A Study on Environmental Monitoring of Open-cut Mining Ground Using Remote Sensing Technique

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Abstract: Since open-cut mining excavates gradually from the top of the mountain, vegetation planting is needed to reduce negative environmental impact on the surrounding environment. Accordingly, this study aimed at performing the environmental monitoring of the open-cut mining ground using the satellite remote sensing technique.

As the research technique, in order to grasp the environmental change around the open-cut mining ground, NDVI (normalized difference vegetation index) was calculated, and every year change of the vegetation activity was analyzed. The results of the study showed lower vegetation activity in the open-cut mining ground compared to the surrounding areas and suggested the need for closed monitoring by remote sensing techniques.

Keywords: Open-cut Mining, Environmental Monitoring, Vegetation Activity.

1. Introduction

Limestone and gravel are the few natural resources available in Japan obtained through open-cut mining. In different locations of Japan stone pit of limestone and gravel are available with an average annual production of 200 million ton and 600 million ton, respectively. In open-cut mining bench cut formula of excavation is followed where steps as big as 100 meters are dug in the mining process. In other countries of the world the same procedure is also followed in open-cut mining for mining of metallic resources, such as iron and copper. Since open-cut mining excavates ground surface and generate wastes, proper care should given for the surrounding environment. Thus after mining is completed various measures such as covering soil with vegetation and planting, are needed. Therefore, after the completion of open-cut mining environmental monitoring of the surrounding environment is essential to reduce negative environmental impact.

Accordingly, this study aimed at performing the environmental monitoring of the open-cut mining ground using the satellite remote sensing technique. As a case study, we have selected Mount Kawara (having three separate mountain peaks: 1, 2 and 3) in the Chikuho District, Fukuoka Prefecture, Japan as the investigation area. The location of the investigation area is shown in **Fig. 1**.

2. Methods

As a research methodology, in order to grasp the environmental change around the open-cut mining ground, NDVI (normalized difference vegetation index) was calculated and annual change of the vegetation activity was analyzed from satellite data.

Images used in the analysis are obtained from LANDSAT5/TM. The details of the images used are shown in **Table 1**. For the purpose of the analysis the mountain is divided into three areas: the hillside of Mt. Peak 1,where open-cut mining is performed and Mt. peaks 2 and 3, where open-cut mining is not performed (see **Fig. 2**).

The procedure for calculating the NDVI is shown by the flowchart in **Fig. 3**. The following formula is used for calculating NDVI:

$$NDVI = \frac{BAND4 - BAND3}{BAND4 + BAND3} \qquad (1)$$

BAND3: Red infrared wavelength
BAND4: Near infrared wavelength

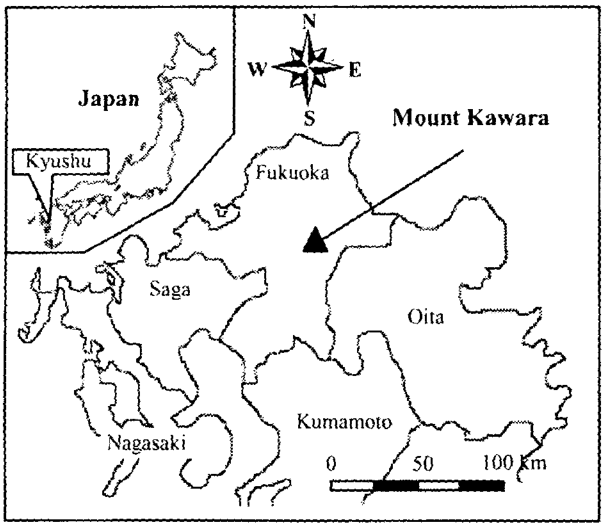


Fig. 1. Location of the study area.

Table 1. The satellite images used in this study.

