

An Analysis between the Ground Surface Temperature and Land Use in Urban Area by Using Landsat-TM Data

Hiroshi ISHIMARU* and Takashi NISHIMURA** and Katsuhiko YAMAMOTO***

(Received September 30th, 2000)

Synopsis

The outline of the artificial satellite LANDSAT-TM data was described at first, and the relations between the ground surface temperature and land use were analyzed by using it. Available data were the morning (10 a.m.) and evening (9 p.m.) data in Osaka are in 6 days in total in the recent separated years from 1990 to 1998 due to the weather condition.

1. Introduction

Nowadays, the urban environmental problems such as car exhaust gas pollution, water pollution, neighborhood noise and others have occurred in the urban wide area due to the concentration of the population and industry. Warming problem in the urban area is a considerably new and important problem as one of those environmental problems too.

There is a phenomenon that tropical night days have been increasing in Osaka (Figure-1), and Osaka has come to be said as the city whose temperature is high very much in the Japanese cities from the records of the Meteorological Agency as well. As for this, this heat island phenomenon is considered to be caused by the urban development due to the change in the urban structure, increase in artificial waste heat, the progress of concretize of the ground surface and decrease of green open space so on ¹⁾.

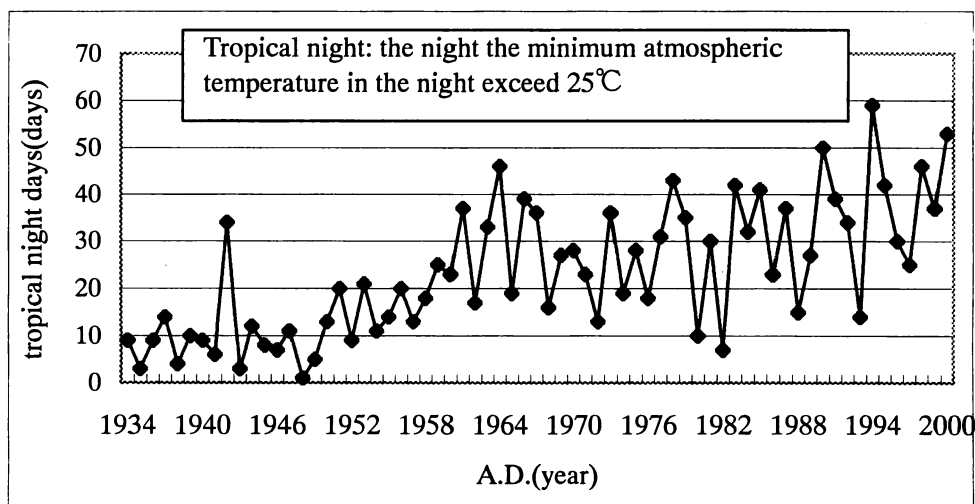


Figure-1 Trend of the tropical nights in Osaka

* Student, Master Course of Department of Civil Engineering

** Professor, Department of Civil Engineering

*** Staff, Environmental Pollution Control Center, Osaka Prefecture

2. An outline of LANDSAT-TM Data

LANDSAT-TM data can be taken widely at the same time in the wide area, and because they are digital data, it has the advantage that it can be disposed with the computer. But, it can be observed periodically in the same ground position every 16 days, and the time that LANDSAT comes round through is the same in the same ground position. Therefore, there are only fixed-time data on about 10 o'clock in the morning and about 9 o'clock in the night in Keihanshin area. And it has an essential deficit to observe in the point with the cloud. And there are a few data, only several times a year, which have no noise by the cloud, because of the comparatively cloudy area.

The TM data of LANDSAT No.5 can observe 7 wavelength bands, and the ground resolution capacity of BAND6 is 120m, and those of other bands are 30m. The character of each BAND is outlined as shown in Table-1.

