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GIS와 RS를 이용한 금강유역 토양침식과 하상변화 연구

이 진 영[1*], 김 주 용[1*], 양 동 윤[1], 남 욱 현[1], 김 진 관[1]
[1]한국지질자원연구원 지질환경재해연구부

Soil Erosion and river-bed change of the Keum river basin using by GIS and RS

Jin Young Lee[1], Ju Young Kim[1*], Dong Yoon Yang[1], Wook Hyun Nahm[1], Jin Kwan Kim[1]
[1]Korea Institute of Geoscience and Mineral Resources

요약: 자연환경과 인위적 환경변화에 의한 홍수재해는 하상변동과 밀접한 관계를 갖는다. 본 연구는 금강유역을 대상으로 지리정보시스템(GIS)과 원격탐사(RS)를 이용하여 유역에서의 토양침식과 하상변동의 관계를 규명하고자 하였다. 지리정보시스템에서 범용토양유실공식 (USLE)을 이용하여 토양침식율을 계산하였다. 공주에서 이포까지 하상지형을 측량하였고, 3차원의 하상변화도를 작성하였다. 1982년에서 2000년까지 Landsat TM 영상을 이용하여 금강유역의 하상변동을 추적하였다. 연구결과, 강경일대의 토양침식율은 1.8 kg/㎡/년이며, 하상증가율은 +5 cm/㎡/년으로 산정되었다. 따라서 금강하류의 하상변화는 일정한 비율로 토양침식에 의하여 영향을 받는 것으로 해석된다. 또한 하상변동은 주로 금강의 지류와 본류의 접합부 하류일대에서 발생하였다. 금강하류에서 하상변동은 하성 세골재 채취가 하나의 원인으로 해석될 수 있으며, 골재채취로 인하여 1991년도에서 1995년도 사이 금강하상 위에 노출된 하상면적의 감소를 초래했던 것으로 추정된다. 한편, 금강유역 하상을 따라 교량건설, 경작지 조성을 위한 사주개간, 제방과 같은 수중 구조물들 설치는 퇴적물 집적과 퇴적하상의 노출면적 증가를 초래하였던 것으로 추정된다.

주요어: 토양유실, 유실, 지리정보시스템(GIS), 범용토양유실공식(USLE), 하상변동

Abstract: Flooding hazard caused by natural and artificial environmental changes is closely associated with change in river bed configuration. This study is aimed at explaining a river-bed change related to soil erosion in the Keum river basin using GIS and RS. The USLE was used to compute soil erosion rate on the basis of GIS. River-bed profiles stretching from Kongju to Ippo were measured to construct a 3D-geomorphological map. The river-bed change was also detected by remote sensing images using Landsat TM during the period of 1982 to 2000 for the Keum river. The result shows that USLE indicates a mean soil erosion rate of 1.8 kg/㎡/year, and a net increase of a river-bed change at a rate of +5 cm/㎡/year in the Kangkyeong area. The change in river-bed is interpreted to have been caused by soil erosion in the downstream of the Keum river basin. In addition river-bed change mainly occurred on the downstream of the confluence where tributaries and the main channel meet. Other possible river-bed change is caused by a removal of fluvial sand aggregates, which might have resulted in a net decrease of exposed area of sediment distribution between 1991 and 1995, while a construction of underwater structures, including a bridge, a reclamation of sand bars for rice fields and dikes, resulted in an increase of the exposed area of river-bed due to sediment accumulation.

Key Words: Soil Loss, Erosion, Geographic information system (GIS), Universal soil loss equation (USLE), Riverbed change.

*Corresponding author: Ju-Yong Kim, Tel. 042-868-3056, E-mail. jykim@kigam.re.kr

INTRODUCTION

Geographic Information System (GIS) is widely used in understanding and prediction of natural processes which are required to manage amounts of data. Results of remote sensing (RS) provides useful information to Geographic Information System (GIS). RS and GIS can be useful tools to understand natural hazards such as flooding.

