Forest Monitoring Using Satellite Remote Sensing

Ken-ichiro MURAMOTO

Department of Information and Systems Engineering, Kanazawa University, Kanazawa 920-8667, Japan

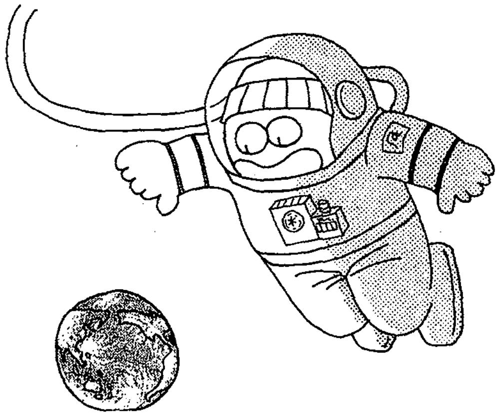
e-mail: muramoto@t.kanazawa-u.ac.jp

Abstract Remotely–sensed images of the Earth provide a valuable source of information concerning the nature and variability of the land and sea surfaces of the world. Since these images are available in digital form, it is natural to use a computer to process and display them. This article provides an introductory and comprehensive review of remote sensing techniques to study of forest monitoring. In many cases, real images taken from a satellite and a helicopter are used to illustrate processing concepts.

1. Introduction

The first human journey to the surface of the Moon began at Kennedy Space Center, Florida with the liftoff of Apollo 11 on a Saturn V booster on 16 July 1969. On July 20, 1969, after a four day trip, the Apollo astronauts arrived at the Moon. Pictures of the earth taken from the moon showed us how unique and beautiful our planet was and how fragile and alone it looked in space(1).

Forests cover large areas of the global land surface. Forests contribute to the fundamental ecological processes which keep the planet in a state of equilibrium. Destruction of the forests will lead to critical damage such as deterioration of watersheds, increased erosion, uncontrolled runoff, flooding and possible subsequent drought in the low lands and depletion of crops. Trees also remove carbon dioxide (an important greenhouse gas) from the air in the process of photosynthesis.



Humans affect forests at many scales: from regional to global level. Management of forested lands is important.

Remote sensing is a useful tool for obtaining data over large areas. And it also provides surface data consistently and repeatedly. However, there are problems in methodology and accuracy to overcome for the technique to be utilized successfully. Therefore, ground surveying data are still necessary when applying remote sensing techniques.

2. Role of Forest

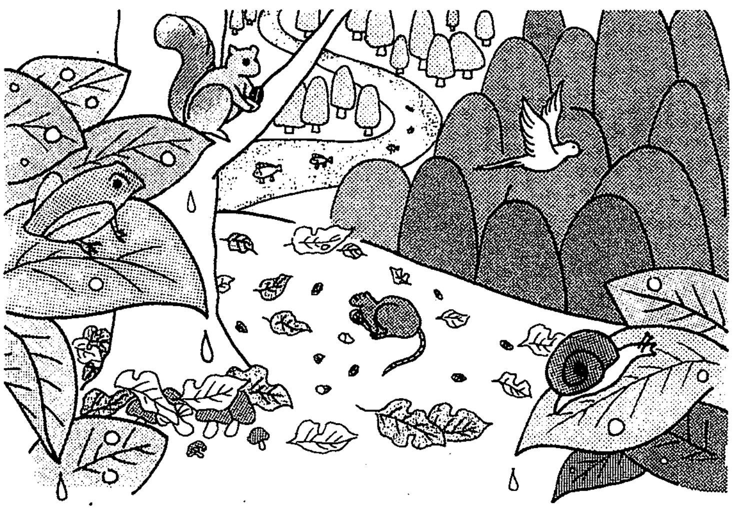
Forests are areas where trees are the dominant vegetation. Forests have always been important to people. In addition to wood products, forested lands provide protective benefits.

Forests contain at least two-thirds of the earth's terrestrial species. Plant diversity ensures a sufficiently wide range of tree species.

Forests make rain locally and keep landscapes moist in periods of drought. They prevent desertification and natural disasters caused by flooding and erosion. Forests regulate water supplies. They collect, store, filter and re-circulate the water.

