COMPARATIVE ANALYSIS OF LANDSAT-5 TM AND SPOT HRV DATA IN KANAZAWA REGION

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ABSTRACT

Landsat-5 Thematic Mapper (TM) and SPOT High Resolution Visible (HRV) data have been compared for the classification of various land cover types in the Kanazawa region of Hokuriku district, Japan. These data were acquired on August 20, 1986. On making use of the Gaussian Maximum Likelihood classifier (GML), after the geometric correction, both of their grey levels were so classified that the different ecological species, several land use and cover types, and others were separated equally to a high accuracy. Particularly, the digital analysis of both data produced the accurate display of a small and complex scene of different vegetation species, in addition to the more information on geomorphological application due to the HRV data.

1. INTRODUCTION

Since the launching of LANDSAT-4 and -5, from the aspects of sensor performance, cartographic accuracy and image processing, the TM-data for various kinds of land cover types have been fully discussed by several authors (cf. Ref.(1)-(6)), allowing for the time-sequential and comparative study of TM and MSS data. On the other hand, carrying the HRV instrument, SPOT-1 was launched on 22 February 1986. Since that time the preliminary analysis of SPOT HRV multispectral scene has been performed by several authors (cf. (7)-(9)).

The principal advantage of the SPOT HRV sensor lies in the sharper spatial resolution than does LANDSAT TM. The sensor characteristics of the SPOT HRV instrument and the LANDSAT TM are shown in Table 1 (cf. Ref.(7)). The HRV instrument pointing 17 degrees off-axis provides the stereoscopic information, particularly useful for the study of topographic effects in rugged terrain. This feature also contributes to the average revisit at any place on earth within three days, whereas an orbital cycle of 28 days of SPOT-1 is longer than that of LANDSAT 16 days. On the other hand, the multispectral HRV instrument on board SPOT-1 has fewer spectral bands than the TM, lacking a blue, middle infrared, and thermal infrared bands. In this context, from the aspects of the land-cover classification in flat and rugged terrains, various kinds of discussion may be required in future.

In our present paper, the following images from space have been discussed from the aspect of supervised classification. The multispectral LANDSAT-5 TM imagery centered on the Kanazawa area, Ishikawa prefecture, Japan, has been acquired at 9.49a.m. local time on August 20 1986 (Figure 1), by the Earth Observation Center (EOC), National Space Development Agency of Japan (NASDA).

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Then, the multispectral SPOT-1 HRV imagery covering the above area has been also acquired at 10.50a.m. local time on August 20 1986 (Figure 2) by SPOT Image.
After the radiometric and geometric corrections, with the aid of the supervised classification, we have done the preliminary comparison of the TM and HRV imagery acquired successively at the same date, allowing for the fine structure of the imagery. In our further works, the unsupervised classification, texture analysis, and the spectral statistics will be taken into account for the comparative study of the TM and SPOT imagery.

2.PREPROCESSING

2.1 Preliminary data handling

2.1.1 Data acquisition

The Landsat-5 TM data in digital format handled by us have been acquired by the Earth Observation Center (EOS), National Space Development Agency of Japan (NASDA), and then have been preprocessed in terms of the systematic radiometric and geometric correction by EOS. On the other hand, the SPOT-I HRV data handled by us have been acquired by the SPOT Image and then have been calibrated radiometrically and geometrically in a manner similar to the TM data.
According to the annotation records, the handling data of both Computer Compatible Tape (CCT) are listed in Table 2. Both TM and HRV data under consideration covered the land-use map (1:25,000) of such areas as "Kanaiwa", "Awagasaki", "Matsuto", and "Kanazawa", in Ishikawa prefecture, Japan.