Flooding is a natural hazard which is closely associated with river−bed change. Change in river−bed configuration is caused by natural processes and artificial activities. Sediment influx from slope erosion results in the accumulation of sediments on the river floor which then reduces discharge of stream flow. Reclamation of sand bars for rice fields along river embankment, construction of dikes across the river, and removal of sand for constructional aggregates modifies the sediment distribution pattern and river−bed configuration.

In previous studies, satellite images were used to monitor change in the geomorphology in an estuary of the Keum River (An et al., 1989). RS and GIS were used to detect topography change in drainage area in the fluvial setting (Oh et al., 1993). Jang et al. (1995) used Landsat TM data to report change in sand bar distribution pattern in Keum River from Kongju to the estuary. Rhyong (1986) used remote sensing data to detect change in morphology of the Nakdong river delta. Most of these studies were carried out to detect topography or morphology change in the estuary or delta. Although some studies were conducted for the inland portion of the river, there has been no study to consider the effect of erosion of slopes to river−bed change. The purpose of this study is to present the trend of river−bed change in the Keum River based on the GIS and RS data, to measure the erosion rate of slope in drainage area, and to estimate the change rate of the river floor.

GEOGRAPHIC AND GEOLOGIC SETTING

Fig. 1. Location map showing the Keum River Basin.

The Keum River is located in the west and middle part of South Korea (Figure 1). The drainage area is 9,810.4 km^2 and its length is 395.9 km. The river is the third largest river in South Korea, following the Han and Nakdong River. The drainage area covers 11% of South Korea. The drainage area of the upper part of the river consists of relatively steep slope valleys in a mountainous region. Tributaries in the middle part of river drain steep slopes and alluvium. The lower part of the river is characterized by low relief drainage area and floodplains.

The geology of the drainage area of the Keum River consists of Precambrian gneiss, Jurassic granite, and Cretaceous sedimentary rocks. Quaternary alluvium is distributed in low relief areas along the main channel and tributaries.

METHODS

Satellite images used by remote sensing analysis including Landsat TM and MSS images were used to detect the river-bed change during the period of 1982 to 2000. A total number of 15 satellite images were processed with geometric correction using GCP with 0.2 RMS error, image enhancement using contrast control and image classification using maximum likelihood method in this period. Satellite images were identified with the naked eye, to check general trend. Color composite method of function memory insertion method (Jensen, 1996) was used to detect the short-term river-bed changes. Satellite images composed of red green blue (RGB) false color were used to reveal the river-bed change. PCA (principal component analysis) was then used to compress images over 25 years were then combined into a single image, so what variation during 25 years was represented in different color.

To compute a soil erosion rate, a modified USLE (Universal Soil Loss Equation) following Wischmeier and Smith's (1978) empirical formula was used. To analyze the mean soil erosion rate the Keum river drainage basin was divided into 11 sub-basins based on tributaries. Factors related to soil erosion are multiplied in USLE (USDA, 1975: Wischmeier, 1978). Each factor was quantified and the amount of soil loss from USLE used an unit (tons/acre/year) and converted unit (kg/m²/year).

The USLE is $A=R\times K\times L\times S\times C\times P$ where A: soil loss(tons/acre/year), R: rainfall erosivityfactor, K: soil erodibility, L:slop-length factor, S: slope-gradient factor, C: vegetative cover and management factor, P: practices used for erosion control (terraces, contouring) (Kim, 1994)

To compute volume change of sediment in the river-bed in Kangkyeong area, transverse topographic profiles of 1988 were compared with those of 1999. 35 profiles were measured from Kongju to Ippo with intervals of 6km. In the Kangkyeong area, transverse profiles of the river including embankment were obtained with 500 m intervals in 20 km by optic wave; echo sounding on river floor was also conducted with 100 m intervals.