Forests, with their soils, contain two to three times the amount of carbon currently held in the atmosphere. They process each year through photosynthesis and respiration an amount of carbon equivalent to 15-20%. When a tree is cut and burned, the carbon that was stored in the tree trunks joins with oxygen and is released into the atmosphere as carbon dioxide (CO_2).

The key to forest management is sustainability. Development could be sustained only if human activities operate within the reality of resource limitations and carrying capacities of ecosystem.



3. Satellite Remote Sensing

The modern era of earth remote sensing began with the first Landsat Multispectral Scanner System (MSS) in 1972. This satellite platform operated in near-circular, sun-synchronous, near-polar orbits at an altitude of 915 km, circling the earth every 103 min, completing 14 orbits per day and viewing the entire earth every 18 days. The characteristics of the sensor were multiple spectral bands from 0.5 to 1.1 μ m, with reasonably high spatial resolution (80 m) and large area (185 km$\times$185 km). Since 1972, we have seen four additional MSS systems, as well as the Landsat Thematic Mapper (TM) in 1982 and 1984 with 30 m spatial resolution and 7 spectral bands.

In principle, remote sensing systems can measure energy emanating from the earth's surface in any sensible range of wavelength. Fig.1a shows principles of the geometric relationships among the source, target, and sensor that apply to all terrestrial remote sensing. Fig.1b shows the spectral irradiance from the sun at the edge of the atmosphere. The spectral distribution of radiant energy emitted by the earth peaks in the thermal infrared wavebands at 9.7 μ m. As the sun's energy is attenuated by the atmosphere before illuminating the terrain, a small amount of the irradiance is actually reflected by the terrain in the direction of the satellite sensor system. The reflectance detected by sensor is varying dependent on the wavelength.

Satellite images are digital images recorded from specific spectral regions. A crucial assumption in satellite remote sensing is that cover types are spectrally separable. For example, water, vegetation, soil have different characteristic reflectance patterns.

4. Analysis of Remotely Sensed Data

When image data is available in digital form, spatially quantised into pixels and radiometrically quantised into discrete brightness value levels.

4.1 Color composites

When the data consists of a large number of bands such as those produced by the Landsat TM, it would provide an additive color image. Additive color composites from various TM band combination are presented in Fig. 2. A natural color image is produced from bands 1, 2, and 3, placed in the red, green, and blue, respectively (Fig. 2b). A color infrared color composite of TM bands 4, 3, and 2 is displayed in Fig. 2c. Healthy vegetation shows up in shades of red.

4.2 Vegetation index

Vegetation is the plant cover in an area. Vegetation indices are empirical formulas designed to emphasize the spectral contrast between the red (R) and near-infrared band (NIR) regions of the electromagnetic spectrum. Several vegetation indices have been developed.