2.1.2 Data processing

Ground cover conditions in the above areas were identified by a joint work of Geographical Survey Institute (GSI) and Ishikawa Research Laboratory for Public Health and Environment (IRLPHE), with the aid of the land-use maps, aerial photographs, and meteorological data. The total number of pixels in ground truth data is several thousands in our study (test) site. The cartographic accuracy was shown to be within twenty five meters in land-use map. Based on the available ground truth data and aerial photographs on the study site, the TM data in unit of thirty meters span under consideration was extracted from the subscene CCT data. In other words, a 800x800 pixel block area was drawn out from the subscene of CCT-PT. In a manner similar to the above case, a 800x800 pixel block area in unit of twenty meters span was drawn out from the SPOT HRV.

2.2 Geometric correction

The study and test sites are almost centered in Ishikawa prefecture and is covered by Landsat-5 subscene whose path-row is given in Table 2. This region is characterized by a blend of aqueous, urban, rural, and ecological land-cover features associated with rugged terrain relief up to several hundred meters high.
In order to implement the geometric correction, an almost uniform network of Ground Control Points (GCP) was identified on both the Landsat-5 TM and SPOT-I HRV image data and the 1:25,000 scale land-use map covering the study (test) area.
In our case we used a pair of global bivariate quadratic polynomial functions. It is of interest to mention that the residuals

of 16 GCP's were found less than one pixel size. Furthermore, the resampling procedure, i.e., the determination of the radiance value to be assigned to each output pixel, was performed via the Nearest Neighborhood Method (NNM). The reason why we referred to this NNM is due to the fact that our CCT data have suffered the resampling based on the cubic convolution by NASDA. In a manner similar to the TM imagery, the geometric correction of SPOT HRV data has been performed. Whereas the spatial resolution of TM and multispectral HRV data are respectively thirty and twenty meters, however, the pixel size of both images is identified with that of the ground truth map prepared by GSI and IRLPHE, i.e., twenty five meters square. The reason why such a modification has been done is to make easy the supervised classification of both imagery compared with the ground truth data prepared by GSI-IRLPHE in pixel size of twenty-five meters.

3. CLASSIFICATION

The legend of the aqueous, urban, rural, ecological, and other cover types adopted by GSI is listed in Table 3. The total number of the ground truth area is about three hundreds, in each of which the number of samples was a few tens. The ground truth site not used for the supervised classification was used as a test site for the verification of the classification accuracy. The Gaussian Maximum Likelihood (GML) classifier has been used for the supervised classification.

Data processing: On making use of the available ground truth data and aerial photographs, the 800x800 TM and HRV pixel area were extracted from the subscene TM data and full scene SPOT data, respectively, and were corrected geometrically. There is a wide range of land use and cover types on the study (and test) site under consideration. The major cover types in the study site are water, forest, agriculture, transportation, routes, commercial, industrial, and residential area. The legend of land cover types adopted for the classification of TM and HRV data is listed in Table 4.

In order to keep the classification accuracy, around a few tens of sample pixels for each of the classes under consideration were extracted from the TM data in study site.

For the color image presentation the overall TM bands except for the 6th band were adopted, whereas in the case of HRV data the bands 1,2, and 3 were together used by the GML classifier.

3.1 Supervised classification

On making use of the GML classifier, we classified the grey levels in TM and HRV data on August 20, 1986. The results in percent of the above classification are listed in Table 5 through 8, respectively. The classification accuracy is defined as the ratio of the number of pixels identified as the class under consideration over the overall total number of pixels in the study (or test) site. In these tables the total numbers of pixels used for the ground truth data are listed.

3.2 Comparison of TM and HRV imagery

It has been pointed out by a few authors (cf. Ref.(7)) that there were only minor differences in spectral response between TM and HRV bands for a comparable environment in Chott et Djerid scene. However, it seems that, with respect to the geomorphological aspects, the improved spatial resolution has given more reliable information on the detailed pattern of fields in flat terrain.

In our present paper, based on the supervised classification results in Tables 5 through 13, it is shown that LANDSAT-5 TM and SPOT-1 HRV identify almost similarly the detailed ground feature categories. In other words, the digital analysis of both above data produced the accurately classified display of a small, complex scene of an area under consideration. Whereas the spatial resolution of TM data is low compared with that of HRV, the many wavelength combinations gave rise to the high resolution monitoring of urban area, field and others.
On the other hand, it seems that the HRV data are useful for acquiring information of spatially complex ground features and ecological analysis. In order to do readily the comparative study of TM and HRV data, in Tables 12 and 13 we showed the classification results of TM and HRV data in five comprehensive categories.