RESULTS & DISCUSSION

RIVER-BED CHANGE

False composite images and PCA images (Figure 2) show the river-bed change from 1982 to 2000. River-bed change mainly occurs at the downstream part of the confluence where tributaries and the main channel meet. Results of image processing show that the exposed area of sediment distribution decreasing from 1991 to 1995 and then increased after 1995 (Table 1 and Figure 2). The river-bed change mainly occurred at a downstream part of the confluence where tributaries and main channel

Table 1. Results of image processing.

Acquisition Date	Sediments (%)	Water (%)
1984. 07. 30	31.85	68.15
1986. 04. 15	54.07	45.93
1987. 05. 20	49.65	50.35
1988. 08. 10	50.16	49.84
1991. 03. 05	60.53	39.47
1993. 03. 17	51.36	48.64
1995. 05. 03	45.31	54.69
1997. 06. 16	52.01	47.99
2000. 06. 08	52.66	47.34

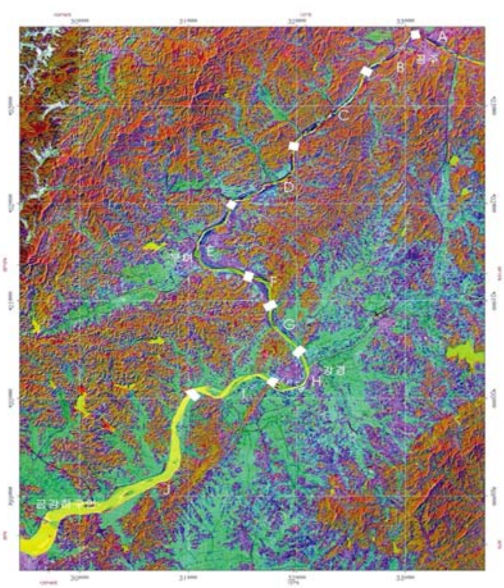

Fig. 2. Image of Principal component analysis (PCA) and segments of analysis area.

meet together. Removal of sands for manufacturing of constructional aggregates resulted in a decrease of the exposed area of sediment distribution between 1991 and 1995. After 1995, the amount of sand removed for the aggregates seems to have decreased.

RATES OF SOIL EROSION IN DRAINAGE BASIN

Rate of soil erosion in drainage area of tributaries are shown in Table 2. USLE indicates the mean soil erosion rate of 1.8 kg/㎡/year. The highest rate of soil erosion was found in the Jungan stream and the lowest rate in the Pukok stream. The distribution pattern of the soil erosion rate reflects the slope of the drainage area, which in turn, is related to the type of basement rocks. The drainage area in the Jungan stream mostly consists of gneiss, whereas that in the Pukok area consists of granite. Although both gneiss and granite are thought to be similar in weathering rate, steep slopes in the gneiss area resulted in a high erosion rate and low slopes in the granite resulted in low erosion rate. This suggests that slope is the most important factor in determining the erosion rate when we assume a similar precipitation condition.