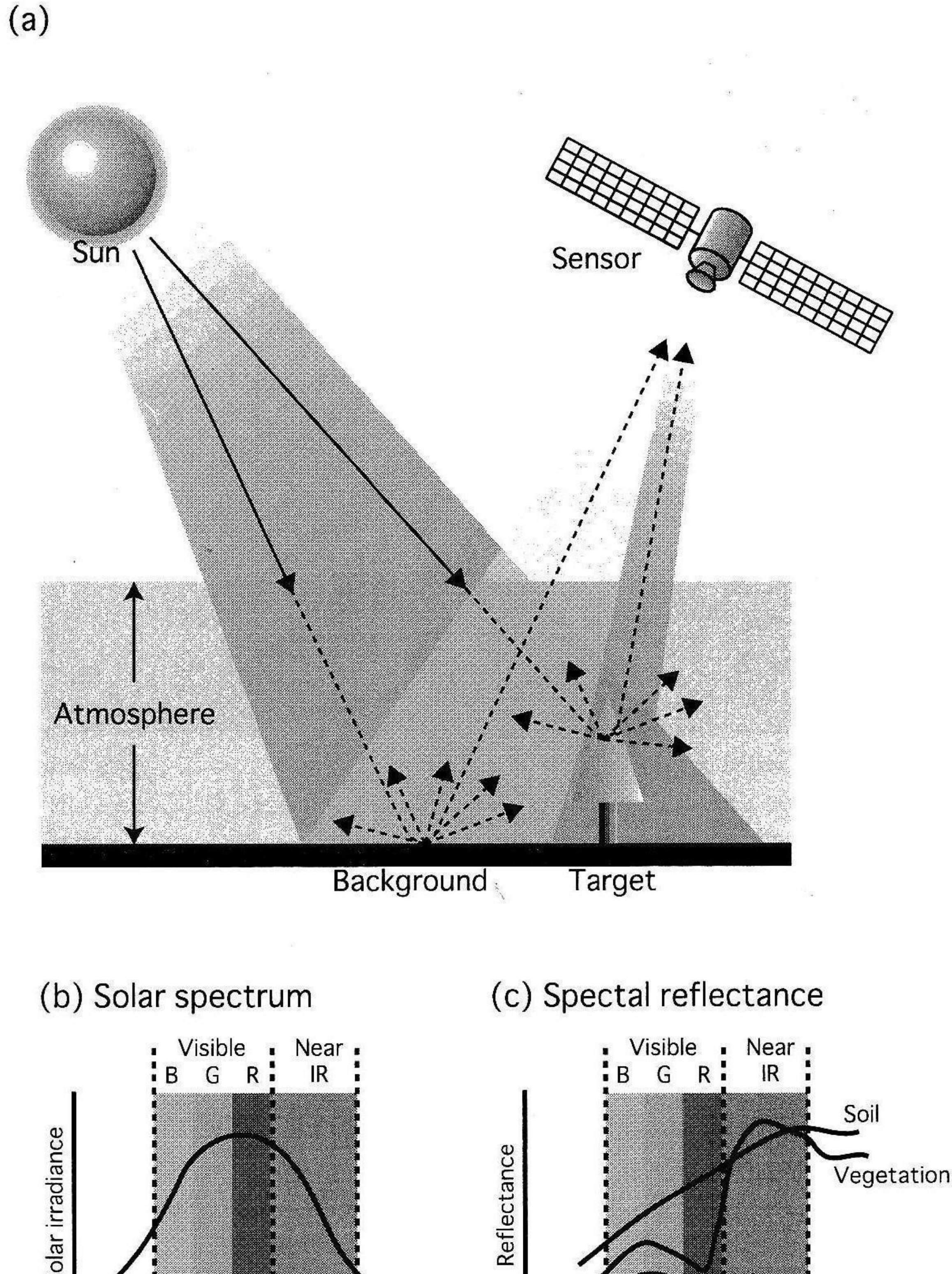


Fig. 1 (a) Principles of the geometric relationships among the source, target, and sensor that apply to all terrestrial remote sensing. (b) Solar spectral irradiance which arrives at the top of the atmosphere (c) Typical spectral reflectance curve of water, vegetation and soil.

