2+10000}}+0.065\right) \quad (4)$$

where L is slope length (m), S is slope steepness (%), m is $S > 5$ % : 0.5, $3.5 < S < 4.5$ % : 0.4, $1 < S < 3$ % : 0.3, $S < 1$ % : 0.2. C is the cover-management factor. The C-factor is used to reflect the effect of cropping and management practices on erosion rates. It is the factor used most often to compare the relative impacts of management options on conservation plans. To calculate C value for each resolution, C value of Table 2 according to each land use type was adopted from Park (2003) (Figure 6).

Table 2. The C value for each Land Use type

Item	QuickBird		Landsat	
	Land use type	C	Land use type	C
1110	Consolidated paddy	0.300	Paddy	0.300
1210	Specialized crop	0.400	Upland	0.400
1211	Red pepper	0.320		
1212	Sesame	0.280		
1213	Corn	0.470		
1414	Bean	0.760		
1220	Pumpkin	0.400		
1221	Potato	0.750		
1222	Sweet potato	0.340		
2110	Grassland	0.050	Grass	0.050
2120	Nature grassland	0.050		
2210	Coniferous forest	0.009	Forest	0.009
2220	Broad leaved forest	0.004		
2230	Mixed forest	0.007		
2320	Graveyard	0.050	Grass	0.050
3140	Bare field	1.000	Bare	1.000
3150	Residential area	0.000	Urban	0.000
3210	Road	0.000		
3211	Farm road	0.000		
3310	Industrial facility	0.000		
3320	Industrial area	1.000		
3330	Mining area	0.000		
3441	Temple	0.000		
3550	Apiary	0.000		
3560	Factory	0.000		
4210	Stream	0.000	Water	0.000

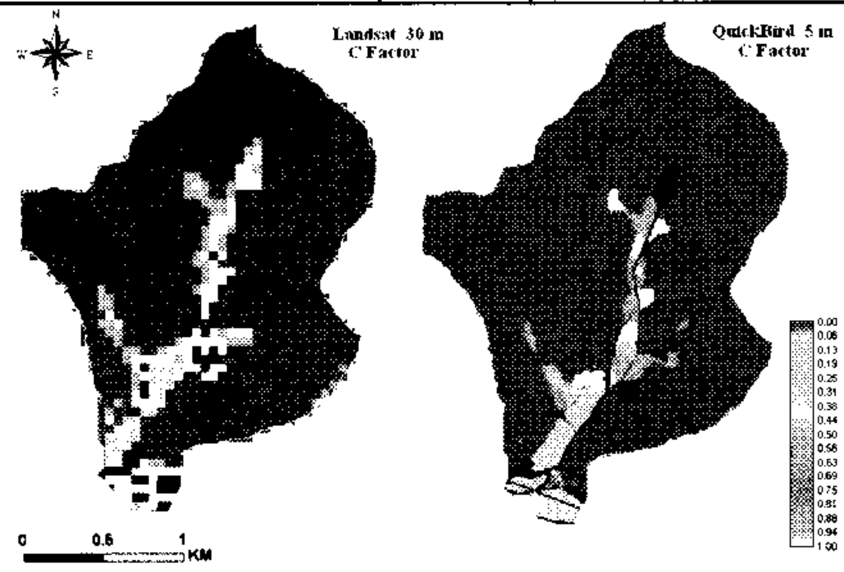


Figure 6. C Factor.

P is the support practice factor. The RUSLE P-factor reflects the impact of support practices the average annual erosion rate. It is the ratio of soil loss with contouring and/or strip-cropping to that with straight row farming up-and-down slope.

The P factor was decided according to land use type and slope. The land use types are contour, strip cropping and terrace. The P factor values were adopted from NIDP (National Institute for Disaster Prevention) (1998).

Table 3. P value

Slope (%)	Contour	Strip cropping	Terrace
1-3	0.6	0.30	0.12
3-9	0.5	0.25	0.10
9-13	0.6	0.30	0.12
13-17	0.7	0.35	0.14
17-21	0.8	0.40	0.16
21-25	0.9	0.45	0.18

The spatial result of soil loss calculated by RUSLE is shown in Figure 7. At a glance, it shows a big difference of spatial distribution of soil loss. It is caused by the different spatial resolution, different land use categories and different topographic characteristics. The average soil losses for 5 m QuickBird land use and 30 m Landsat land use were 2.93 kg/m^2/year and 12.34 kg/m^2/year respectively. The coarse and large areal distribution of land use type of high potential soil loss such as grass and upland in Landsat land use caused the increase of total soil loss in the watershed.

