APPLICATION OF QUICKBIRD SATELLITE IMAGE TO STORM RUNOFF MODELLING

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ABSTRACT: This study is to apply QuickBird satellite image for the simulation of storm runoff in a small rural watershed. For a 1.05 km^2 watershed located in Goesan-Gun of Chungbuk Province, the land use from the QuickBird image was produced by on-screening digitising after ortho-rectifying using 2 m DEM. For 3 cases of land use, soil and elevation scale (1:5,000, 1:25,000 and 1:50,000), SCS (Soil Conservation Service)-CN (Curve Number) and the watershed physical parameters were prepared for the storm runoff model, HEC-HMS (Hydrological Modelling System). The model was evaluated for each case and compared the simulated results with couple of selected storm events.

KEY WORDS: Storm Runoff, QuickBird Satellite Image, SCS Curve Number, HEC-GeoHMS, HEC-HMS

1. INTRODUCTION

Land use is essential information in hydrologic modelling. The information affects the hydrological components such as evapotranspiration, infiltration and soil water storage, the dynamics of surface runoff, subsurface flow and groundwater recharge. The effects of land use are directly linked to changes in streamflow such as runoff volumes, peak discharges, runoff velocities, flooding and baseflow.

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 (United States Geological Survey) Level IV (0.25 - 1.0 m spatial resolution) land use data. This data can be used to identify detail hydrological cycle, soil erosion process, sediment and pollutant transport mechanism.

KOMPSAT-3 has similar spectral characteristics with QuickBird image. This study is to apply land use data from QuickBird image for streamflow simulation using GIS-based storm runoff model, HEC-HMS developed by US Army Corps. Under 3 cases of map scale for land use, soil and elevation, the simulated results are compared and discussed.

2. MATERIAL AND METHODS

2.1 QuickBird Satellite 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, 17 November 2004 image was used for the study area. It lies between the coordinates of latitude N 36° 48' 51" to N 36° 52' 48" and longitude E 127° 40' 23" to E 127° 46' 59". 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 1:5,000 digtal map and 30 GCPs (Ground Control Points) acquired from Trimble GeoExplorer III.

2.2 SCS-CN Method for Runoff Calculation

SCS-CN method is widely used in direct runoff calculation in unobserved watershed by only the data in detail about soil characteristics and vegetal cover condition. SCS-CN method considers land use, vegetal cover treatment, hydrologic condition of soil, and antecedent moisture condition (AMC) that affect to direct runoff. Direct runoff is calculated by following equation (1).

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \quad (1)$$

where Q = direct runoff (mm), P = total rainfall for event (mm), I_a = initial abstract (interception, infiltration, depression etc.) (= $0.2 \cdot S$) (mm), S = potential maximum retention (mm). CN is determined by the hydrological soil cover complex, such as soil, land use and vegetal cover treatment of the watershed. S that indicates the runoff capability of watershed is then indirectly calculated using CN.

$$S = \frac{25{,}400}{CN} - 254 \quad (2)$$

2.3 HEC-HMS Storm Runoff Model

HEC-HMS was adopted to simulate streamflow using land use data from QuickBird image. The model calculates direct runoff based on SCS-CN method with soil, land use and elevation data. To prepare the model input, a pre-processing module of the model, HEC-GeoHMS developed by US Army Corps of Engineers and Environmental Systems Research Institute, Inc. (ESRI) in 2000 as the extension module of ArcView GIS, is used to determine hydrologic parameters through terrain processing, watershed hydrologic processing and creating GIS input data of the model.

3. RESULTS AND DISCUSSION

3.1 The Study Watershed

The watershed is located in Sosu-Myun, Goesan-Gun of Chungbuk Province in South Korea. The watershed area is 1.05 ㎢ (Figure 1).

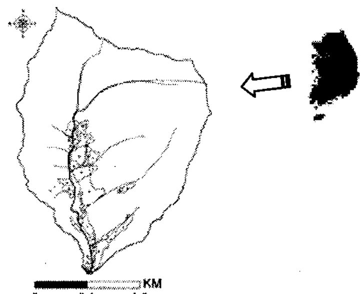


Figure 1. Study Watershed.

3.2 GIS Data

Three kinds of spatial resolution (2 m, 10 m and 20 m) for elevation, land use and hydrological soil group were prepared using 1:5,000, 1:25,000 and 1:50,000 scale of NGIS digital map respectively.

Elevation data were rasterized from a vector map that was supplied by the Korea National Geography Institute. Watershed elevation of 2 m resolution is seen in Figure 2. Elevation ranges from 175 m to 542 m. Land use from QuickBird image was produced by on-screen digitizing method with GPS field investigation data (Figure 3). The 10 m and 20 m land use data were obtained from Ministry of Environment and Ministry of Construct & Transportation respectively. Soil data were rasterized from a vector map that was supplied by the Korea Rural Development Administration. Hydrological Soil group was obtained among the attributes of the vector map (Figure 4). The soil group A, B, C, and D indicates high, moderately high, moderately low, and low infiltration rate for rainfall respectively.