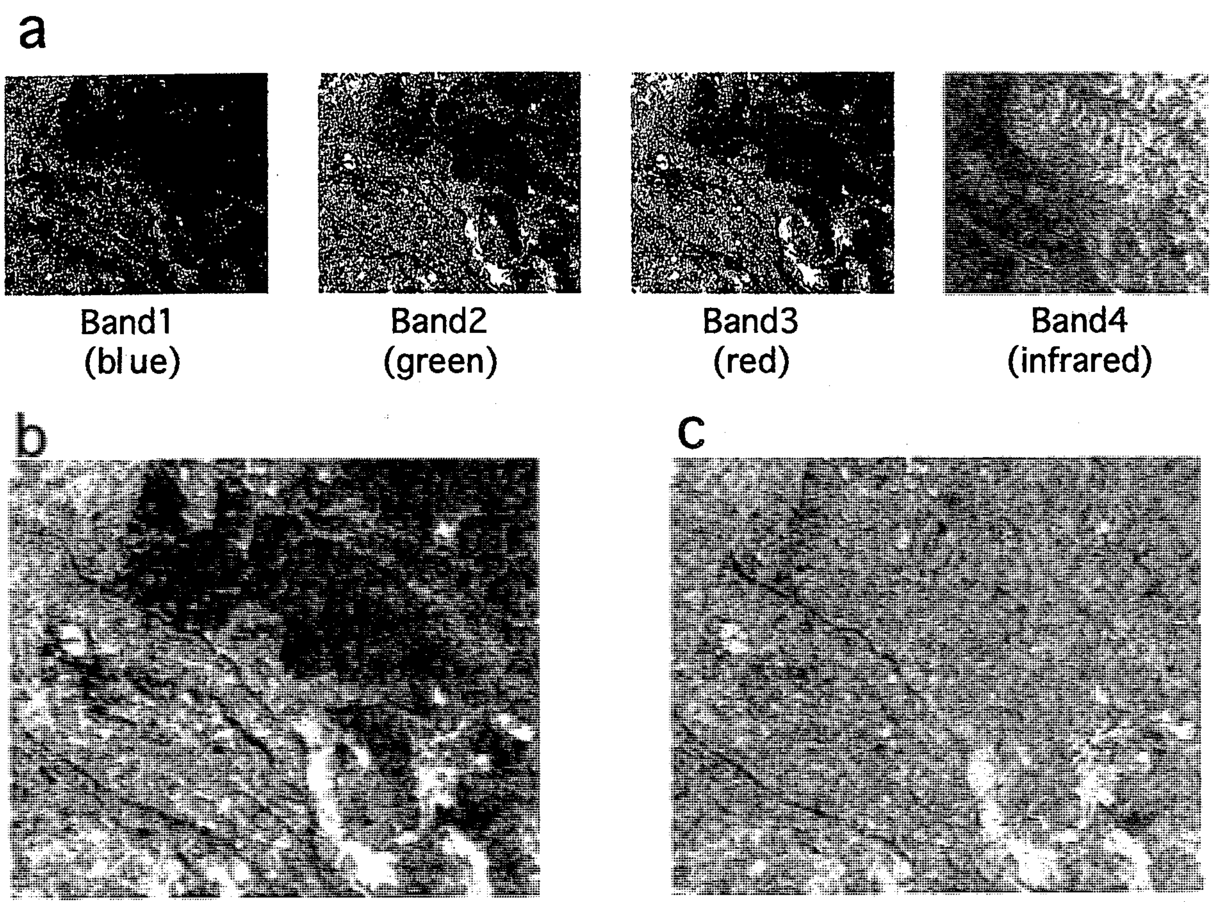


Fig. 2 Color composites of Landsat TM data around Kanazawa (a) Landsat TM data. (b) Composite image made by computer from TM bands 3, 2, and 1, placed in the red, green, and blue (RGB), respectively. (c) TM bands 4, 3, and 2 (RGB).

One of the most widely used vegetation indices is the normalized difference vegetation index[(2),(3)], that is NDVI = (NIR – R) / (NIR + R). The NDVI enhances vegetation and reduces variations caused by changes in irradiance, which varies as a function of solar elevation. It produces an index value ranging between –1 (no vegetation) and +1 (completely healthy green vegetation cover). Comparisons of NDVIs from different times can yield information on variations in vegetation productivity and condition.

5. Observation of Vegetation From Ground, Helicopter and Satellite

The visible and near-infrared reflectance are commonly used for the identification and characterization of the vegetation. The reflectance data obtained at higher altitudes is a kind of average over a certain extension of area. Therefore, in the interpretation of the remote sensing data, knowing the difference between the data obtained at different scales and distances is important. Fig. 3 presents the outline of simultaneous satellite, airborne and on site measurements. Vegetation spectra will be measured at visible and infra-red bands at different altitudes. The Landsat TM instrument is collecting data with a surface resolution of 30 m over the site. The helicopter hovers above the site at an altitude from 150 to 300 m and acquires radiometric and image data. The tower is a platform to set up various instruments for close range observations. The goal of this experiment is to perform all measurements simultaneously when the Landsat satellite flies over the area.

The higher resolution of the aerial photograph as compared to the lower spatial resolution of the satellite imaginary, provides additional elements, such as size, shape, structure of smaller detail such as crowns and part of tree crowns, which can be essential for recognition and measurements.

Fig. 4a shows a visual satellite image around the center of Kanazawa city. Two circles show the Kenrokuen garden, and Kakuma campus of Kanazawa University. Fig. 4b shows vegetation activities (NDVI) caliculated using satellite data. Although there are a few vegetations around the center of Kanazawa city, Kenrokuen garden is covered by green vegetation. On the contrary, though mountainous area is covered by green vegetation, there are few forests at Kakuma campus of Kanazawa University. Fig. 5 shows the same areas photographed from helicopter. From this observation distance, individual trees in each area can easily distinguish. The general relocation plan of Kanazawa University to Kakuma area is now continuing. There is a large construction area depleted of vegetation.

