EVALUATION OF SPOT 4 HRV-IR IMAGE FOR LAND COVER AND LAND USE MAPPING

In-Chul Jung
Assistant Professor, Pusan National University, Korea

Introduction

Regional planning requires current and accurate surface information such as land cover and land use. Without accurate information, decision-makers can make incorrect decisions. A significant method for providing current, reliable surface information is remote sensing. Aerial photography has traditionally been used to collect this information. However, it is costly and difficult to obtain with sufficient frequency. Satellite remote sensing can provide a method for acquiring regular, recent information about urban areas which may be particularly useful for monitoring within and on the fringes of urban development (Harris and Ventura, 1995).

Using satellite data, land use maps can be frequently updated. But the accuracy of the map depends on the spatial and spectral resolution of the satellite. SPOT and Landsat are currently the only systems that routinely provide worldwide images in the visible and infrared spectral regions. SPOT image (20 meters and 10 meters) has better spatial resolution than Landsat TM (30 meters) does. But it does not cover the important reflected infrared region that is recorded by TM bands 5 and 7. But, in 24 march 1998, SPOT 4 was launched and the HRV instrument has been extended to provide an additional 20-meter resolution channel in the mid-infrared region and now

called HRV-IR (Table 1). SPOT 4 can now provide even richer and complementary information thanks to this new SWIR band. The purpose of this paper is to investigate the utility of integrating this new band for the classification of land cover and land use and to compare the result with that of Landsat TM image.

Table 1. Characteristics of the HRV-IR sensor on SPOT 4

Spectral bands (μ m)	0.50 ~ 0.59
	0.61 ~ 0.68
	0.79 ~ 0.89
	1.58 ~ 1.75
Pixel size	20 m × 20 m
Swath width (vertical viewing)	60 km × 60 km

Data Description

Pusan Metropolitan Area is covered spatially by two SPOT images. Two SPOT HRV-IR multispectral (XI) images of Pusan and Yangsan (Korea) acquired on 27 April and 2 May 1999 were required to provide complete scene. It can be safely assumed to be free of significant temporal change in land cover. Landsat TM data was acquired on 7 July 1999, but no major changes in land cover were observed. They were geometrically corrected and geocoded to the Transverse Mercator co-ordinate system. They were then spatially resampled using a nearest neighbor algorithm with a root-mean-square error of less than 1 pixel. We chose histogram matching technique to mosaic SPOT imagery. In this investigation, a study site of 1,286 by 1,437 pixels covering Pusan Metropolitan Area was extracted from the mosaicked image. Same area was extracted from Landsat TM imagery. The study area was identical and it is composed of 858 by 958 pixels.

Classification

The classification scheme selected for the analysis was designed to display all the major land cover encountered in the area. The CORINE (Coordination of Information on the Environment) land use and land cover classification system level 3 was used with the following sixteen classes: continuous urban fabric, discontinuous urban fabric, industrial or commercial units and transport, road and rail networks, port areas, airports, sport and leisure facilities, permanently irrigated land, rice fields, forests, beaches or dunes and sands, salt marches, intertidal flats, water bodies, sea and ocean, and green house (Table 2). Green house is not included in the CORINE category. But green houses mainly cover some parts of the agricultural area of Pusan. So the author included green house into the classes. For forest, we have not discerned it by broad-leaved forest, coniferous forest and mixed forest owing to the difficulty of accuracy assessment. Field visits for discerning forest types was not possible due to "Keep out of the mountain".

Three sets of images (SPOT bands 1-3, SPOT bands 1-4, and Landsat TM bands 1~5 and 7) were classified using a supervised technique, based on maximum likelihood decision rules. For this, training data were acquired by identifying, for each class, blocks of representative pixels from the imagery.

Table 2. Land-Cover Types Used in the Classification

1. Continuous Urban Fabric	9. Rice Fields
2. Discontinuous Urban Fabric	10. Forests
3. Industrial or Commercial units and Transport	11. Beaches or Dunes and Sands
4. Road and Rail Networks	12. Salt Marches
5. Port Areas	13. Intertidal Flats
6. Airports	14. Water Bodies
7. Sport and Leisure Facilities	15. Sea and Ocean
8. Permanently Irrigated Land	16. Green House

Post Classification

The accuracy was compared overall and by category between 3 bands only (XI 1~3) and 3 bands plus new band (XI 1~4). The reference pixels were selected according to a stratified random sampling scheme. In principles, reference pixels are selected from the reference areas for each class with the number approximately proportional to the class's size. But the number of samples should be adjusted based on the relative importance of that category within the objective of the project or by the inherent variability within each class. And the minimum number of samples should be increased to 75 or 100 samples per class if the map has more than 12 classes (Jensen, 1996). Considering these, for the accuracy assessment, about 1203 pixels were selected. Reference points were then visited in the field or evaluated using 1/ 5000 topographic map.

For study area, forest, sea and ocean have large areas. But they show little variability. Discontinuous urban fabric has small area, but it is more variable. Sport and leisure facilities have small area and are less variable. So by stratified random sampling, approximately 75 individual reference pixels were selected for each of the 16 land-use classes.