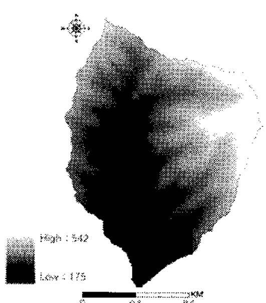


Figure 2. Elevation.

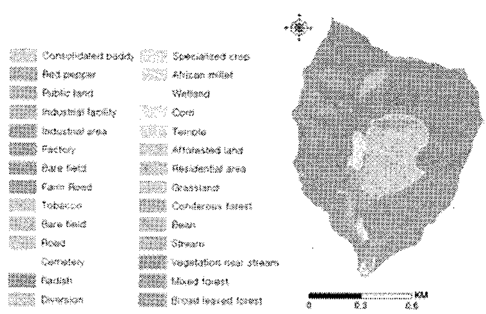


Figure 3. Land Use.

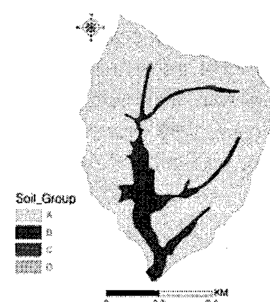
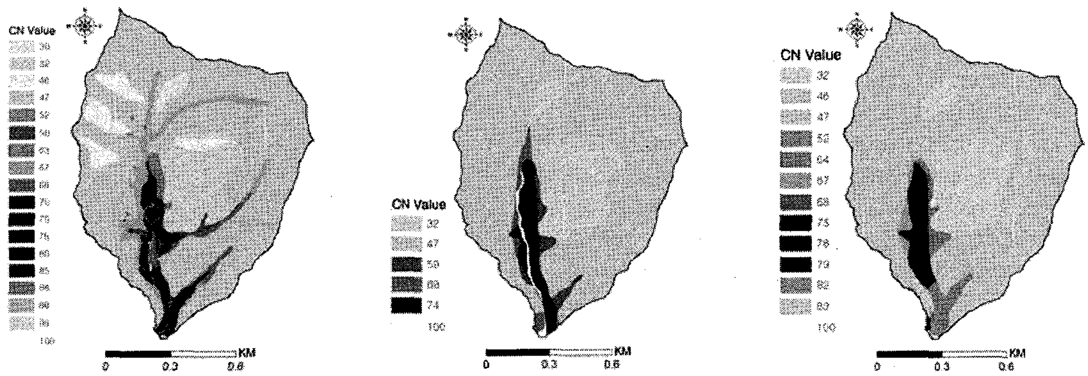


Figure 4. Hydrological Soil Group.

3.3 Distributed SCS-CN Using Land Use and Hydrological Soil Group Data

The CN data was prepared for model input. It is used to calculate direct runoff and the time of concentration parameter. Figure 5 shows the 2 m, 10 m, and 20 m resolution CN distribution data for the 1:5,000, 1:25,000 and 1:50,000 map scale respectively and Table 1 shows the summary of watershed characteristics and the average CN values under different AMC conditions. AMC I, II and III represent dry, medium, wet soil moisture condition before storm event respectively. The watershed average CN values of 1:5,000 scale increased 1.6 and 1.8 irrespective of AMC comparing with those of 1:25,000 and 1:50,000 scale. A grid element of 1:25,000 derived land use is 25 times more classified in 1:5,000 scale. This means that a grid element representing homogeneously pervious land use in 1:25,000 scale is subdivided into pervious and impervious land use in 1:5,000 scale including rural residence and small paved road. Thus, the newly revealed impervious land use in 1:5,000 scale influenced an increase in watershed average CN value comparing with the CN value of smaller map scale.



(a) (b) (c)

Figure 5. SCS-CN Distribution from (a) 1:5,000 Soil and QuickBird Land Use, (b) 1:25,000 Soil and Land Use, (c) 1:50,000 Soil and Land Use.

Table 1. Summary of Watershed Characteristics and Average CN for Three AMC Conditions

Map Scale	Hydrologic Soil Group (%)				Land Use (%)		CN			CN AMC II (%)	
	A	B	C	D	Pervious	Impervious	AMC I	AMC II	AMC III	> 60	< 60
1:5,000	86.2	13.6	0.2	0.0	99.2	0.8	29.6	48.6	68.6	14.2	85.8
1:25,000	92.3	7.7	0.0	0.0	99.1	0.9	28.0	47.0	67.0	7.8	92.2
1:50,000	93.9	5.6	0.5	0.0	99.9	0.1	27.8	46.8	66.8	19.6	80.4