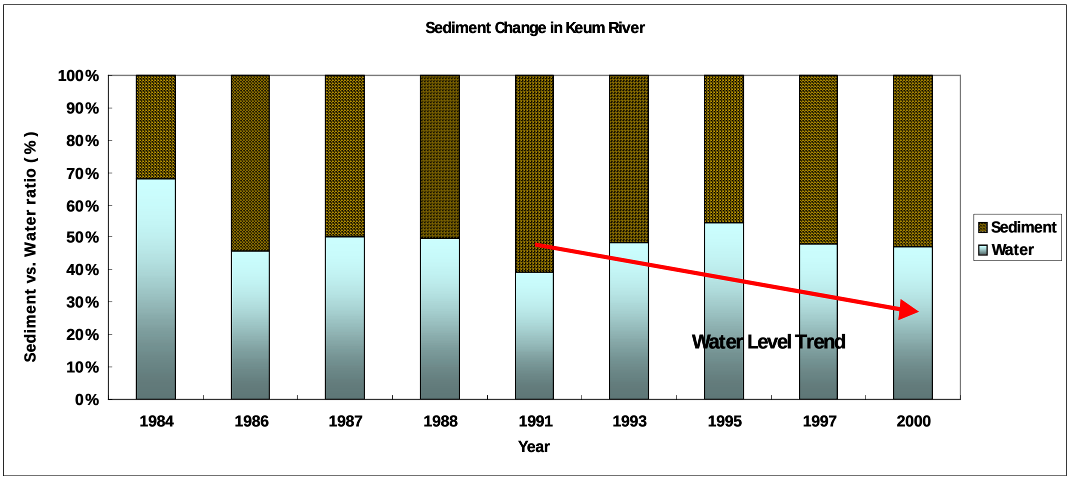

Fig. 3. Diagram shows the variations of exposed area of the sediment deposits (sand bar) and the water in Keum River. The results acquired from remotely sensed images during the period from 1984 to 2000.

Table 2. Rate and amount of soil erosion in drainage area of tributaries calculated with USLE after K value correction.

Watershed Area (Major stream)	Soil erosion rate			Watershed Area (ha)	Amount of Soil erosion (ton/year)
	Minimum (kg/㎡/year)	Maximum (kg/㎡/year)	Mean (kg/㎡/year)		
Jungan stream	0.004	64.65	2.62	15,497	405,946
Yuku stream	0.004	64.65	2.58	31,015	799,689
Ji stream	0.006	64.03	2.47	46,176	1,142,203
Dosung stream	0.006	60.30	2.55	14,790	376,478
Keum stream	0.008	54.03	1.71	17,466	299,270
Sadong stream	0.008	52.53	1.64	14,006	229,706
Uhmsung stream	0.004	58.68	2.29	13,365	306,477
Eastern Puyoe	0.009	57.20	1.98	9,768	193,523
Suksung stream	0.008	52.98	1.20	15,918	191,264
Nonsan stream	0.003	56.54	0.81	54,953	446,956
Pukok stream	0.005	61.74	0.43	10,417	44,812
Sum				243,370	4,436,324

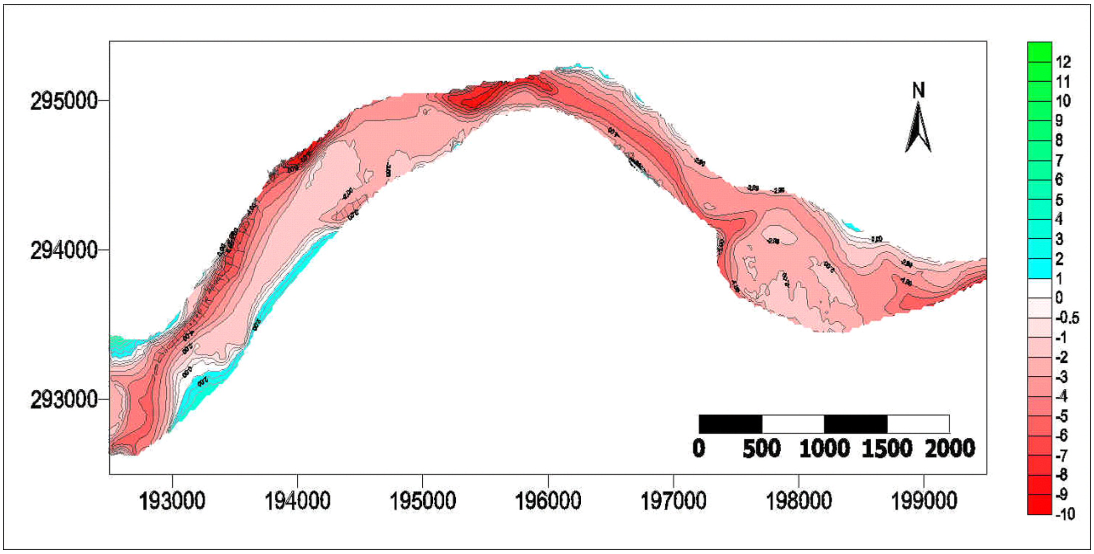

Fig. 4. Map showing topographic height with respect to sea level in Kangkyeong area measured in 1988; green and blue represent above sea level and red represents below sea level. Bar scale is in meters.