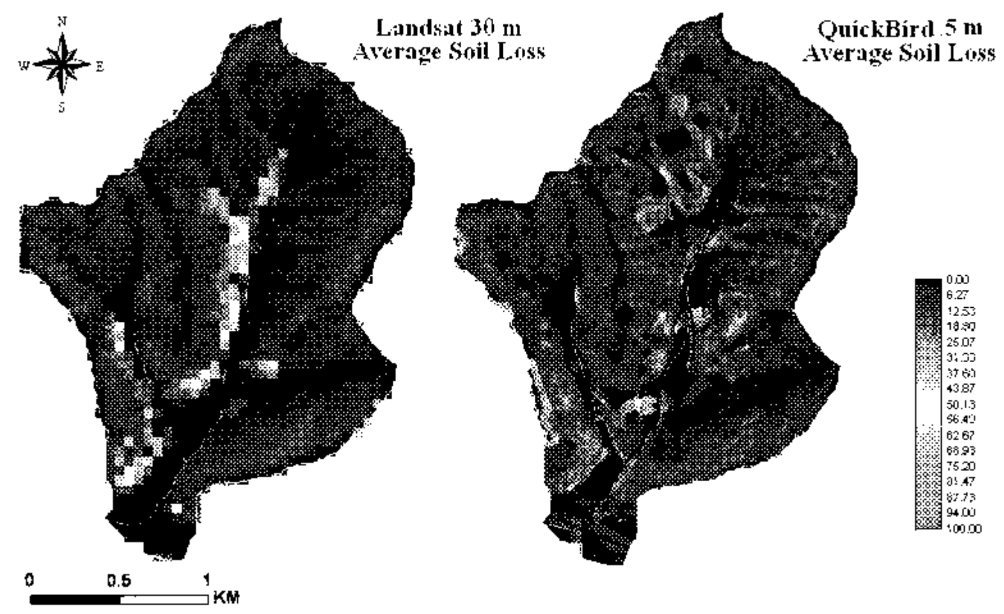


Figure 7. Average soil loss by each resolution.

3.2 Comparison of Average Soil Loss by the 30 m Resampled QuickBird Land Use and Landsat Land Use Condition

To compare the soil loss with the condition of same spatial resolution by QuickBird land use and Landsat land use, the 30 m QuickBird land use was prepared by resampling the 5 m QuickBird land use (Figure 8). Table

4 summarizes the result of land use area for 30 m resolution of QuickBird land use and Landsat land use.

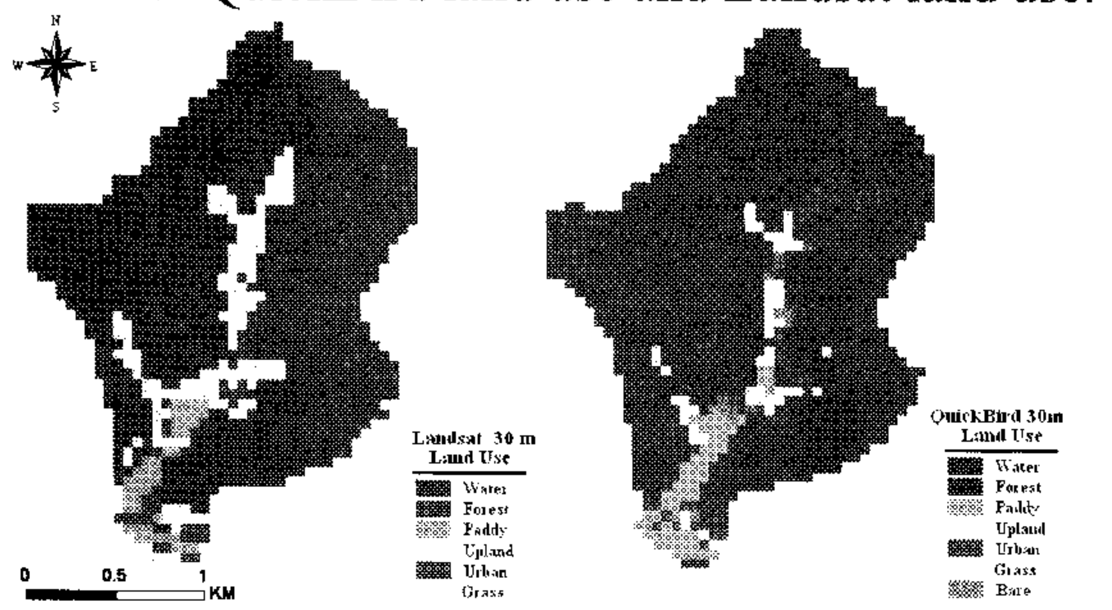


Figure 8. 30 m resolution of land use (a) Landsat, (b) QuickBird.

