Generation of an Impervious Surface Map by Applying a stepwise Extraction technique to the IKONOS Image

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ABSTRACT

The efforts for the urban restoration are changing toward sustainable development in case of land-use. Accurate partitioning of pervious and impervious surface in urban area is a necessary part, because it is deep associated with urban development. Therefore, for the generation of impervious surface map using high resolution satellite image which has various spectral characteristics, this study attempted new classification method by applying a stepwise extraction technique using spectral enhancement.

Three changed indexes such as Soil brightness index(SBI), green vegetation index(GVI), None-such wetness index(NWI) are constructed through the tasseled-cap transformation which a spectral enhancement methods. DN confidence intervals of each class are defined from these tree indexes. Suitable range of DN distribution was defined by changing control coefficient(α) of non-exceedance probability. As a result of defining DN range, error was indicated the smallest when α is 1. That means confidence intervals of class are involved to 68% non-exdance probability. Based on obtained DN value range from calculating confidence intervals, suitable DN values of each class are spread to the each layer.

Obtained 14 layers through above process are reclassified to 7 classes with grouping. And then Impervious map generated and impervious ratio calculated by block-size of area. Overall impervious ratio of study area was 50.38%.

Keywords: Impervious Surface Map, Tasseled-cap Transformation Model, Enhancement technique, IKONOS

1. Introduction

The extension of urban area by the past development thoughtless for the environment caused pollution. The efforts for the urban restoration are changing toward sustainable development in case of land-use. Numerous studies have been investigating to attempt urban regeneration by constructing institutional installation such a Total Maximum Daily Load(TMDL)s program. Land-use analysis in TMDL is very important factor, and it used to determine target water quality according pollutant loads of non-point source in case area. Previously, a study about how impervious surface impacts to runoff and sediment discharge by laboratory rainfall simulation(E.A. Pappas., el, 2007) had carried out, and in case of Korea, a study to analyze effects of imperviousness on river water quality had done.

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Present, accurate partitioning of pervious and impervious surface in urban area is a necessary part, because it is deep associated with urban development. The generation of impervious surface map using mid-resolution such a Landsat-TM could not provide correct information to calculate impervious ratio of area. Supplying advanced high resolution satellite image helps to calculate impervious ratio more correctly. Therefore, the information of accurate impervious ratio of each block in area should be provided using high resolution image by correct classification technique.

However, the conventional image classification methods have shortcoming in estimating impervious surface. The DN(Digital number) value of the each pixel in imagery is mixed result of spectral character of various objects which exist in surface. But conventional image classification methods force each pixel to be allocated only one class(Cho. & Jeong, 2005).

Therefore, for the generation of impervious surface map using high resolution satellite image which has various spectral characteristics, this study attempted new classification method by applying a stepwise extraction technique using spectral enhancement.

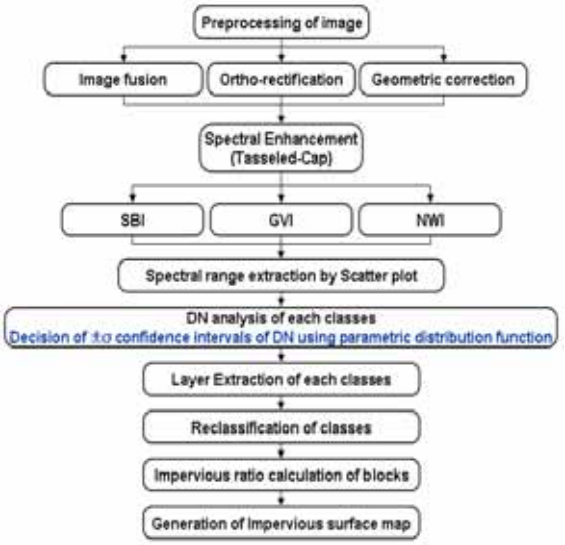

FIGURE 1. Progress of study

2. Progress of study

Study area located in Gwangju-si, Gyeonggi-do, Korea, is including various artificial features and nature fields.