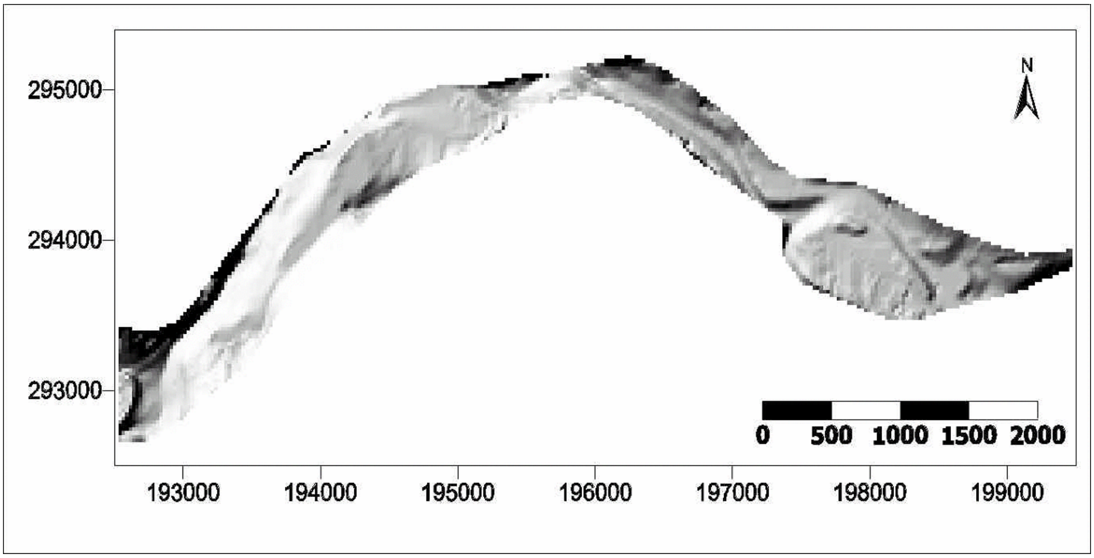

Fig. 5. Shadow relief map of riverbed in Kangkyeong area measured in 1988.

