Methodological Approach for the Detection of Ground Cover Classification and Surface Temperatures of the Waterfront using Landsat TM Data

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Abstract

In this research, natural areas and urbanized areas in a waterfront of southern Osaka were classified according to ground cover using Landsat TM data, and an attempt was made to improve the accuracy of such classifications. DN values from band 6 were then used to investigate the relationship between the above ground cover classifications and surface temperature. It was found that accuracy was high in classifying forested and other green categories. In urbanized areas, which have long been thought difficult to classify accurately, it was found that uniform ground cover conditions generate uniform band characteristics. Thus it was demonstrated that even urbanized areas can be classified with some degree of accuracy. Regardless of classification category, areas where the ground cover was urbanized areas had a higher surface temperature than other areas, and it was found that the sea had the effect of lowering surface temperatures on adjacent land.

Purpose of Research

One method of classifying ground cover is by using Landsat data. This method is particularly effective because it reveals conditions over a broad area simultaneously. One drawback is that accuracy is low in non green surfaces except treed area. Landsat # 4 and later satellites are equipped with thermal infrared band 6 as a special TM feature, and use of this feature is important to understanding the urban heat environment. In this research, high-resolution TM data from band 6, which provides pixel with a radius of 120 meters, and the six other TM bands, which provide pixel with a radius of 30 meters, were used. Natural areas and urbanized areas in a waterfront of southern Osaka were classified according to ground cover, and an attempt was made to improve the accuracy of such classifications. DN values from band 6 were then used to investigate the relationship between the above ground cover classifications and surface temperature.

Research Method

In this research, two study areas were chosen in a waterfront of southern Osaka. A natural area was selected in the town of Misaki, while an urbanized area was selected in the city of Kishiwada. Both study areas were rectangular, measuring 2.19 km from east

to west and 1.65 km from north to south. They had a combined area of 3.61 km^2. Photo 1, a true color image from Landsat TM data, shows the locations of the study areas. In order to compare Landsat data with ground truth data, which are mainly read from aerial photographs, 1987 was established as the analytic year. The Landsat data used in this research were the bulk corrected TM data (73 columns×55 lines) taken by Landsat # 5 on June 29, 1987. In the course of analysis, the FREDAM System[1] developed by Tsuyuki, who also employed the Nexus-Qube image processor, was used.

Research proceeded according to the flowchart shown in Figure 1.

Prior to analysis, TM data image coordinates had to be matched with map coordinates. A geometric correction was carried out based on ground control points on the land surface, and data were then analyzed as described below.

First of all, existing research[2-4] was used as a reference in defining classification categories. Then training areas corresponding to the classification categories were selected. Based on the classification accuracy of each combination of four bands, one particular combination was chosen for classifying the ground cover over both entire study