Firstly, study area image of 1m multi-spectral image was obtained through the image fusion with 1m panchromatic and 4m multi-spectral image. Then, ortho-rectification was carried out by provided RPC(Rational Polynomial Coefficient) data from IKONOS and then, Geometric correction also carried out by using 1:5,000 digital reference data. Result of geometric correction, X axial and Y axial and overall root mean squared error(RMSe) were indicated 1.48119 and 1.7218 and 2.2717, respectively. Therefore, this preprocess result of image was permitted to use to this study. In this study, secondly, spectral enhancement method was used for the generation of impervious surface map. Three changed indexes such as Soil brightness index(SBI), green vegetation index(GVI), None-such wetness index(NWI) are constructed through the tasseled-cap transformation which a spectral enhancement methods. These are operated and converted by 4 bands of IKONOS on basis of 6 bands from the former Landsat-TM data(James H. Horne, 2003).

$$SBI = 0.326*B1+0.609*B2+0.660*B3+0.667*B4$$
$$GVI = -0.311*B1-0.356*B2-0.325*B3+0.819*B4$$
$$NWI = -0.612*B1-0.312*B2+0.722*B3-0.081*B4$$

In the above equations, B1, B2, B3, B4 refer to Blue, Green, Red, NIR band, respectively, from IKONOS image.

Transformed 3 indexes were created as a new image has peculiar DN value established three bands. Based on this new tasseled-cap transformed image, each class's DN values were extracted using region growing in scatter plot.

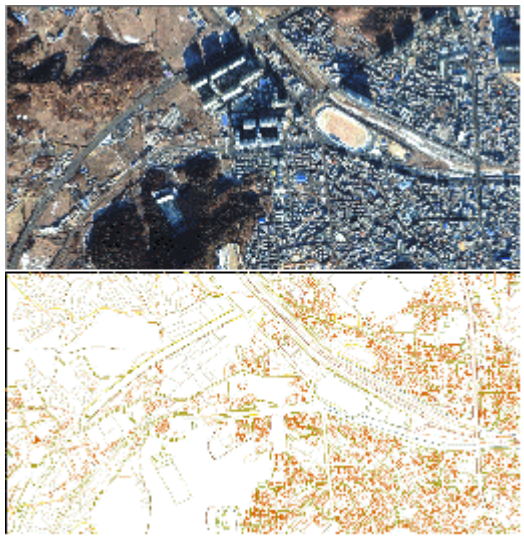

FIGURE 2. IKONOS image(above) and digital map(below) of study area, Gwangju-si in Gyeonggi-do, Korea

Then, confidence intervals of extracted DN values are selected through statistic analysis of each class. And then, including DN values in calculated confidence intervals are spread to the each layer. Classified layers through this process are combined to the one image, and obtained image was reclassified with 7 classes. Finally, an impervious surface map was generated by separated blocks in area.

Overall process of study is shown as fig 1.

3. Result of study

3.1 Comparison DN histogram and non-exceedance probability between original image and tasseled-cap indexes

The result of tasseled-cap transformed is as fig 3 and the result of comparing characteristics between original IKONOS image and Tasseled-cap transformed image is as fig 4. In case of original image, frequencies of each band in the histogram analysis are different, but DN values distribution characteristic of each band is overlaid with other bands. On the other hand,