Table-1 The explanation of the band

BAND	wavelength unit(μ m)	explanation
1	0.45~0.52	Observed in the wavelength band of the visible range from blue to green, and this band can be applied to detect the condition of the coastal water, the distinction of the deciduous tree and the conifer, and so on.
2	0.52~0.60	This band corresponds to the wavelength band which is seemed to be green with the human eyes, and the distinction of the sea and land is made better than band 1 image. It seems not to distinguish the waters from the plant. A newly-constructed road, a railroad, and so on are distinguished.
3	0.63~0.69	This is the wavelength band which seems to be red with the human eyes, and the boundary of the sea and land is considerably clear. As for the plant stage, it can be seen thickly and clearly.
4	0.76~0.90	It is observed in the wavelength of near infrared range, and the difference in brightness value of the land and the sea is clear in this band. And, because radiation from the plant is caught well, it is suitable for the investigation of the amount of plant and green surface.
5	1.55~1.75	Plant, the water content estimation of the soil, cloud and snow can be distinguished in this band by the thing that it is observed in the wavelength band of the middle infrared range.
6	10.4~12.5	As for the wavelength of the band 6, the ground resolution capacity is 120m(30m in other bands) by the observation in the far-infrared range. This band is, however, suitable for grasping heat distribution on the surface of the earth.
7	2.08~2.35	Band 7 aims at the distinction of the geological heat water change by the observation in the middle. It is dark in the plant area as in the waters, too. Brightness value of the vacant land is large.

The ground surface temperature is shown by using brightness value of band 6 with the following formula ²⁾.

$$T_c = \sqrt{780.74 + 107.53V} - 1.010 \times 10$$

T_c :ground surface temperature($^{\circ}$ C), V :brightness value of band 6

3. Relationship between Land use Data and Ground Surface Temperature

The land use estimation data based on the LANDSAT-TM data of April 21, 1992 were used in this research to grasp the relationship between land use conditions and surface temperature. (Table-2)

Table-2: Land use by Landsat-TM data in 1992.4.21

No	Land use type
①	high-rise building area
②	commercial area
③	high density residential area
④	low-density residential area
⑤	factory area
⑥	vacant land
⑦	paved surface
⑧	develloping areas
⑨	cemetery
⑩	quarry
⑪	green tract of land
⑫	the water surface

The range of the analysis was limited to the central part of the Osaka metropolitan area surrounded by the area surrounded by the solid lines, and dotted lines. (Figure -2)

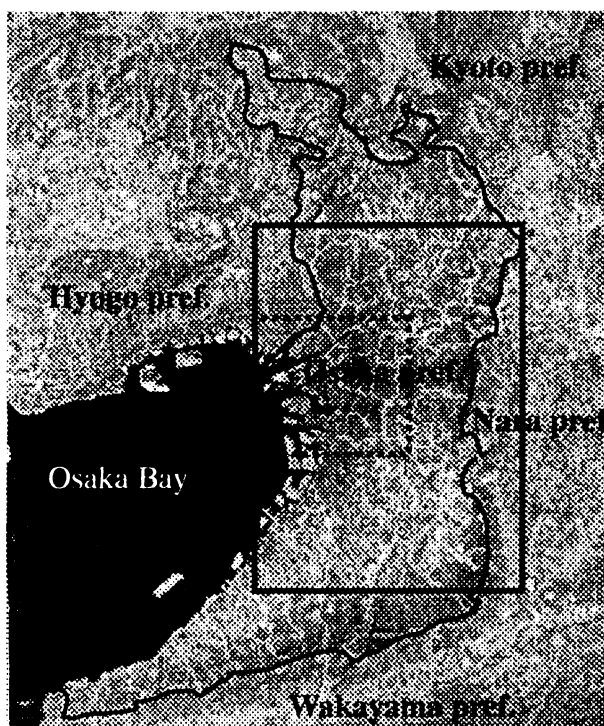


Figure-2 The range of the analysis

Relations between the land use classification and the corresponding averaged ground surface temperature were analyzed as shown in Figure-3, in the area surrounded by the solid lines except for the area surrounded by the dotted lines, based on these land use data. Six data were used in total as shown below; four morning data, August 20 (summer), 1995, March 18 (early spring), 1997, April 21 (spring), 1992 and December 18 (winter), 1998 and two night data, October 18, 1994 and March 13, 1990.