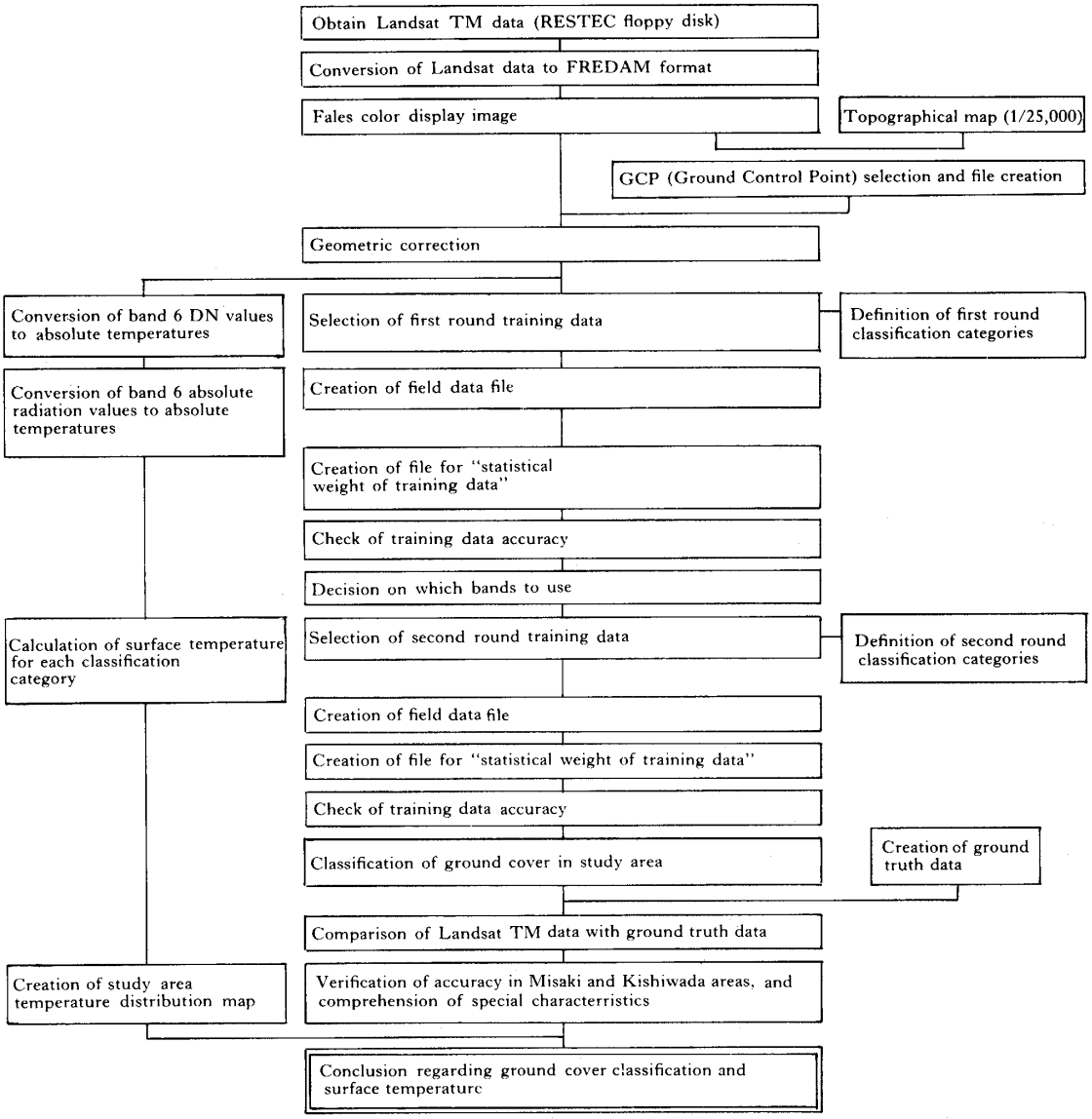


Fig. 1 Data Processing Flowchart

areas. At the same time, problems in classification categories were checked. Next, problematic categories were redefined and training areas corresponding to the new categories were selected. A classification trial was carried out using training data in an attempt to improve accuracy. The above training data were used to classify ground cover over both entire study areas by the minimum distance classification. Classification accuracy was verified by comparison with ground truth data drawn up from aerial photographs and topographical maps. Classification categories were unified as a means of improving classification accuracy.

In analyzing surface temperatures, the average DN values from band 6 of the training area in the final ground cover classification were used. Surface temperatures were recorded and their relationship with ground cover was investigated.

Results of Analysis and Discussion

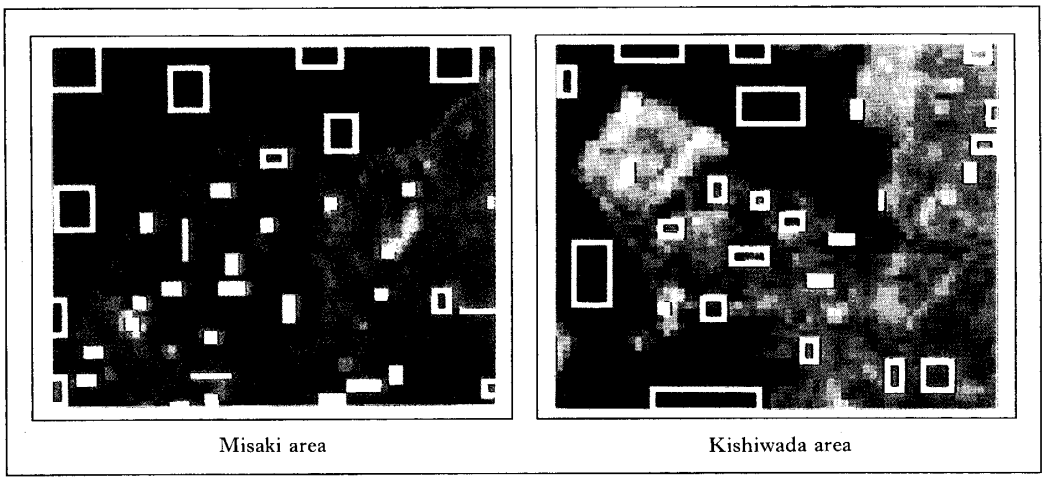
1) Defining ground cover classification categories