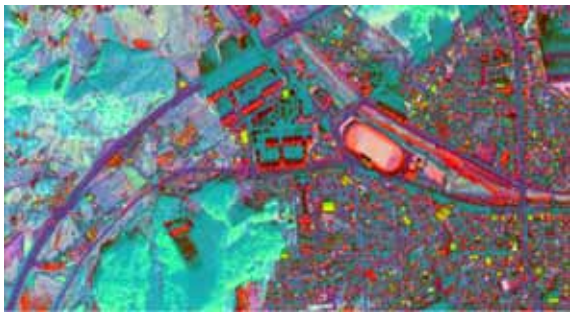

FIGURE 3. Tasseled-cap transformed image

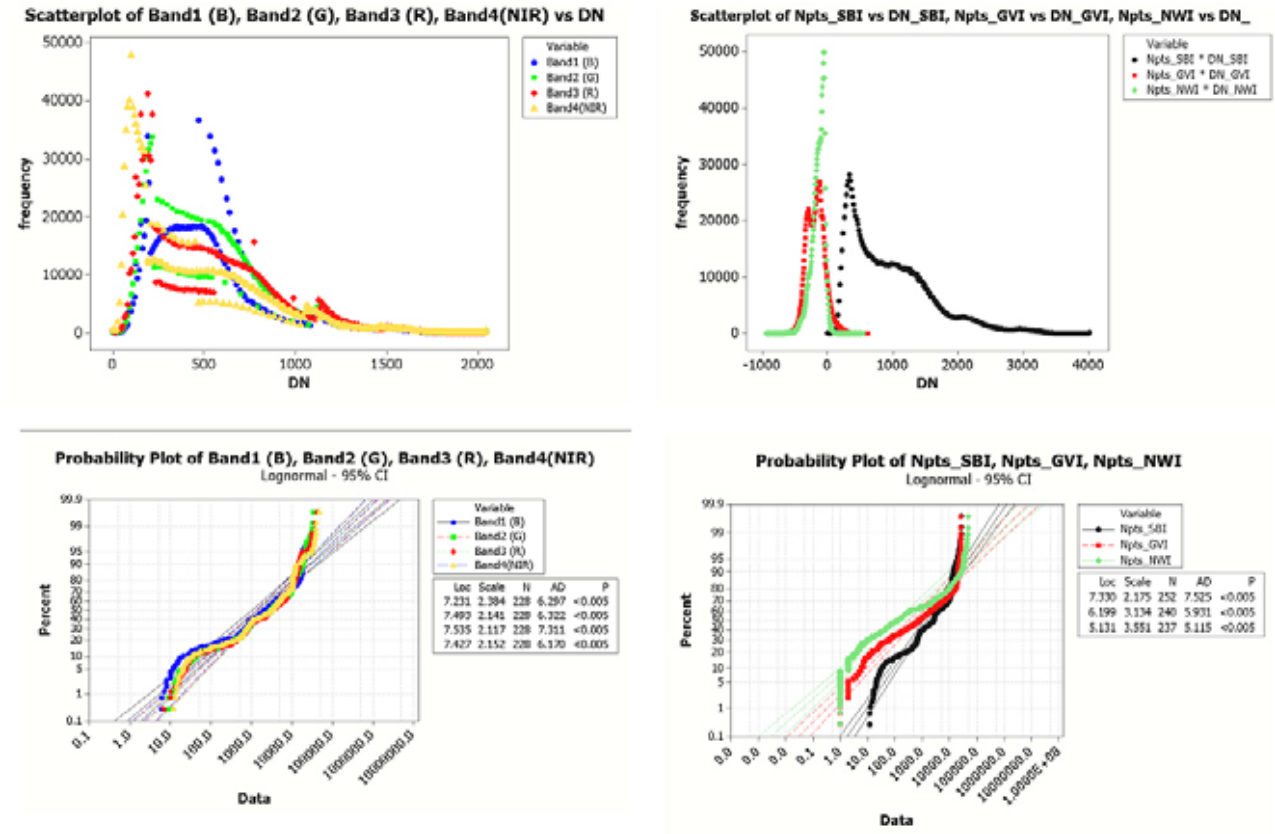

FIGURE 4. Comparison histograms(above) and probability plots(below) between original IKONOS image bands(left) and tasseled-cap transformed image(right)

enhanced pixels of SBI by tasseled-cap transformation have very different pattern from GVI and NWI in case of distribution. Also, characteristics of each index in tasseled-cap transformed image in case of probability plot obviously indicated.

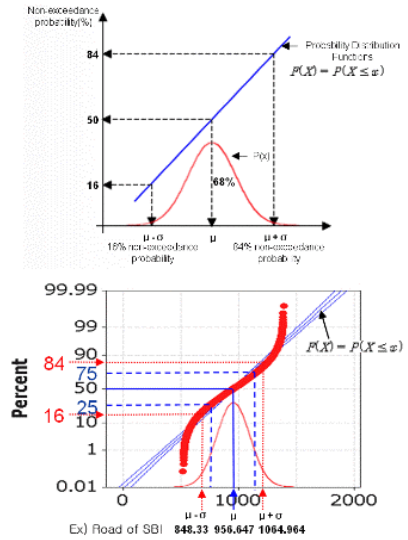

FIGURE 5. An example of non-exceedence probability calculation

3.2 Decision of each class's μ±σ confidence intervals

Suitable range of DN distribution is defined by changing control coefficient(α) of non-exceedance probability(Ha & Bae., 2007).

DN Ranges of each class are as follows table 1. As a result of defining DN range, error was indicated the smallest when α is 1. So, DN values of each class are extracted by defined ranges.