Results and Discussion

Results for both SPOT HRV-IR data and Landsat TM data are listed in Table 3, 4 and 5. With the inclusion of SWIR band, overall accuracy was ameliorated by about 3 percents. Improvements in classification accuracy have been observed for classes 5 (port areas), 7 (sport and leisure facilities), 8 (permanently irrigated land), and 13 (intertidal flats). Only slight accuracy improvements happened to 4 (road, rail networks) and 9 (rice fields). But accuracy was worsened for class 16 (green house). This deterioration is due to the spectral similarity between classes 11(beaches or dunes and sands) and 16. The mean values of classes 11 and 16 in SWIR band are 225 and 223 respectively.

Table 3. Confusion Matrix for Land-Cover Classification Using SPOT Data (band 1-3)

	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Producer's accuracy	User 's accuracy
1	122	61	11	31	5	6	0	0	0	7	0	0	0	1	0	0	0	81.33	50.00
2	81	5	36	4	5	0	0	0	3	15	0	0	5	0	0	0	8	48.00	44.44
3	52	0	0	3	7	13	2	0	0	1	0	0	1	3	22	0	0	3.90	5.77
4	74	1	0	9	47	2	0	0	0	1	0	0	1	13	0	0	0	62.67	63.51
5	135	6	8	17	3	46	6	65	0	0	0	28	0	19	1	1	0	61.33	34.07
6	75	0	0	1	0	4	54	10	0	0	0	15	0	0	0	0	1	71.05	72.00
7	94	0	0	0	0	0	0	0	8	0	21	0	0	0	0	0	0	85.53	69.15
8	80	0	0	0	0	0	0	1	64	0	4	0	1	0	0	0	1	85.33	80.00
9	64	1	11	1	0	0	1	0	0	49	0	0	0	0	0	0	1	65.33	76.56
10	51	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	66.67	98.04
11	71	1	7	3	1	3	13	0	0	2	0	32	3	0	0	0	6	42.67	45.07
12	69	0	0	2	3	0	0	0	0	0	0	0	64	0	0	0	0	85.33	92.75
13	49	0	0	6	4	0	0	0	0	0	0	0	0	39	0	0	0	52.0	79.5
14	42	0	0	0	0	0	0	0	0	0	0	0	0	0	42	0	0	56.00	100.00
15	84	0	0	0	0	0	0	76	0	0	0	0	0	0	10	74	0	98.67	88.10
16	61	0	2	0	0	1	0		0	0	0	0	0	0	0	0	58	77.33	95.08
Total	1204	75	75	77	75	75	76		75	75	75	75	75	75	75	75	75		

Overall accuracy = 784/1204 = 65.12 % Kappa Coefficient = 0.6279

Table 4. Confusion Matrix for Land-Cover Classification Using SPOT Data (band 1~4)

Class	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Producer'saccuracy	User's accuracy
1	116	61	12	32	4	5	0	0	0	2	0	0	0	0	0	0	0	81.33	52.59
2	79	6	38	4	6	1	0	0	1	15	0	0	6	0	0	0	2	50.67	48.10
3	94	0	2	11	4	13	1	0	0	2	0	6	0	22	32	1	0	14.29	11.70
4	71	1	0	12	52	1	0	0	0	0	0	0	1	4	0	0	0	69.33	73.24
5	92	4	3	13	5	52	5	0	0	0	0	8	0	2	0	0	0	69.33	56.52
6	83	0	1	0	0	1	53	0	0	0	0	27	0	0	0	0	1	69.74	63.86
7	84	0	0	0	0	0	0	71	2	0	11	0	0	0	0	0	0	93.42	84.52
8	93	0	3	1	0	0	0	4	70	1	13	0	0	0	0	0	1	93.33	75.27
9	59	0	6	0	0	0	0	0	0	53	0	0	0	0	0	0	0	70.67	89.83
10	51	0	0	0	0	0	0	1	0	0	50	0	0	0	0	0	0	66.67	98.04
11	93	3	5	2	0	2	17	0	0	2	1	34	4	0	0	0	23	45.33	36.56
12	69	0	0	1	4	0	0	0	0	0	0	0	64	0	0	0	0	85.33	92.75
13	47	0	0	0	0	0	0	0	0	0	0	0	0	47	0	0	0	62.67	100.00
14	43	0	0	0	0	0	0	0	0	0	0	0	0	0	43	0	0	57.33	100.00
15	74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	74	0	98.67	100.00
16	56	0	5	1	0	0	0	0	2	0	0	0	0	0	0	0	48	64.00	85.71
Total	1204	75	75	77	75	75	76	76	75	75	75	75	75	75	75	75	75		

Overall accuracy = 821/1204 = 68.19 %Kappa Coefficient = 0.6607

Table 5. Confusion Matrix for Land-Cover Classification Using Landsat TM Data.