(1) *Band selection*

Based on examples in existing research, the following ground cover categories were used in the first round of classification in the Misaki study area: forested land, grassland, bare land 1/soil, bare land 2/concrete, water, low-density urban 1, and high-density urban 2. In the Kishiwada study area, the following categories were used: bare land 2/concrete, water, high-density urban 2, and industrial urban 4. For each classification category, a training area with uniform ground cover conditions was selected. These training areas are shown in Photo 2.

Ground cover classifications were done on the training areas using four different combinations of bands. The classification accuracy of each combination is shown in Table 1.

Looking at classification accuracies in Table 1, it can be seen that the overall rate of correlation was 94.1% in the Misaki area and 88.0% in the Kishiwada area when bands 1, 2, 3 and 4 were used. These were the highest classification accuracies achieved in either study area. However, this combination of bands was not equally suitable for classifying every individual category of ground cover. In the Misaki study area, accuracy was a low 52.0% in classifying the bare land 1 category. Therefore, instead of the 1, 2, 3 and 4



Misaki area Kishiwada area

* White frames are training area

Photo 2. Selection of training areas

Table 1. Classification accuracy of different combination of bands

	No.	Classifacation categories	Band 1. 2. 3. 4	Band 1. 3. 4. 5	Band 1. 4. 5. 7	Band 3. 4. 5. 7
	1	Forested land	95.5	97.7	97.7	97.7
	2	Grassland	100.0	100.0	100.0	100.0
	3	Bare land 1/Soil	52.0	68.0	68.0	68.0
	4	Bare land 3/Concrete	100.0	94.1	88.2	64.7
	5	Water	99.0	98.3	99.3	98.6
	6	Low-density urban 1	66.7	75.0	80.6	97.7
	7	High-density urban 2	97.7	97.7	100.0	75.0
		Overall rate	94.1	91.7	88.1	93.3
	1	Bare land 3/Concrete	92.4	96.8	97.9	95.7
	2	Water	96.4	97.1	97.5	97.5
	3	High-density urban 2	77.5	74.2	47.5	48.3
	4	Industrial urban 4	70.2	66.7	67.9	70.2
		Overall rate	88.0	87.8	82.2	83.0

(Unit: %)

combination, the bands chosen for this research were 1, 3, 4 and 5 because this combination gave consistently high rates of correlation, and the lowest rate of accuracy for any category of ground cover was better than 60%. Still, the rates of accuracy in classifying bare land 1 in the Misaki area and urban 4 in the Kishiwada area were only 68.4% and 66.7%, respectively. This indicated some problems.

(2) *Restructuring the ground cover classification categories*

It was thought that the two problematic categories —bare land 1 in the Misaki area and urban 4 in the Kishiwada area— had reflective properties that were too broad for use as single categories. In the Misaki area, the bare land 1 category was divided, resulting in the establishment of bare land 2 as a new category. In the Kishiwada area, the urban 4 category was divided, resulting in the establishment of bare land 1, aquatic log-storage, and medium-rise housing urban 3 as new categories. Furthermore, the bare land 2 category in the Misaki area was meant to describe rice paddies, but since the Landsat images were taken in late June, when rice paddies would normally be full of water, the category description was changed from bare land to water-covered bare land.

Figure 2 shows the band characteristics of the training data, which are based on the categories used in the second round of classification. These include the restructured categories. Table 2 shows the classification accuracy of the second round of training data.

It can be seen from Table 2 that the overall rates of correlation in the two study areas were very high at 96.4% and 97.8%, respectively. Moreover, accuracy was better than 86% for every individual category of ground cover. These classification categories were therefore used without change in the analysis described below.