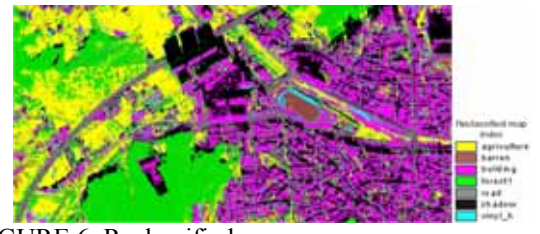

FIGURE 6. Reclassified map

FIGURE 7. impervious surface map of study area

TABLE 1. μ±σ confidence intervals of each class

		min	max	mean	stdv	(μ-0.5σ)	(μ+0.5σ)	(μ-σ)	(μ+σ)	(μ-1.5σ)	(μ+1.5σ)
road	SBI	757	1118	956.647	108.317	902.4885	1010.806	848.33	1064.964	794.1715	1119.123
	GVI	-477	625	-260.446	111.549	-316.221	-204.672	-371.995	-148.897	-427.77	-93.1225
	NWI	-184	-59	-132.607	25.576	-145.395	-119.819	-158.183	-107.031	-170.971	-94.243
building	SBI	1828	4015	2683.66	488.296	2439.512	2927.808	2195.364	3171.956	1951.216	3416.104
	GVI	-799	276	-222.561	126.334	-285.728	-159.394	-348.895	-96.227	-412.062	-33.06
	NWI	-851	119	-368.033	123.447	-429.757	-306.31	-491.48	-244.586	-553.204	-182.863
barren	SBI	1922	2252	2072.193	74.227	2035.08	2109.307	1997.966	2146.42	1960.853	2183.534
	GVI	-279	156	-68.055	48.013	-92.0615	-44.0485	-116.068	-20.042	-140.075	3.9645
	NWI	-137	4	-75.412	31.444	-91.134	-59.69	-106.856	-43.968	-122.578	-28.246
slab roof	SBI	590	1843	1363.593	241.492	1242.847	1484.339	1122.101	1605.085	1001.355	1725.831
	GVI	-676	583	55.991	183.243	-35.6305	147.6125	-127.252	239.234	-218.874	330.8555
	NWI	-935	-468	-580.596	76.915	-619.054	-542.139	-657.511	-503.681	-695.969	-465.224
agriculture	SBI	1104	1622	1364.724	122.847	1303.301	1426.148	1241.877	1487.571	1180.454	1548.995
	GVI	-445	569	-96.092	103.329	-147.757	-44.4275	-199.421	7.237	-251.086	58.9015
	NWI	-137	4	-65.639	28.346	-79.812	-51.466	-93.985	-37.293	-108.158	-23.12
vinyl house	SBI	2033	2614	2279.102	133.511	2212.347	2345.858	2145.591	2412.613	2078.836	2479.369
	GVI	2506	220	-271.567	49.115	-296.125	-247.01	-320.682	-222.452	-345.24	-197.895
	NWI	-341	-200	-284.665	29.649	-299.49	-269.841	-314.314	-255.016	-329.139	-240.192
forest	SBI	175	489	358.119	76.55	319.844	396.394	281.569	434.669	243.294	472.944
	GVI	-275	361	-116.763	73.738	-153.632	-79.894	-190.501	-43.025	-227.37	-6.156
	NWI	-215	-27	-109.445	50.193	-134.542	-84.3485	-159.638	-59.252	-184.735	-34.1555
shadow	SBI	120	497	302.805	70.988	267.311	338.299	231.817	373.793	196.323	409.287
	GVI	-235	-34	-135	32.803	-151.402	-118.599	-167.803	-102.197	-184.205	-85.7955
	NWI	-244	-32	-109.113	38.937	-128.582	-89.6445	-148.05	-70.176	-167.519	-50.7075

3.3 Generation of land-cover map and impervious surface map

Obtained 14 layers through above process were reclassified to 7 classes with grouping. Reclassified image is as follows fig 6, and area distribution of result is table 2. Especially, classified shadow was removed through visual classifying. Finally, Impervious map generated and impervious ratio calculated by block-size of area for the analyzing impervious surface distribution based on geometric information map of study area. Generated an impervious map is as fig 7.

4. Conclusion

This study attempted to generate an impervious surface map by applying a stepwise extraction technique through the tasseled-cap spectral enhancement methods to the IKONOS image.

Three Indexes such as SBI, GVI, NWI are constructed by tasseled-cap transformation, and these indexes indicated different DN distribution.

In part of determining confidence intervals of each class's DN, control coefficient was decided α=1. DN values of each class are extracted by defined ranges based on this control coefficient.

Obtained 14 layers through above process are reclassified to 7 classes with grouping. And then Impervious map was generated and impervious ratio was calculated by block-size of area. Overall impervious ratio of study area was 50.38%.

Reference

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TABLE 2. Area distribution of reclassified image

class	agricultural field	barren	building	forest	road	shadow	vinyl	total
area (m^2)	290,442	44,454	211,727	317,251	210,492	306,953	66,022	1,447,341