In the study site the mean classification accuracy in percent of TM and HRV data into five comprehensive categories are 91.9% and 78.2%, respectively. On the other hand, in the case of the test site the mean classification accuracy in percent of TM and HRV data into five categories are 78.2% and 76.2%, respectively. It seems that, whereas in the study site there may be some difference of the mean classification accuracy between TM and HRV data, in the test site it reduces to the negligible difference. Such a tendency is also shown in the mean classification accuracy in percent of TM and HRV data into 13(or 15) categories.

It seems to be due to the fact that the spatial high resolution of HRV instrument in study site consisting of small number of ground-truth data gives rise to especially the large dispersion of the statistical quantities in other area, i.e., the fields, and meadow, consisting of non-unoform miscellaneous ground patterns. However, from the aspect of the classification accuracy in percent of the TM and HRV data in test site, both data have almost comparable high reliability. On the other hand, from the geomorphological aspect, the HRV data are superior to the TM data, particularly in the area consisting of the complex patterns, e.g., the residential region, the ridge between fields and others.

4. DISCUSSION

The classification accuracy of Landsat TM data is so high even as compared with that of SPOT HRV data. Whereas the instantaneous field-of-view for HRV data is much higher than that of TM data, the classification accuracy of HRV data seems to be of the same order of magnitude as compared with that of TM data. It may be due to the fact that the total number of spectral bands useful for the supervised classification for TM data exceeded that of the SPOT HRV data. On the other hand, HRV imagery is much superior geomorphologically to the TM imagery. Finally, in Figure 1 and 2 are shown the TM and HRV images in full scene classified in Tables 6 and 8. For our comparative study of the supervised classification accuracy of TM and HRV data, it requires to prepare the HRV imagery in unit pixel size of twenty meters span.

Furthermore, the clustering, texture and multitemporal analysis of these data for the land cover classification will be performed later on.

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Table 1. Comparison of the SPOT HRV instrument and the LANDSAT Thematic Mapper.

	HRV instrument of SPOT		Thematic Mapper of LANDSAT-4,-5
Spectral bands 1	0.50-0.59μm	1	0.45-0.52μm
2	0.61-0.68μm	2	0.52-0.60μm
3	0.79-0.89μm	3	0.63-0.69μm
panchromatic	0.51-0.73μm	4	0.76-0.90μm
		5	1.55-1.75μm
		6	10.4-12.5μm
		7	2.08-2.35μm
Field of view	60km(at nadir)		185km
Spatial resolution	20m*		30m**
Satellite altitude	832km		705km
Frequency of coverage	26days		16days

*The HRV panchromatic band has 10m spatial resolution.
**The TM thermal infrared band (10.4-12.5μm) has 120m spatial resolution.

Table 2. Constants of acquired TM and SPOT data.

	Landsat TM	SPOT HRV
Acquired data	20 Aug. 1986	20 Aug. 1986
Path-Row	109-35	324-277
Central Latitude	N. 36° 3′	N. 36° 22′
Central Longihude	E. 136° 59′	E. 136° 42′
Solar Altitude	53°	62° 12′
Solar Azimuth	121°	143° 23′
ID Number	8J50902-00493-0	0135638L
Resampling Scheme	Convolution	Convolution

Table 3. Legend of land cover types listed by GSI in study (test) site.