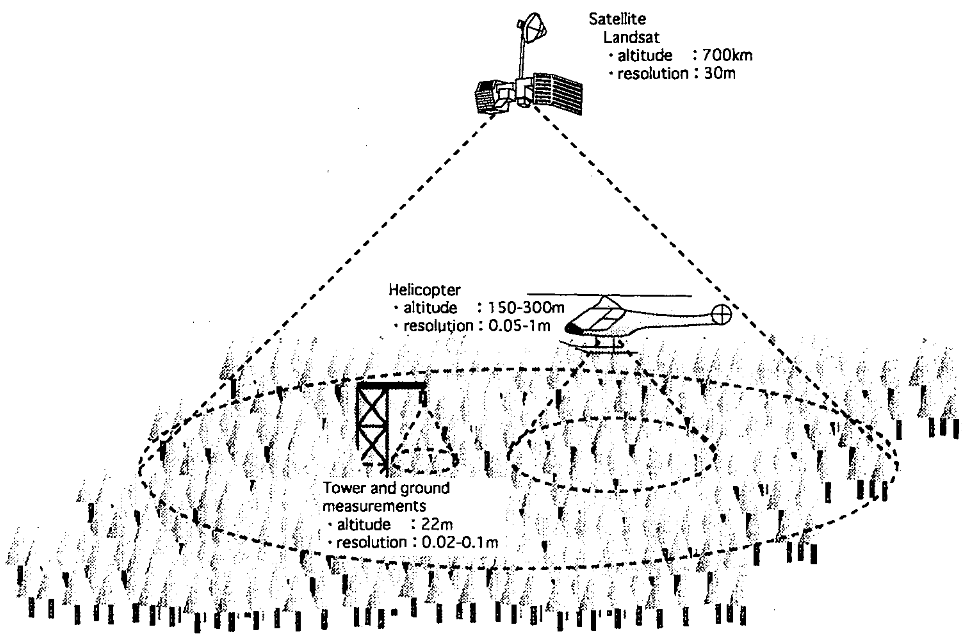


Fig. 3 Outline of simultaneous satellite, airborne and on site measurements. Vegetation spectra will be measured at visible and infra-red bands at different altitudes.