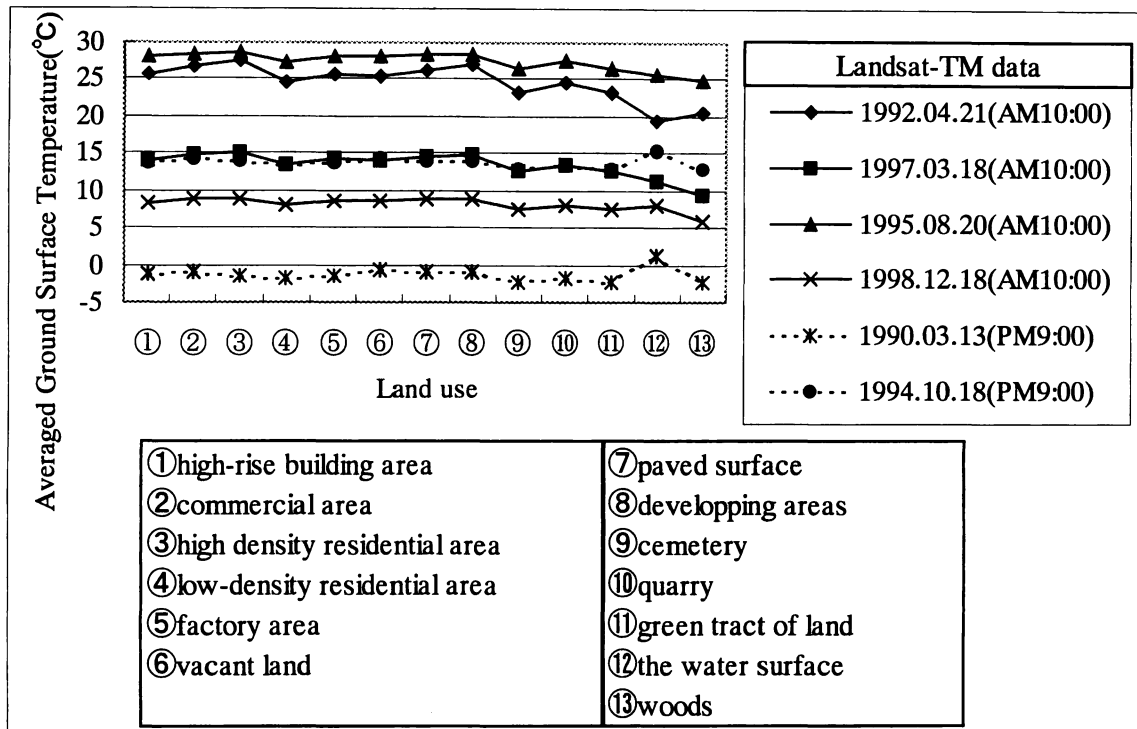


Figure-3: A relationship between Averaged Ground Surface Temperature and Land use (suburban area)

Next, relations between the land use classification and the ground surface temperature were shown about the urbanized area surrounded by a dotted line. (Figure -4)