NO	Cover type	NO	Cover type
1	High-densed urban area	25	Golf links
2	Medium-densed urban area	26	Green park
3	Low-densed urban area	27	Silverberry grove
4	Residential area	28	Meadow
5	Factory	29	Grass plot
6	Concrete structure	30	Waste land
7	High building	31	Timber plot
8	Other structure	32	Grove in temple
9	Street	33	False acasia
10	High way	34	Cedar plantation
11	Rail road	35	Cedar forest
12	Parking lot	36	Pine forest
13	Break water	37	Red pine forest
14	Rice field	38	Green pine forest
15	Rice field with mixed soil	39	Beech forest
16	Corn field	40	White fir forest
17	Other field	41	Takekamba forest
18	Orchard	42	Other broadleaved forest
19	Orchard with green house	43	Other coniferous forest
20	Bamboo grove	44	Mixed conifer
21	Play ground	45	Cutover
22	Maked land	46	Collapsed land
23	Sands	47	Sea water
24	Gravel	48	Water except sea

Table 4. Legend of cover types used in supervised classification for TM and SPOT data in terms of cover types by GSI.

Cover Types	Classification categories of GSI
1.High-densed urban area	1,6,7,13
2.Medium-densed urban area	2
3.Residential area	3,4,5,8,21,22,31,46
4.Highway	9,10,11,12
5.Sands	23,24
6.Rice field	14,15
7.Field	16,17
8.Meadow	25,28,29,30,45
9.Deciduous forest	18,19,20,33,39,41,42
10.Mixed forest	26,27,32,44
11.Coniferous forest	34,35,36,37,38,40,43
12.River (lagoon) water	48
13.Sea water	47

Table 5. Classification accuracy* in percent of TM data in study site into 13 cover-types category.

Predicted category	Actual category**													Total number of pixels §
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	
(1)High-densed urban area	75.0	14.3	1.8	5.4				3.6						56
(2)Medium-densed urban area	13.0	78.3	6.5					2.2						46
(3)Residential area	7.1	38.1	42.9	2.4		4.8	2.4	2.4						42
(4)High way			5.7	94.3										53
(5)Sands					100.0									12
(6)Rice field	1.7		5.2			86.2	3.4	3.4						58
(7)Fields	6.5	10.9	6.5	4.3		2.2	54.3	15.2						46
(8)Meadow		1.8	8.8				3.5	68.4		7.0	10.5			57
(9)Deciduous forest									100.0					9
(10)Mixed forest										96.5	3.5			57
(11)Coniferous forest										7.4	92.6			27
(12)River water		3.2	1.6	1.6								93.6		62
(13)Sea water													100.0	63
														588***

*Calculated by dividing the number of correctly classified pixels for any category by the total number of pixels evaluated for that category.
**The class numbers correspond to those used in the predicted category column.
***This number corresponds to the sum of the total number of pixels used for ground-truth data.
§Used for ground-truth data

Table 6. Classification accuracy in percent of TM data in test site into 13 cover-types category.

Predicted category	Actual category													Total number of pixels §
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	
(1)High-densed urban area	49.0	20.6	12.0	11.6			2.2	3.7		0.7		0.2		535
(2)Medium-densed urban area	21.2	39.2	25.0	7.4			2.5	3.4				1.0		472
(3)Residential area	10.9	27.2	36.5	8.7		4.3	6.1	5.0		0.9	0.2	0.1		806
(4)High way	2.6	1.1	19.5	68.3		6.3	1.1	1.1						189
(5)Sands	18.6		4.7	2.3	62.8		4.7			4.7		2.3		43
(6)Rice field	0.2		2.9			95.6	0.4	1.1						562
(7)Fields	8.0	13.7	14.3	2.9		1.1	41.1	14.3		4.6				175
(8)Meadow	1.2	0.3	23.4	1.6		1.0	13.2	48.1	0.2	5.9	4.8			1073
(9)Deciduous forest	7.9	12.7	13.5	0.8		4.0	1.6	15.9	8.7	21.4	13.5			126
(10)Mixed forest	7.0	12.8	22.5	3.1		1.9	1.9	5.4		43.2	1.9			257
(11)Coniferous forest			7.7			1.3	2.6	12.8		32.1	43.6			78
(12)River water	1.1	1.9	8.2	0.5			0.3	0.8		5.3		82.0		377
(13)Sea water												0.4	99.6	1055
														5741

§Used for ground-truth data

Table 7. Classification accuracy in percent of HRV data in study site into 15 cover-types category.