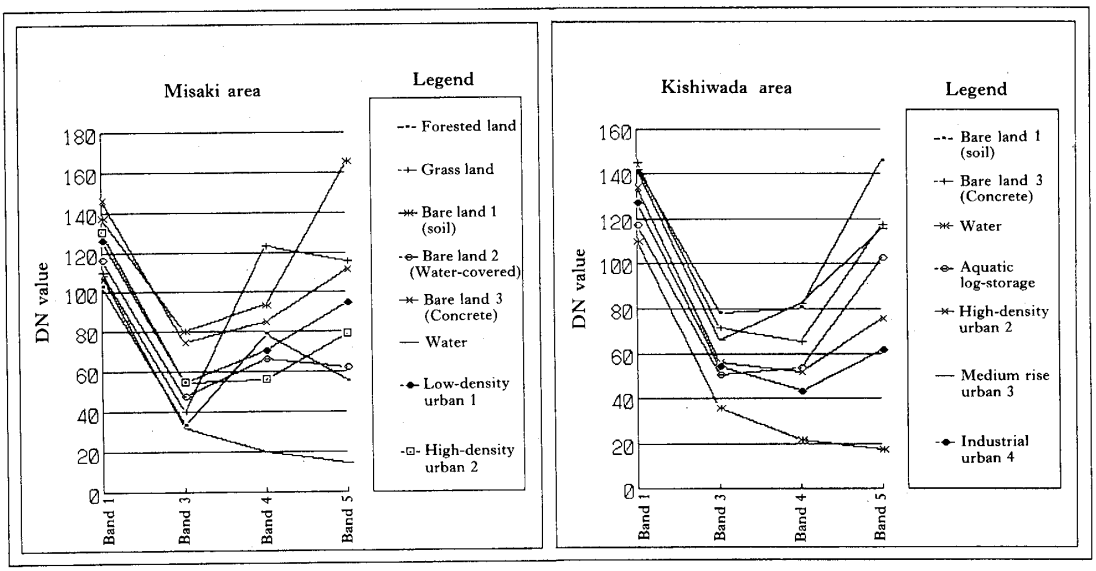


Fig. 2 Band characteristics redefined training data

Table 2. Classification accuracy of the redefined training date

No.	Classification categories	Classification accuracy
1	Forested land	98.0
2	Grassland	100.0
3	Bare land 1/Soil	87.0
4	Bare land 2/ Water-covered	90.0
5	Bare land 3/Concrete	94.1
6	Water	98.0
7	Low-density urban 1	88.9
8	High-density urban 2	95.5
	Overall rate	96.4

No.	Classification categories	Classification accuracy
1	Bare land 1/Soil	100.0
2	Bare land 3/Concrete	100.0
3	Water	98.7
4	Aquatic log-storage	100.0
5	High-density urban 2	98.6
6	Medium-rise Urban 3	86.4
7	Industrial Urban 4	96.6
	Overall rate	97.8

(Unit: %)

2) Ground cover classification over both entire study areas

At this point, a ground cover classification was done over both entire study areas using training data based on the classification categories obtained from the previous analysis. Classification accuracy was determined through a comparison with ground truth data.

As shown in Table 3, a comparatively high rate of correlation was obtained over the entire study areas: 72.4% in the Misaki area and 71.8% in the Kishiwada area. Looking at the rates of correlation for individual classification categories, it can be seen that high rates of 99.1% for water, 82.6% for forested land, and 78.0% for grassland were obtained in the Misaki area. Likewise, high rates of 96.9% for water and 79.1% for urban 2 were obtained in the Kishiwada area. In both areas, however, the rates of correlation for bare land categories were less than 60%. It can be surmised from the 0% classification accuracy for aquatic log-storage in Kishiwada that Landsat images and aerial photos were taken

Table 3. Verification of accuracy between ground truth data and Landsat TM data-1