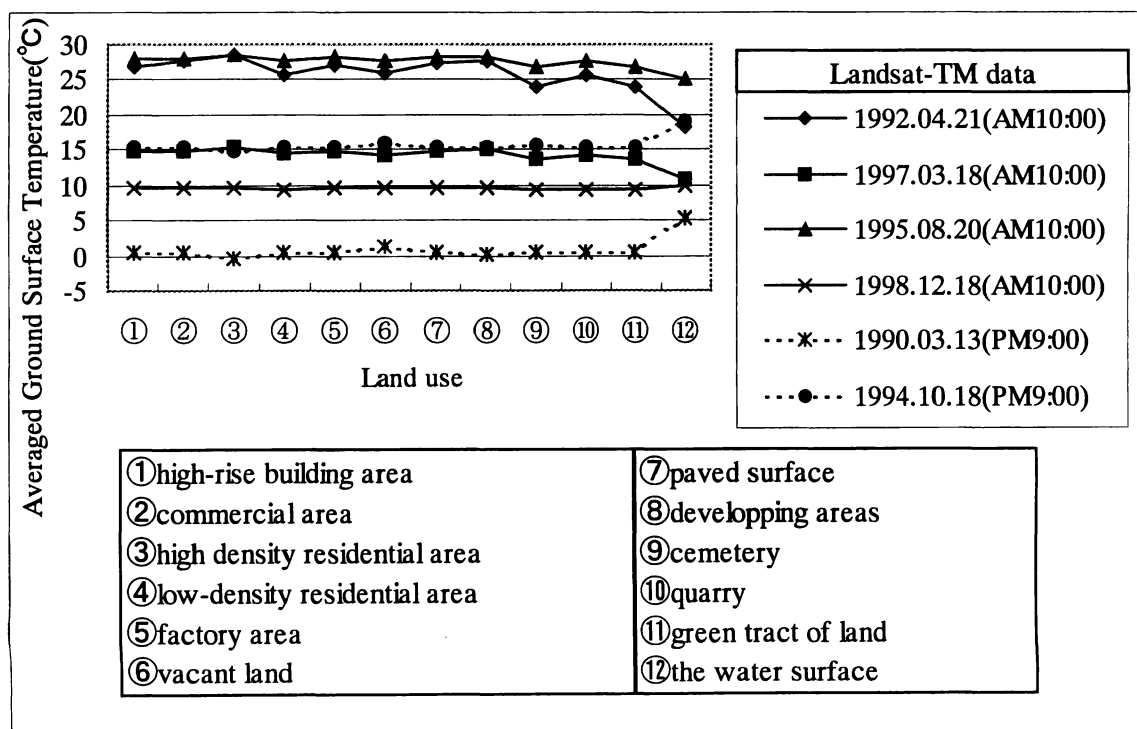


Figure-4: A relationship between Averaged Ground Surface Temperature and Land use (urban area)

From these figures, in the data of early spring, spring and summer, variations in the ground surface temperature are comparatively large in the morning data (10 o'clock) in comparison with those in winter. The variations of the ground surface temperature by the land use type in the suburban area are larger than in the urban

area. The ground surface temperature of the high-rise building area is lower than that of high density residential area, and the ground surface temperature of the residential area is lower than the ground surface temperature of the high density residential area in the data of early spring, spring and summer. And the ground surface temperature of the vacant land, cemetery, a green tract of land, surface of the water is lower than other land use. On the contrary ground surface temperature of the vacant land, the surface of the water is higher than other land use in the data of p.m. 9 o'clock, and large difference isn't seen in the ground surface temperature of other land uses.

Next, the difference in the ground surface temperature between the urban area and the suburban area is shown Figure -5.