Predicted category	Actual category															Total number of pixels §
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)*	(15)**	
(1)High-densed urban area	71.3	4.3	3.2			2.1	17.0								2.1	94
(2)Medium-densed urban area	27.0	45.9	10.8				10.8								5.4	37
(3)Residential area		21.4	45.2	4.8		4.8	14.3	2.4			7.1					42
(4)High way	16.7	13.3	3.3	66.7												30
(5)Sands			15.0	5.0	80.0											20
(6)Rice field			3.3			83.6	1.6	6.6			4.9					61
(7)Fields		4.3	23.9	2.2		37.0	10.9	4.3	15.2	2.2						46
(8)Meadow		2.9	40.0		5.7	2.9	2.9	14.3	8.6		20.0			2.9		35
(9)Deciduous forest			22.2						55.6	22.2						9
(10)Mixed forest			10.6						4.3	59.6	25.5					47
(11)Coniferous forest						11.1		11.1	3.7	25.9	48.2					27
(12)River water												88.9			11.1	18
(13)Sea water												1.9	98.1			54
																520

*This class number corresponds to the cloud.
**This class number corresponds to the cloudy shadow.
§Used for ground-truth data

Table 8. Classification accuracy in percent of HRV data in test site into 15 cover-types category.

Predicted category	Actual category															Total number of pixels §
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)*	(15)**	
(1)High-densed urban area	52.7	17.6	3.4	22.6	0.4		0.2	0.4	0.2	0.6		0.2		0.7	1.1	535
(2)Medium-densed urban area	23.4	36.4	25.4	8.9	2.4		0.3	2.1							1.0	291
(3)Residential area	17.8	13.6	22.0	33.7	1.5	1.7	0.6	2.5	1.9	0.6	0.6			3.1	0.4	522
(4)High way	36.6	11.4	2.4	48.0				1.6								123
(5)Sands		5.0	20.0	2.5	46.9	0.6	3.1	5.6	6.3	9.4	0.6					160
(6)Rice field			0.5			96.8	0.5	1.2			1.0					410
(7)Fields	3.2	12.1	31.8	0.6	1.9	22.3	5.7	2.5	12.7	3.2	0.6				3.2	157
(8)Meadow		1.4	11.2	2.9	3.2	22.1	7.7	3.7	10.9	7.7	28.4			0.9		349
(9)Deciduous forest		0.8	4.8		2.4	4.0	3.2	1.6	16.7	63.5	3.2					126
(10)Mixed forest	3.1	3.1	26.8	3.1	0.4	1.6	1.2	1.6	11.3	28.4	17.1			2.3		257
(11)Coniferous forest			1.3				1.3	1.3	7.7	33.3	55.1					78
(12)River water	2.0											90.7			7.3	150
(13)Sea water												3.1	96.9			225
																3383

*This class number corresponds to the cloud.
**This class number corresponds to the cloudy shadow.
§Used for ground-truth data

Table 9. Legend of five cover types used in comprehensive classification in test site

Predicted category	Cover types in actual category*
Structual area (1)	(1),(2),(3),(4)
Rice field (2)	(6)
Forest (3)	(9),(10),(11)
Aqueous area (4)	(12),(13)
Other area (5)	(5),(7),(8),(14),(15)

*This class number corresponds to the actual category in Table 5~8.