Class	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Producer 's accuracy	User 's accuracy
1	111	62	8	33	3	5	0	0	0	0	0	0	03	0	0	0	0	82.67	55.86
2	86	6	58	9	7	0	0	0	3	0	0	0	0	0	0	0	0	77.33	67.44
3	61	2	4	9	0	5	2	0	0	4	0	4	1	27	4	0	0	11.69	14.75
4	68	2	1	3	49	2	0	0	0	1	0	0	0	9	0	0	0	65.33	72.06
5	106	1	0	16	14	54	0	0	0	0	0	5	0	10	6	0	0	72.00	50.94
6	108	1	1	6	0	9	51	0	0	0	0	33	0	1	0	0	6	68.00	47.22
7	86	0	0	0	0	0	0	74	4	0	8	0	6	0	0	0	0	97.37	86.05
8	71	0	0	0	2	0	0	0	63	0	0	0	6	0	0	0	0	84.00	88.73
9	75	0	0	0	0	0	0	0	0	69	0	0	0	0	0	0	0	92.00	92.00
10	68	0	0	0	0	0	0	1	0	0	67	0	1	0	0	0	0	89.33	98.53
11	60	1	2	1	0	0	22	0	0	0	0	33	58	0	0	0	0	44.00	55.00
12	60	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	77.33	96.67
13	28	0	0	0	0	0	0	0	0	0	0	0	0	28	0	0	0	37.33	100.00
14	59	0	0	0	0	0	0	0	0	0	0	0	0	0	59	0	0	78.67	100.00
15	81	0	0	0	0	0	0	0	0	0	0	0	0	0	6	75	0	100.00	92.59
16	75	0	1	0	0	0	0	0	5	0	0	0	75	0	0	0	69	92.0	92.00
Total	1203	75	75	77	75	75	75	76	75	75	75	75		75	75	75	75		

Overall accuracy = 878/1203 = 72.98% Kappa Coefficient = 0.7118

Classification was also made excluding class 16. In this case, the overall accuracy was improved by 4.5 percents (Kappa coefficient 0.0476). It can be said that the inclusion of a 1.5-micron band on SPOT 4 satellite increases the classification accuracy.

Mid-infrared portion is a most important for vegetation studies. In principle, it permits discrimination between broad-leaved and coniferous woodland. It is also important in snow and ice studies (Legg, 1996). For our case study, this was made certain. But accuracy of permanently irrigated land, that of sport and leisure facilities which were mainly composed of golf courses were largely ameliorated.

In other applications, the SWIR band clearly highlights linear features such as roads, airport runways, railway lines, lines of trees, rivers and streams (http:\\www.spot.com). In our application, it is also made certain. Identification of road and rail networks was ameliorated.

But misclassification remains within industrial or commercial units and transport. In general, the SWIR band makes it easier to determine industrial infrastructures. But in Pusan, industrial area is mixed with factory, residence, and commerce. The spectral signature is not sufficient for the discrimination. The accuracy of discontinuous urban fabric is also low for the same reason. The area is covered by rice paddy field, dry field, and dwellings. But dwellings are clustered around roads. Confusion with continuous urban fabric is inevitable. The confusion between class of airport and that of beaches or dunes and sands is a little astonishing. But airport runway and beaches have similar signature characteristics.

If we compare the classification result of SPOT HRV-IR with that of Landsat TM, Landsat TM is still better in overall accuracy. But this result can not be asserted here, because one disadvantage of classifying mosaicked imagery is an increase in spectral variability and the potential to increase misclassification rates of spectrally similar but ecologically different cover types (Homer, Ramsey, Edwards and Falconer, 1997). This result needs to be revalued after segmentation into some ecoregions.

In general, decrease in accuracy occurs as spatial data are improved but other sensor characteristics are kept unchanged (Gong and Howarth, 1990).

The inclusion of SWIR band is not sufficient for improving accuracy in comparison with Landsat TM. Especially in accuracy of classes 2 (discontinuous urban fabric), 9 (rice fields), 10 (forest), 14 (water bodies) and 16 (green house), SPOT image is inferior to Landsat TM. But for classes 8 (permanently irrigated land), and 13 (intertidal flats), SPOT has better accuracy than Landsat TM does. In this standing, SPOT image is very useful for wetland research.

The result show that significant improvements can be achieved by the inclusion of SWIR band for the production of accurate land use maps, especially for some vegetation and wetland related classes.

Conclusion and Recommendations

This study showed that SWIR band could improve land-use classification accuracy of SPOT satellite imagery. It has produced some improvement in the accuracy of some classes. This may be a result of the fact that some classes contain vegetation. But from the low overall accuracy, we can say that the spectral resolution of the SPOT data is still not sufficient for the accuracy of CORINE level 3.

Furthermore, the spatial resolution (20 by 20 meters) is still inadequate. But the classification method used in this paper performed class assignment based only on the spectral signatures of selected training areas. Spatial information as texture or ancillary data can improve largely the accuracy of land cover or land use map (Jung, 1999). The combination with SPOT Panchromatic image would also improve the accuracy. In this paper, inclusion of SWIR band for land-use classification accuracy was only evaluated.

Future studies will include a comparison of the maximum likelihood with that of other classifiers, and an evaluation of the incorporation of SWIR band in other study sites.

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