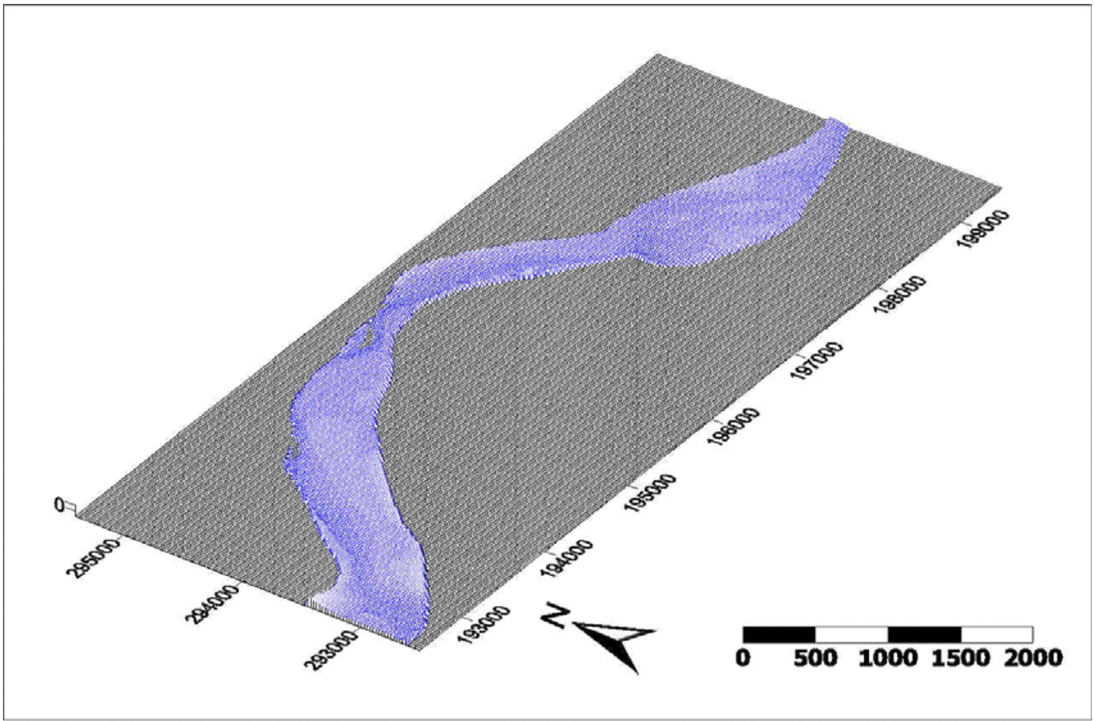

Fig. 6. 3-dimensional map of river floor in Kangkyeong area measured in 1988; blue represents deep and white represents shallow area.

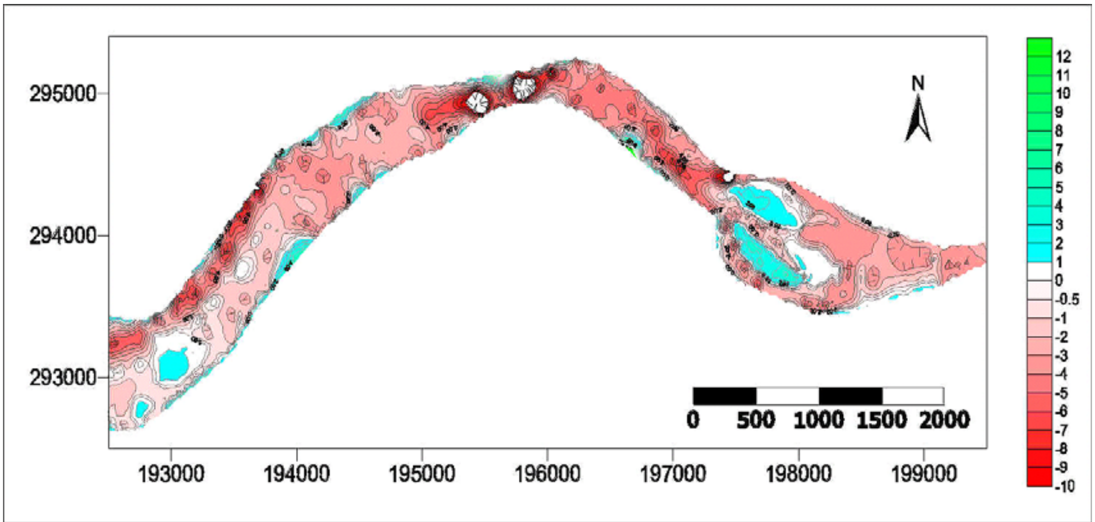

Fig. 7. Map showing topographic height with respect to sea level in Kangkyeong area measured in 1999; green and blue represent above sea level and red represents below sea level. Bar scale is in meters.