Table 10. Classification accuracy in percent of TM data in test site into 5 cover-types category

Predicted category	Actual category (1)	(2)	(3)	(4)	(5)	Total number of pixels used for ground-truth
Structual area (1)	89.2	2.4	0.7	0.2	7.7	1996
Rice field (2)	3.0	95.6			1.4	562
Forest (3)	36.2	2.4	49.9		11.5	461
Aqueous area (4)	3.1		1.4	95.3	0.3	1432
Other types (5)	28.4	1.0	9.8	0.1	60.8	1290

Sum of total numbers of pixels in actual category = 5741
Mean percentage in identified pixel numbers of classification accuracy = 81.8%

Table 11. Classification accuracy in percent of HRV data in test site into 5 cover-types category

Predicted category	Actual category (1)	(2)	(3)	(4)	(5)	Total number of pixels used for ground-truth
Structual area (1)	92.8	0.6	1.4		5.2	1471
Rice field (2)	0.5	96.8	1.0		1.7	410
Forest (3)	21.9	2.0	70.7		5.4	461
Aqueous area (4)	0.8			96.3	2.9	375
Other types (5)	26.0	17.0	32.4		24.6	666

Sum of total numbers of pixels in actual category = 3383
Mean percentage in identified pixel numbers of classification accuracy = 77.2%

Table 12. Comparison of classification accuracy in percent of TM and HRV data in study site into 5 cover-types category

	Actual category: Structual area	Rice field	Forest	Aqueous area	Other area	Mean percent
Landsat-5 TM data	96.2	86.2	100.0	96.8	80.5	91.9
SPOT HRV data	85.4*	83.6	81.7	100.0*	39.4	78.2*

*The effect of clouds and cloudy shadow is included.

Table 13. Comparison of classification accuracy in percent of TM and HRV data in test site into 5 cover-types category

	Structual area	Rice field	Forest	Aqueous area	Other area	Mean percent
Landsat-5 TM data	89.2	95.6	49.9	95.3	60.8	78.2
SPOT HRV data	92.8	96.8	70.7	96.3	24.6	76.2