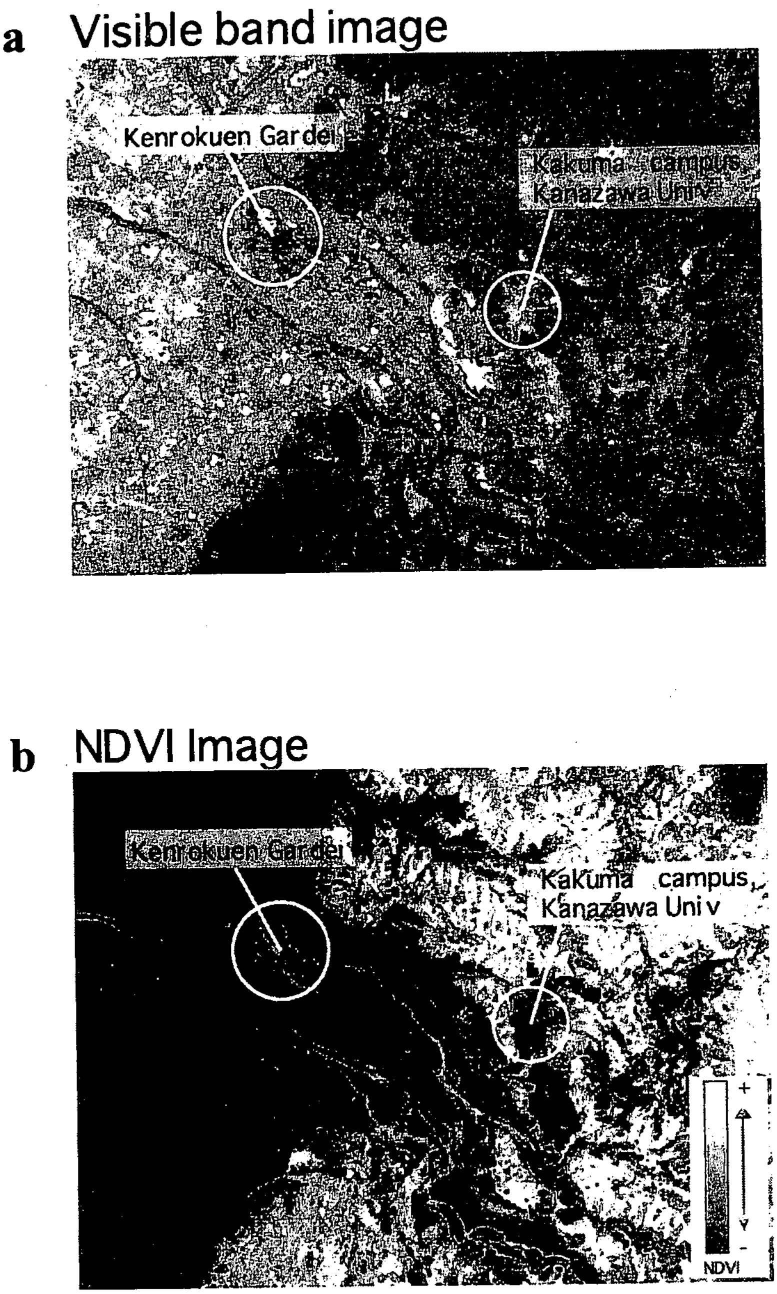


Fig. 4 (a) A visual satellite image around the center of Kanazawa city in May 2000. Two circles show the Kenrokuen garden, and Kakuma campus of Kanazawa University. (b) Vegetation activities (NDVI) image using satellite data. As the gray level becomes lighter, vegetation activity increases.

6. Conclusion

Different data sources, like land survey, aerial photography and satellite imagery can be used depending on the level of detail required and the extension of the area under study. There still, however, seem to be gaps in the application of remote sensing techniques for forest monitoring. I expect that this seminar will contribute to be a better understanding of se of remote sensing imagery for forest monitoring.

a

b

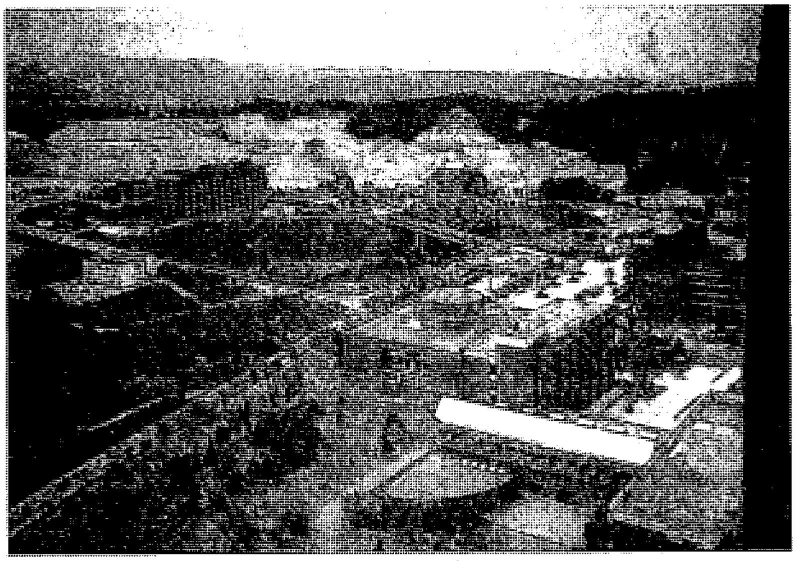


Fig. 5 The same areas photographed from helicopter in August 2000. (a) The Kenrokuen garden. (b) Kakuma campus of Kanazawa University.

References

(1) NASA photo ID AS11-44-6552, http://nssdc.gsfc.nasa.gov/planetary/lunar/apollo_11_30th

(2) F. J. Kriegler, W. A. Malila, R. F. Nalepka, W. Rechardson : Preprocessing transformations and their effects on multispectral recognition, Proc. 6th Int. Symp. Remote Sensing Environment, 97-131, 1969.

(3) J. W. Rouse, R. H. Haas, J. A. Schell, D. W. Deering, J. C. Harlan : Monitoring vegetation systems in the great plains with ERTS, 3rd ERTS Symposium NASA SP-351, 1, 309-317, 1973.