Misaki area	Overall rate 72.4%		Ground truth data							
Classification categories	Total no. of pixels	Rate	Forested land	Glassland	Bare land 1	Bare land 2	Bare land 3	Water	Low-density urban 1	High-density urban 2
Uncategorized	7	—	0.0	14.3	0.0	0.0	71.4	14.3	0.0	0.0
Forested land	599	82.6	82.6	8.7	1.3	4.2	0.8	1.0	1.3	0.0
Grassland	313	78.0	16.6	78.0	0.6	2.9	0.3	0.0	1.3	0.3
Bare land 1	98	53.1	11.2	1.0	53.1	3.1	2.0	0.0	25.5	4.1
Bare land 2	413	54.0	17.9	0.5	2.4	54.0	6.1	2.7	14.5	1.9
Bare land 3	585	20.9	16.4	2.2	3.8	13.5	20.9	0.5	32.8	9.9
Water	1383	99.1	0.0	0.0	0.0	0.8	0.0	99.1	0.0	0.1
Low-density urban 1	403	65.0	3.2	0.5	6.0	3.4	11.9	0.0	65.0	9.9
High-density urban 2	214	65.4	2.3	0.0	0.0	7.0	7.0	0.5	17.8	65.4

Kishiwada area	Overall rate 71.8%		Ground truth data							
Classification categories	Total no. of pixels	Rate	Bare land 1	Bare land 3	Water	Aquatic log-storage	High-density urban 2	Medium rise urban 3	Industrial urban 4	Log-storage
Uncategorized	52	—	3.8	17.3	7.7	0.0	7.7	0.0	63.5	0.0
Bare land 1	332	37.8	37.8	12.0	1.8	0.0	23.4	1.8	6.9	1.6
Bare land 3	611	38.6	2.5	38.6	1.3	0.0	28.2	0.0	26.4	3.1
Water	1346	96.9	0.0	0.7	96.9	0.1	1.0	0.0	0.8	0.4
Aquatic log-storge	26	0.0	3.8	3.8	88.5	0.0	3.8	0.0	0.0	3.8
High-density urban 2	1143	79.1	2.2	5.9	1.2	0.0	79.1	0.1	11.2	0.3
Medium rise urban 3	38	65.8	5.3	7.9	5.3	0.0	10.5	65.8	2.6	2.6
Industrial urban 4	467	61.2	0.4	8.1	18.8	0.4	7.7	0.0	61.2	3.2

(Unit: %)

at slightly different times, and that log storage conditions differed at the times of the two shoots. Classification results over the entire study areas are shown in the pseudo color image of Photo 3.

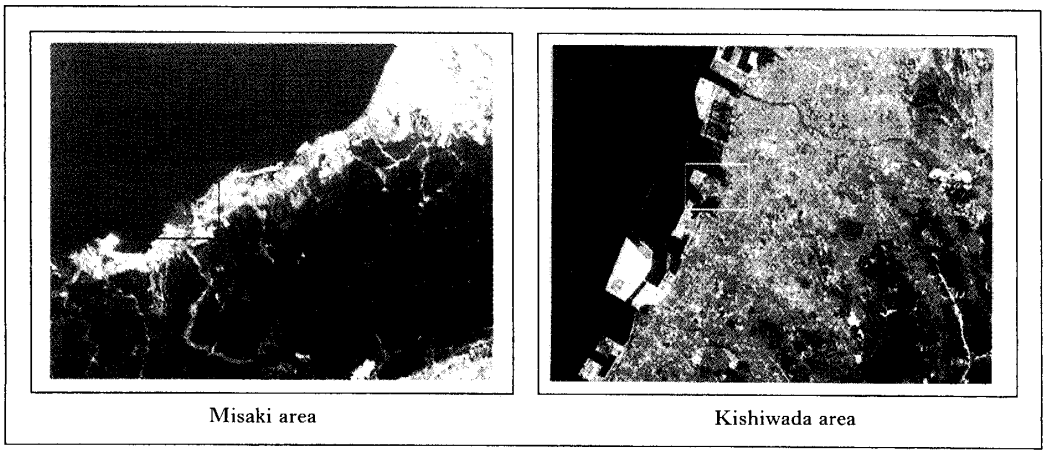
Next, categories between which there were numerous mutually incorrect classifications (see Table 3) were unified in order to raise classification accuracy. Table 4 shows classification accuracy after categories were unified.