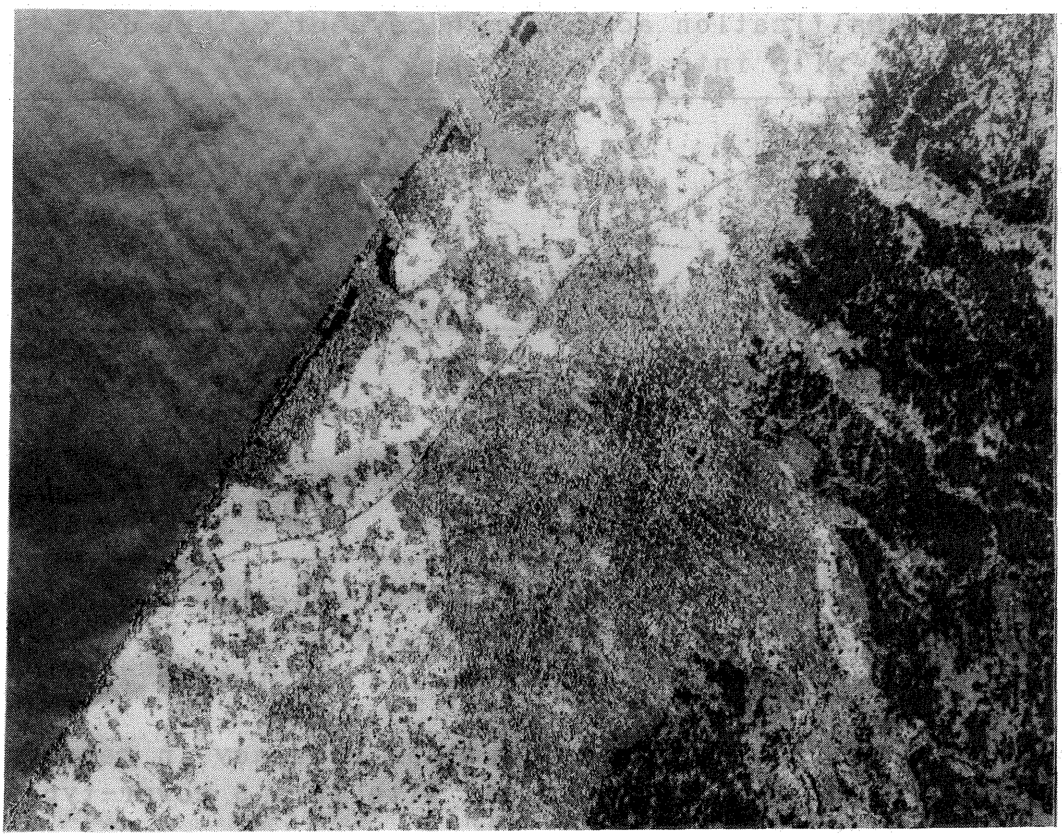

Figure 1. The Landsat-5 TM classified image of the multispectral bands for Kanazawa subscene (800X800 pixels of 25m size)

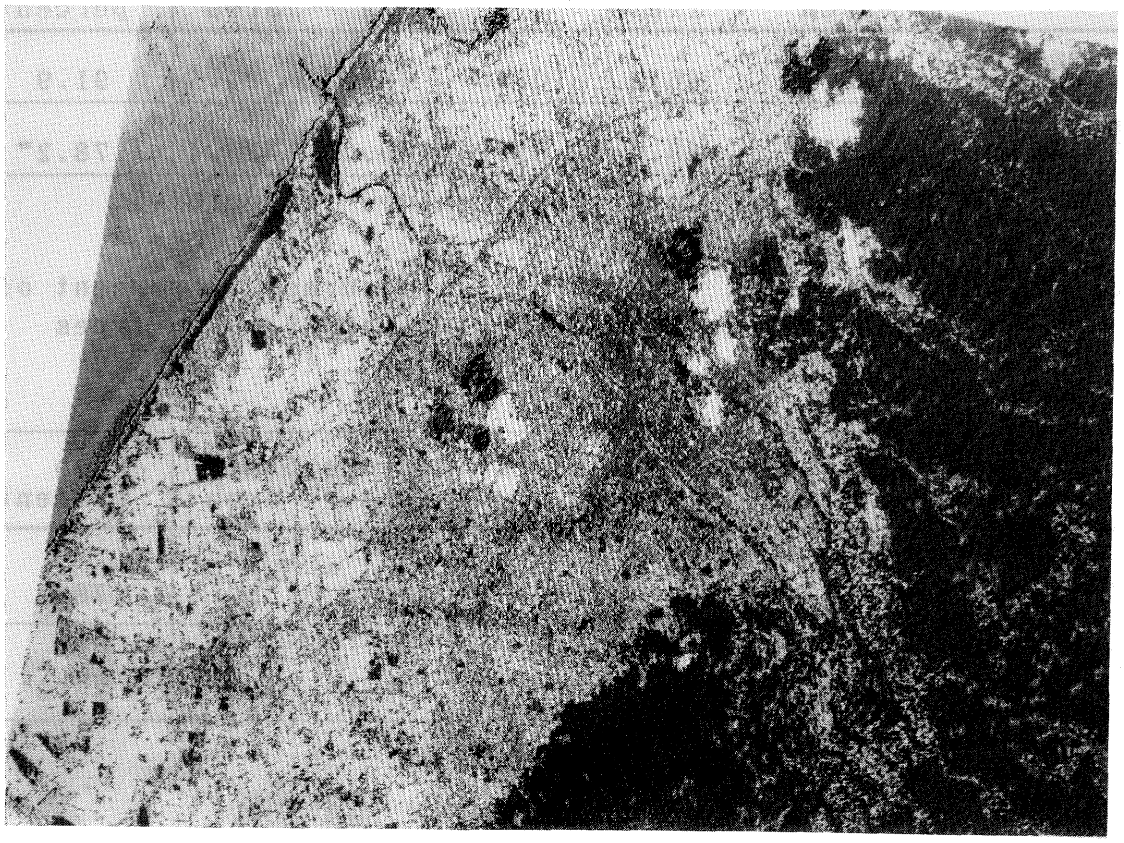

Figure 2. The SPOT-I HRV classified image of the multispectral bands for Kanazawa scene (800X800 pixels of 25m size)