Table 4. The result of land use area for 30 m resolution of QuickBird land use and Landsat land use

Item	Land use (km^2)			
	Landsat		QuickBird	
	Area	Ratio (%)	Area	Ratio (%)
Water	0.00	0.0	0.01	0.7
Forest	1.00	83.2	1.05	87.0
Paddy	**0.04**	**3.2**	**0.05**	**4.4**
Upland	**0.07**	**6.0**	**0.02**	**1.3**
Urban	0.04	3.1	0.04	3.0
Grass	**0.05**	**4.5**	**0.03**	**2.5**
Bare	0.00	0.0	0.01	1.0

To calculate the soil loss for 30 m resolution of QuickBird land use, the RUSLE factors were re-calculated. Figure 9 shows the result of soil loss. The average soil loss for 30 m QuickBird land use was 7.75 kg/m^2/year. The increase of soil loss came from the reclassification of precise land use type of 5 m QuickBird land use and the increase of high potential soil loss area such as grass and upland in the process of resampling.

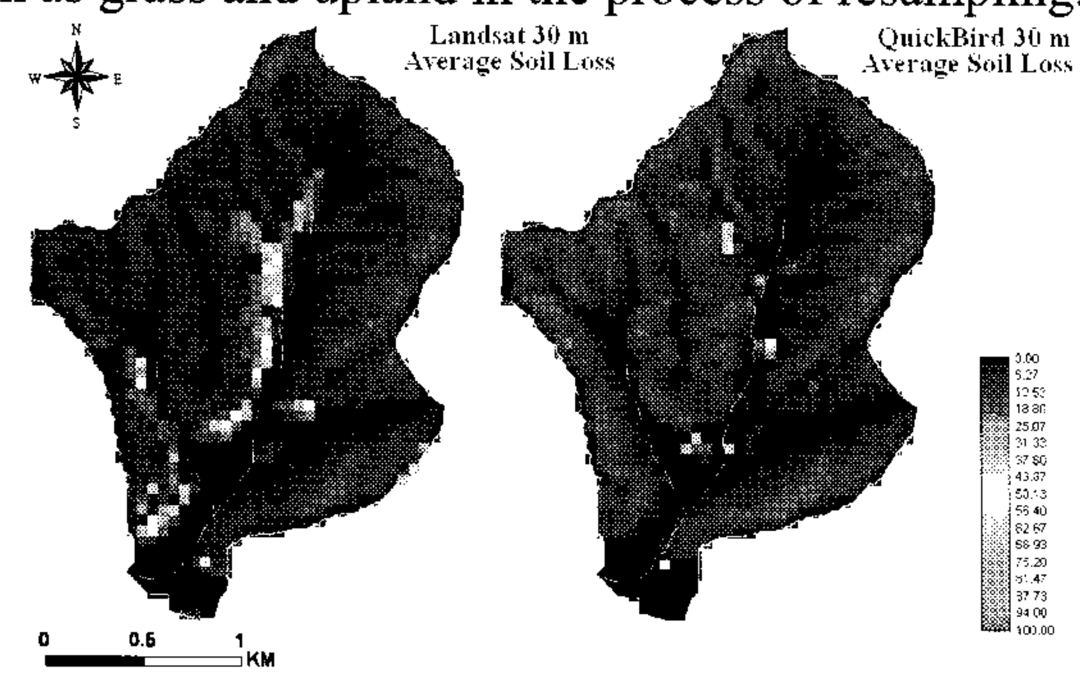


Figure 9. Average soil loss resolution by 30 m Landsat land and 30 m QuickBird land use

4. CONCLUSIONS

In this study, a comparison of spatial distribution of soil loss using the land use data acquired from QuickBird and Landsat satellite images was accomplished.

Two cases of spatial soil loss were estimated using RUSLE method. In comparing the result by using 5 m QuickBird land use and 30 m land use, a big difference of spatial distribution was detected by the different spatial resolution, different land use categories and different topographic characteristics. The coarse and large areal distribution of land use type of high potential soil loss such as grass and upland in Landsat land use caused the increase of total soil loss in the watershed. In comparing the result by using 30 m resampled QuickBird land use and 30 m Landsat land use, the total average soil loss by 30 m QuickBird land use increased comparing with 5 m QuickBird land use. It was caused by the reclassification of precise land use type of 5 m QuickBird land use and the increase of high potential soil loss area such as grass and upland in the process of resampling.

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4.2 Acknowledgements

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