Table 4. Verification of accuracy between ground truth data and Landsat TM data-2

Misaki area	Overall rate 85.2%		Ground truth data					
Classification categories	Total no. of pixels	Rate	Forested land	Glassland	Bare land 1	Bare land 2	Water	Uraban
Uncategorized	7	—	0.0	14.3	0.0	0.0	14.3	71.4
Forested land	599	82.6	82.6	8.7	1.3	4.2	1.0	2.2
Grassland	313	78.0	16.6	78.0	0.6	2.9	0.0	1.9
Bare land 1	98	53.1	11.2	1.0	53.1	3.1	0.0	31.6
Bare land 2	413	54.0	17.9	0.5	2.4	54.0	2.7	22.5
Water	1383	99.1	0.0	0.0	0.0	0.8	99.1	0.0
Urban	1202	76.1	9.5	1.2	3.8	9.0	0.3	76.1

Kishiwada area	Overall rate 78.6%		Ground truth data					
Classification categories	Total no. of pixels	Rate	Bare land 1	Water	High-density urban 2	Medium rise urban 3	Industrial urban 4	
Uncategorized	52	—	3.8	7.7	7.7	0.0	80.8	
Bare land 1	332	53.9	53.9	1.8	23.5	1.8	19.0	
Water	1372	96.7	0.8	96.7	1.0	0.0	1.6	
High-density urban 2	1143	79.0	2.4	1.2	79.0	0.1	17.1	
Medium rise urban 3	38	65.8	7.9	5.3	10.5	65.8	10.5	
Industrial urban 4	1078	66.9	4.9	8.9	19.3	0.0	66.9	

(Unit: %)



* White frames are study area

Photo 1. Location of study areas

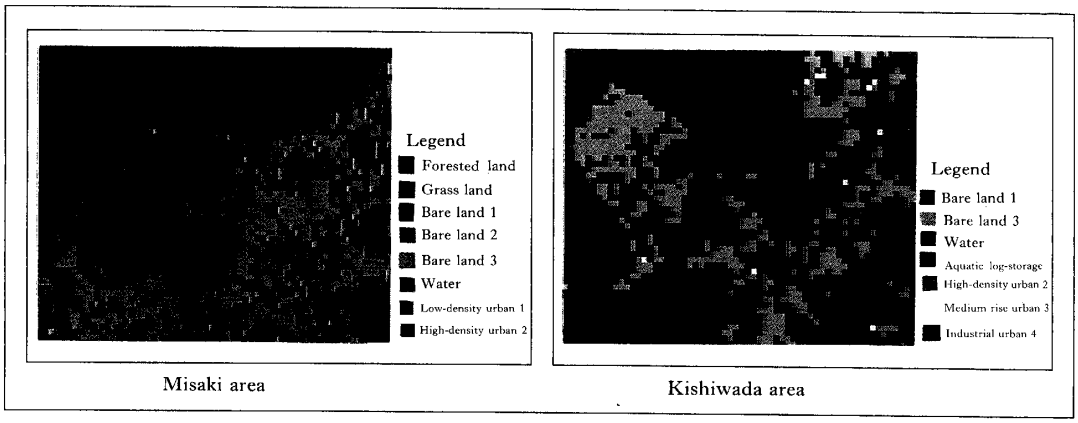


Photo 3. Distribution map showing each classification

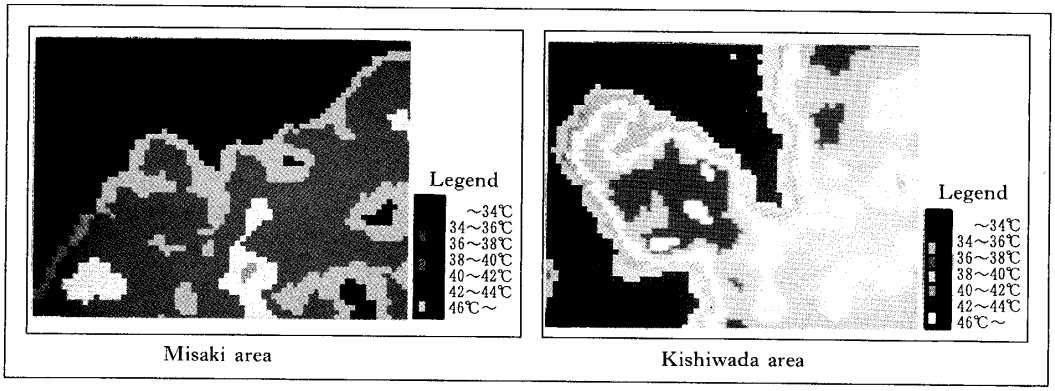


Photo 4. Distribution of surface temperatures

In the Misaki area, the three categories with the largest number of mutually incorrect classifications were urban 1, urban 2 and bare land 3. These categories had classification accuracies of 65.0%, 65.4% and 20.9%, respectively. The classification accuracy of the single "urban" category that resulted from the combination of these three categories was an improved 76.1%. In the Kishiwada area, the two categories with the largest number of mutually incorrect classifications were bare land 3 and urban 4. By unifying these two categories into urban 4, classification accuracy was improved from 38.6% and 61.2%,