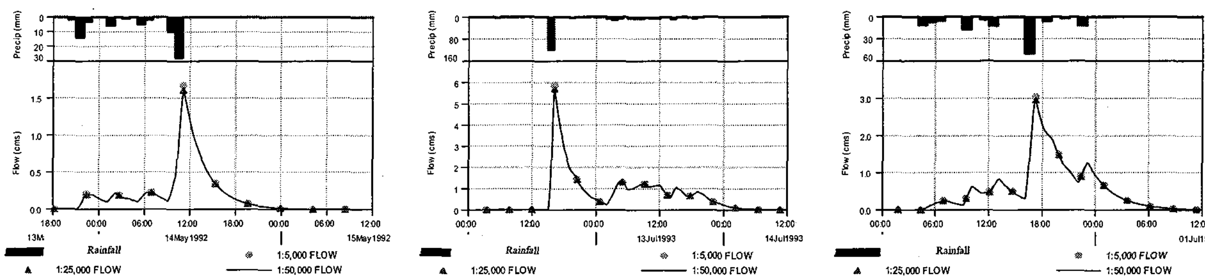
3.4 Storm Runoff Simulation Using HEC-HMS

Watershed input data for model run were created using the preprocessor HEC-GeoHMS. The watershed is divided into number of small sub-watersheds and created stream map through the terrain pre-processing such as flow direction, flow accumulation, stream definition, watershed delineation and stream segment processing based on DEM. As a next step, the watershed was finally divided into 4 sub-watersheds through basin processing such as parcel and merge the sub-watersheds extracted from terrain pre-processing. After then, hydrologic processing was carried out to extract stream factors such as stream length, stream elevation and slope of upstream and downstream, and watershed factors such as longest flow path and centroidal flow path. Figure 6 shows the comparison of simulated results for 3 cases of map scale and Table 2 summarizes the comparison results. For 3 storm events ranging from 71 mm to 209 mm rainfall, the 1.6 and 1.8 increased watershed CN of 1:5,000 scale comparing with those of 1:25,000 and 1:50,000 scale caused 4.29 % and 4.82 % increase of total runoff and 4.24 % and 4.94 % increase of peak flow respectively under AMC II.

Table 2. Summary of Simulated Results for 3 Cases of Map Scale

Storm Event	Rainfall (mm) (a)	Map Scale	Total Runoff (mm) (b)			Peak Flow (m^3/s)			Runoff Ratio (b / a)		
			CN I	CN II	CN III	CN I	CN II	CN III	CN I	CN II	CN III
13 May 1993	71	1:5,000	7.57	15.03	27.23	0.49	0.96	1.68	0.11	0.21	0.38
		1:25,000	7.06 (6.74)	14.28 (4.99)	26.00 (4.52)	0.46 (6.12)	0.92 (4.17)	1.61 (4.17)	0.10 (9.09)	0.20 (4.76)	0.37 (2.63)
		1:50,000	6.99 (7.66)	14.19 (5.59)	25.85 (5.07)	0.46 (6.12)	0.91 (5.21)	1.60 (4.76)	0.10 (9.09)	0.20 (4.76)	0.36 (5.26)
12 July 1993	209	1:5,000	53.72	91.46	134.30	1.98	3.65	5.91	0.25	0.44	0.64
		1:25,000	50.67 (5.68)	88.17 (3.60)	130.75 (2.64)	1.86 (6.06)	3.49 (4.38)	5.71 (3.38)	0.24 (4.00)	0.42 (4.55)	0.63 (1.56)
		1:50,000	50.29 (5.55)	87.76 (4.05)	130.30 (2.98)	1.84 (7.07)	3.47 (4.93)	5.68 (4.03)	0.24 (4.00)	0.42 (4.55)	0.62 (3.13)
30 June 1994	127	1:5,000	22.05	40.75	66.28	1.04	1.92	3.08	0.17	0.32	0.52
		1:25,000	20.67 (6.26)	39.00 (4.29)	63.96 (3.50)	0.98 (5.77)	1.84 (4.17)	2.98 (3.25)	0.16 (5.88)	0.31 (3.13)	0.50 (3.85)
		1:50,000	20.49 (7.08)	38.78 (4.83)	63.67 (3.94)	0.97 (6.73)	1.83 (4.69)	2.96 (3.90)	0.16 (5.88)	0.31 (3.13)	0.50 (3.85)

( ): Percent of decrease based on 1:5,000



(a) 13 May 1993 (b) 12 July 1993 (c) 30 June 1994

Figure 8. Comparison of Runoff under AMC II for 3 Cases of Map Scale.

4. CONCLUSIONS

A HEC-HMS storm runoff modelling was tried using land use data derived from QuickBird image. The precise land use caused an increase in watershed average CN value by classifying impervious land use such as rural residence and small paved road that were hidden in the land use of smaller map scale. The increased CN value subsequently increased peak flow and total runoff for a storm event. This study showed a potential use in hydrologic modelling using detail land use information less than 1.0 m spatial resolution.

4.1 References

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4.2 Acknowledgements

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