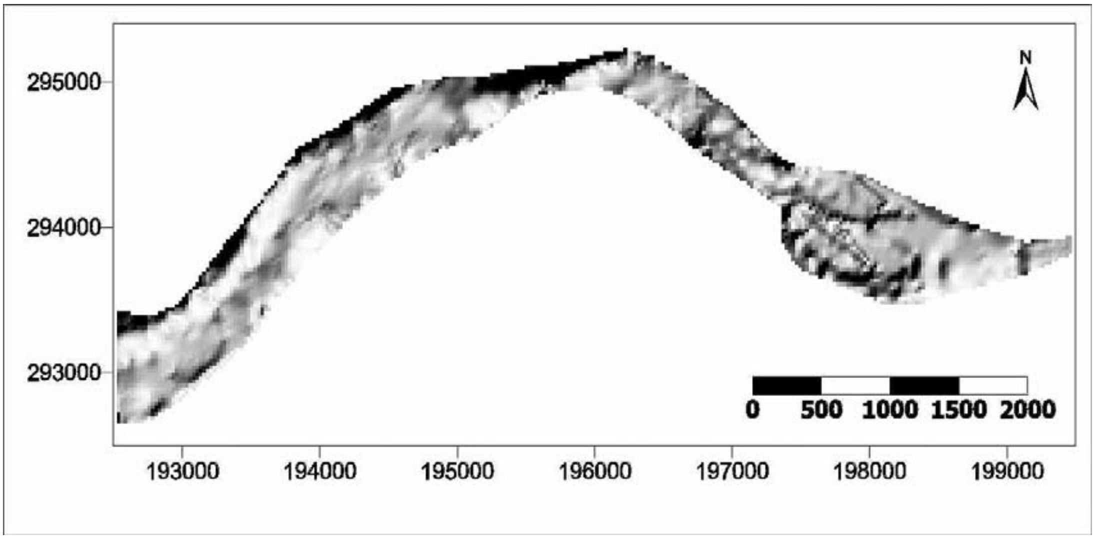

Fig. 8. Shadow relief map of river floor in Kangkyeong area measured in 1999.

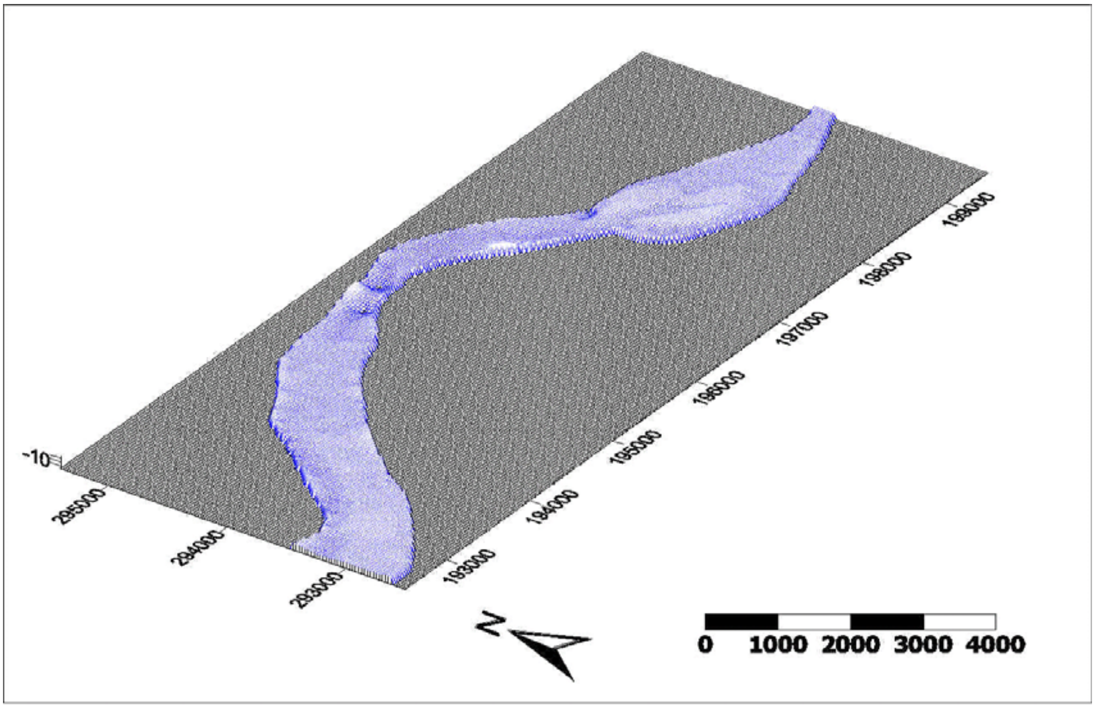

Fig. 9. 3-dimensional map of river floor in Kangkyeong area measured in 1999; blue represents deep and white represents shallow area.