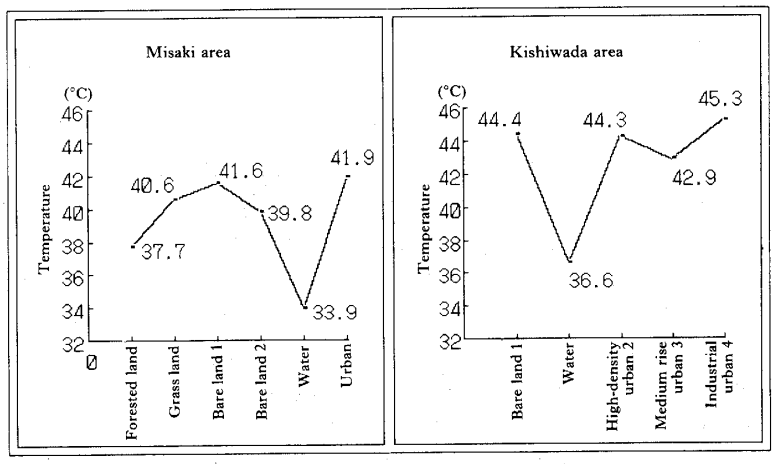


Fig. 3 Relationship between ground cover and surfase temperature

respectively, to 66.9%. Then the aquatic log-storage category, which was frequently confused with water, was unified with the water category. Classification accuracy was thus improved from 0.0% for aquatic log-storage and 96.9% for water to a unified 96.7%.

These efforts to improve the classification accuracy of individual ground cover categories resulted in improved correlation rates of 85.2% over the entire Misaki area and 78.6% over the entire Kishiwada area. It was found, as these figures suggest, that classification accuracy was higher in the natural area category, represented by Misaki, than in the urbanized category, represented by Kishiwada.

3) The relationship between ground cover and surface temperature

At this point, the average DN values (V) of thermal infrared band 6, which were taken from training data based on final classification categories, were used to calculate the surface temperature of each type of ground cover. The following formula was used to convert ground temperatures into absolute temperatures (T). Results are shown in Figure 3.

$$V = 7.0506 \times 10^{-3} \times T^{-2} - 2.583 \times 10^{-2} \times T + 212.023$$

Figure 3 shows the surface temperature of each classification category. Water temperatures were the lowest, at 33.9°C in the Misaki area and 36.6°C in the Kishiwada area. The next lowest temperature was that of forested land in the Misaki area, at 37.7°C. Urbanized land and bare land were warmer, ranging from 39.8°C to 45.3°C. For all the classification categories that were common to both study areas —water, bare land 1/soil, bare land 3/concrete, and high-density urban 2— temperatures were 1.3°C to 3.4°C higher in the Kishiwada area than in the Misaki area.

The distribution of surface temperatures over both entire study areas is shown in Photo 4. When the two areas are compared, it can be seen that surface temperatures were lower overall in the natural area, represented by Misaki, than in the urbanized area, represented by Kishiwada. In both areas, land surface temperatures tended to be lower near the sea, and sea surface temperatures tended to be higher near the land.

Conclusion

In classifying ground cover using Landsat TM data, it was found that classification of forested land and other green categories was highly accurate. In urbanized areas, which have long been thought difficult to classify accurately, it was found that uniform ground cover conditions generate uniform band characteristics. Thus it was demonstrated that even urbanized areas can be classified with some degree of accuracy. As for the relationship between surface temperature and ground cover, the tendency for natural areas to have lower surface temperatures than urbanized areas was seen in both study areas. Furthermore, the tendency for land surface temperatures to be lower near the sea indicated that the sea had the effect of lowering surface temperatures on adjacent land.

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