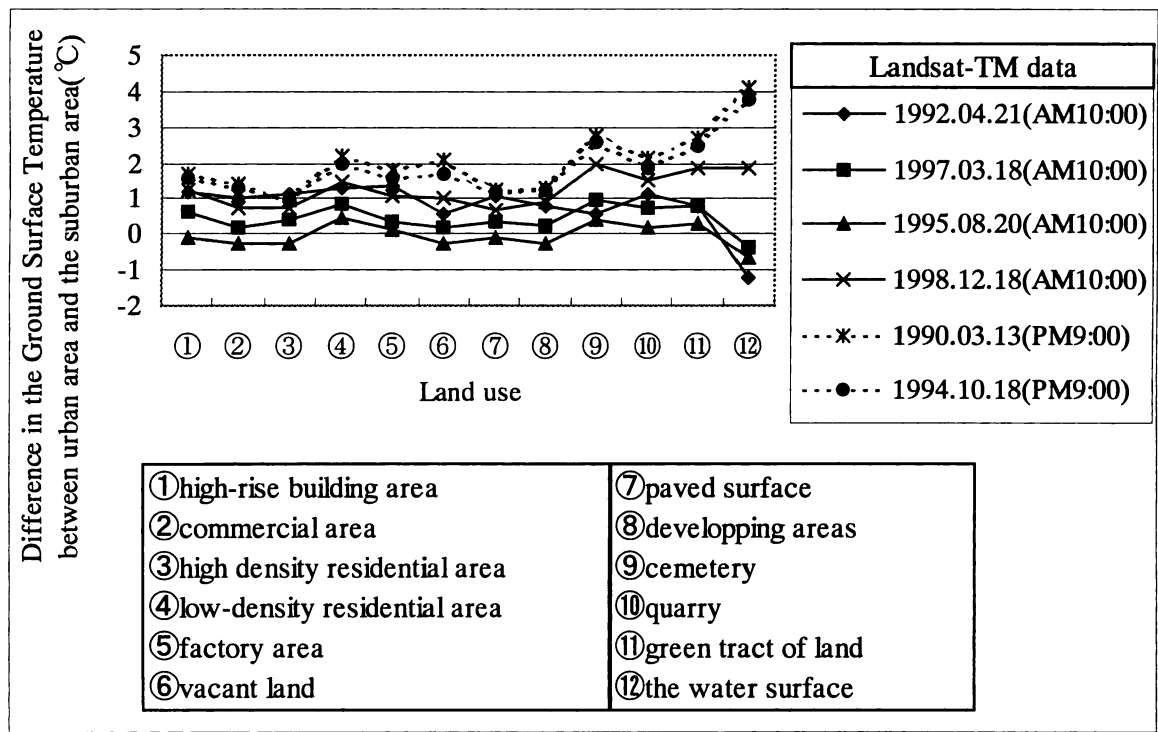


Figure-5: Difference in the Ground Surface Temperature between the urban area and the suburban area

Generally the surface temperature in the urban area is about 1-2°C higher than in the suburban area, especially in the night time and wintertime. The ground surface temperature of the water area in the urban area is considerably higher than that in the suburban area in the nighttime and wintertime, but converse in spring, early spring and summer.

4. Relationship between NDVI and Land Surface Temperature

Heat environment was evaluated by analyzing the ground surface temperature by using the heat band, and it was found out that effect on the ground surface temperature reduction of the green tract of land like the open space was considerably large as shown in the previous section. Next, it was examined about the relationship between NDVI index, which is considered to be the index that the activities of the plant is shown, and the ground surface temperature in this section. NDVI is the index that the plant activities (the amount of green land) are reflected, and it is the index expressed by using the value of BAND3 and BAND4³⁾. (The following formula)

$$NDVI = \frac{BAND\ 4 - BAND\ 3}{BAND\ 4 + BAND\ 3}$$

(-1 < NDVI < 1)

The relationships between the ground surface temperature and NDVI based on the data of April 21 1992, the morning data is shown in Figure-6, to judge whether NDVI is effective as an index of urban heat environment.

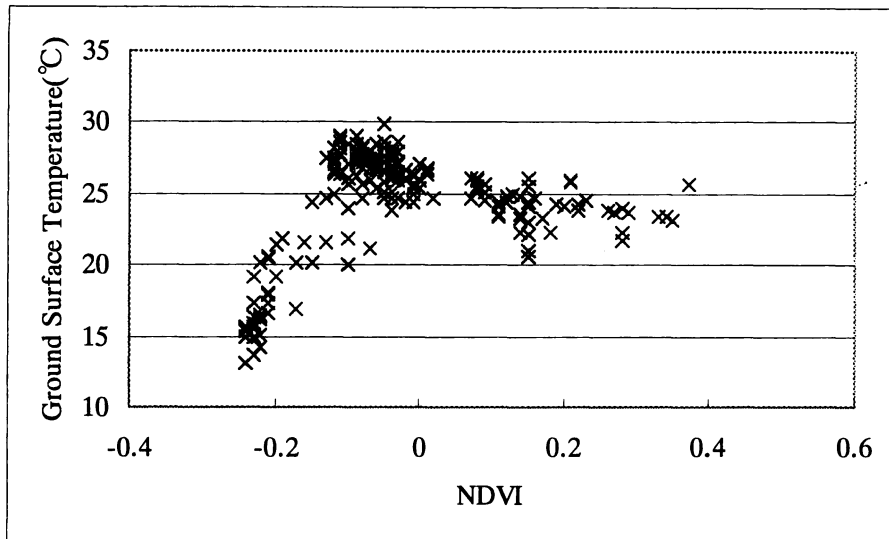


Figure-6: the relationships between the ground surface temperature and NDVI

When the value of NDVI is larger than about -0.1, the relationships between the ground surface temperature and NDVI are in the negative correlation from Figure-6. On the contrary NDVI and the ground surface temperature are in the positive correlation when the value of NDVI are smaller than about -0.1. The area where the value of NDVI is smaller than about -0.1 is thought to be influenced by the waters. So, the land use classification influenced by water (like ⑫) are removed, then, the relationships between NDVI and the ground surface temperature was transformed from Figure-6 to Figure-7.