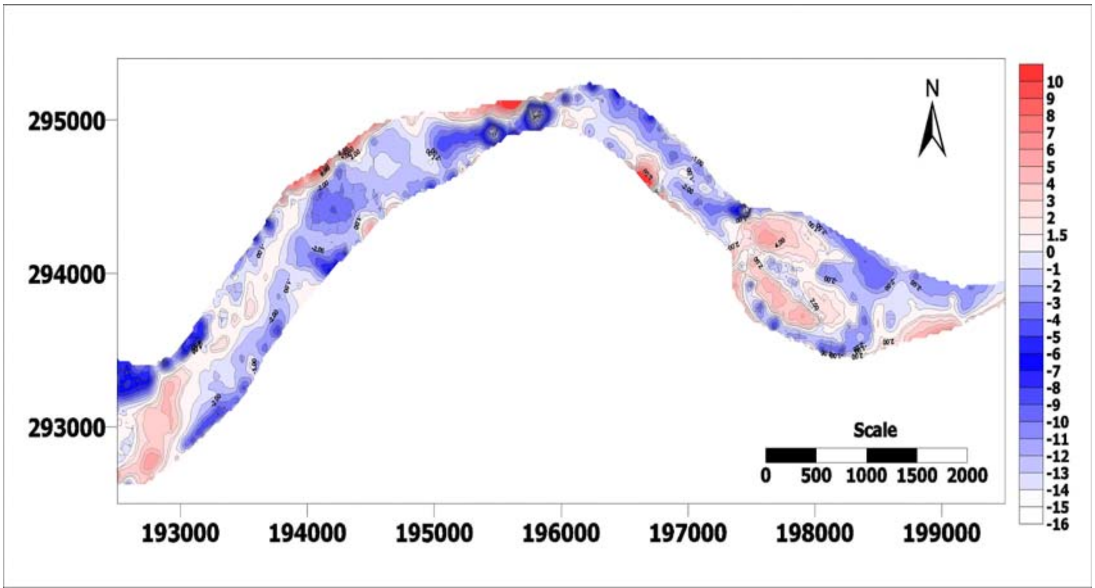

Fig. 10. Map showing the change in bottom topography between 1988 and 1999. Red represents increase in bottom topography and blue represents decrease in bottom topography.

SURVEY ON BOTTOM TOPOGRAPHY

Based on bottom topography measured in 1988 (Figures 4 to 6) and 1999 (Figures 7 to 9), the rate of net change in bottom topography was calculated. Comparison shows volume of sediments deposited during this period is 5.3 x 107 m^3 and volume of sediments eroded is 3.7 x 107m^3. The difference between deposition and erosion during 11 year period (Figure 10) is 1.6 x 107 m^3. This value corresponds to 5 cm/m^2/year. Figure 10 shows the result of river−bed change. Red color shows net deposition on the river floor and blue color shows net erosion during 11 year period.

CONCLUSION

1. RS analysis shows that substantial change in river−bed configuration occurs at the confluence where tributaries meet with a main channel after flooding.
2. USLE based on GIS allows determination of the erosion rate of soil in slopes of the drainage area of the Keum River, (1.8 kg/m^2/year).
3. Survey of bottom topography and comparison of profiles shows a rate of aggradation of the river bed to be 5cm/m^2/year.
4. A removal of sand for manufacturing of constructional aggregates might have resulted in a net decrease of the exposed area of sediment distribution between 1991 and 1995. On the other hand, a construction of underwater structures, including a bridge, reclamation of sand bars for rice fields, and dikes, may result in an increase of the exposed area of sediment distribution.

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이진영, 김주용, 양동윤, 남욱현, 김진관

305-350, 대전광역시 유성구 가정동 30 한국지질자원연구원 지질환경재해연구부 (Geological and environmental hazard division, Korea Institute of Geology and Mineral Resources, Deajeon, Korea, 30 Gajeong-dong, Yuseong-gu, Daejeon, 305-350, Korea)