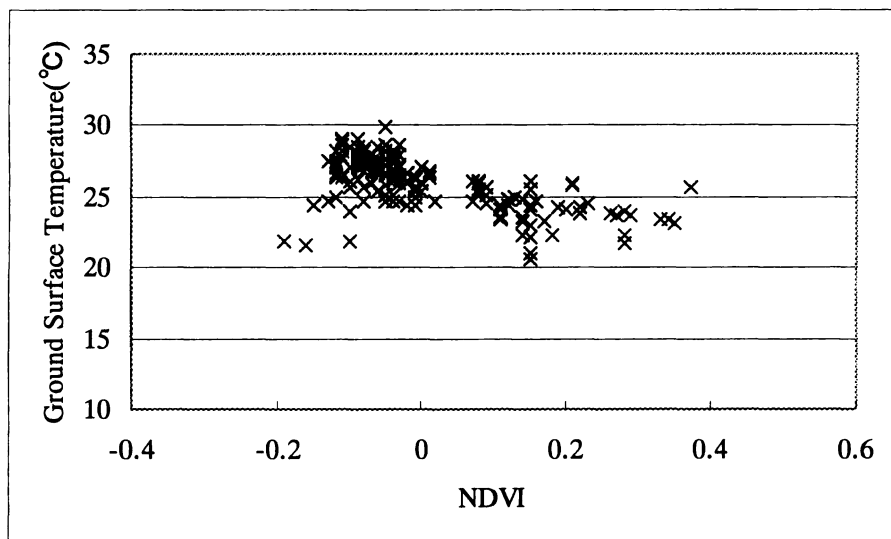


Figure-7: the relationships between the ground surface temperature and NDVI (without the waters)

Then, it can be seen that the value of NDVI becomes large, the ground surface temperature becomes lower in the land except the water area land use.

5. Conclusion

The relationships between land use and the ground surface temperature were analyzed mainly in this research. The following knowledge could be acquired as a result.

- ①As for the data of early spring, spring and summer, variation in the ground surface temperature is comparatively larger than that in winter in the morning data (on 10 o'clock).
- ②The ground surface temperature of the high-rise building area is lower than that of high density residential area , and The ground surface temperature of the residential area is lower than that of the high density residential area in early spring, spring and summer. And the ground surface temperature of the vacant land, cemetery, green tract of land, the water surface is lower than those of other land uses.
- ③The ground surface temperature of the vacant land and the surface of the water is higher than that of other land use in the data of p.m. 9 o'clock, but large difference isn't seen in the ground surface temperature of other land uses.
- ④The variation of the ground surface temperature by the land use in the suburban area is larger than in the urban area.
- ⑤Generally the surface temperature of the urban area is about 1-2°C higher than the surface temperature in the suburban area in the nighttime and wintertime. The ground surface temperature of the water surface in the urban area is considerably higher than that in the suburban area in the nighttime and wintertime.
- ⑥Negative correlation was obtained in the relation between the ground surface temperature and NDVI in the part of the land except water surface.

References

- 1) Asia Air Survey Company (1994): The examination inquiry of investigation document of heat island countermeasure in Osaka City, Bureau of Environment and Public Health, Osaka City
- 2) Earth Observation Center, National Space Development Agency of Japan (1990): Revised edition of Landsat edition of the handbook of the earth observation data use, Foundation of Remote Sensing Technology Center of Japan
- 3) R.R.NEMANI and S.W.Running (1988): Estimation of Regional Surface Resistance to Evapotranspiration from NDVI and Thermal-IR AVHRR Data, Journal of Applied Meteorology, Vol.28 pp.276-284