Date (yyyy/mm/dd)	Time (hh:mm)	Angle of Elevation	Azimuth Angle
1986/05/12	10:18 AM	59.49	112.62
1987/05/12	10:17 AM	59.83	111.30
1988/04/15	10:23 AM	54.54	124.61
1994/03/31	10:14 AM	47.64	127.01
1995/05/05	10:01 AM	55.00	112.00
1996/04/05	10:02 AM	47.69	122.08
1997/04/24	10:21 AM	56.40	120.94
1998/04/27	10:30 AM	59.00	123.00
1999/04/30	10:32 AM	60.00	123.00

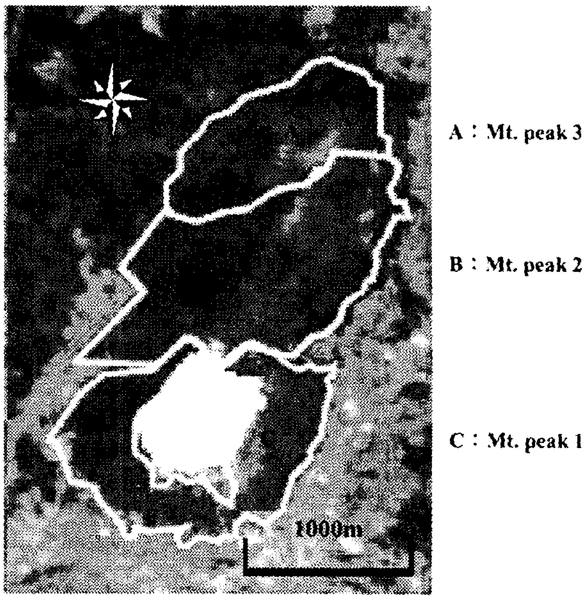


Fig. 2. Mount Kawara. (1986/05/12)

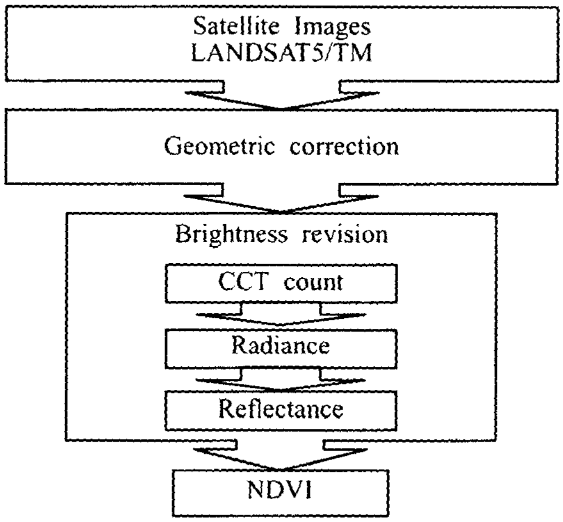
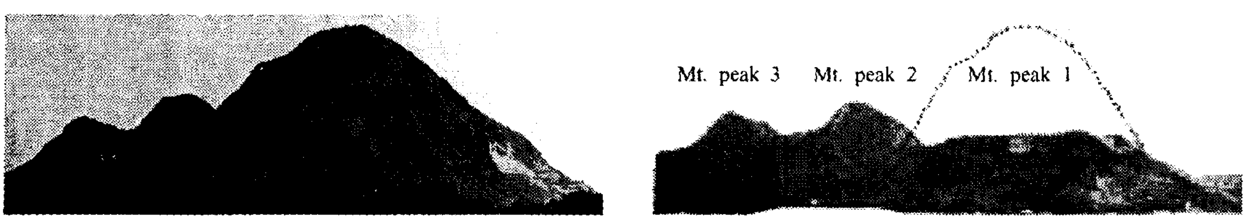


Fig. 3. The flowchart of this study.

3. The Present Vegetation Condition of Kawara Mountain

The Kawara Mountain is located in the southernmost tip of Fukuchi Mountain Range located in the Chikuho District, Fukuoka Prefecture, where almost all the mountain contains limestone. It is divided into three mountain peaks from north to south and named as Mt. peak 1, Mt. peak2 (altitude is 468m) and Mt. peak 3 (altitude is 511m). Almost all the portions of the west side slope of the mountain are rocks, and there is large-scale cliff of 60 degree angle. Although there is a slope in the eastern side, it is not so steep as the western side and contains soil. Since 1935 the open-cut mining of limestone started and Mt. Peak 1 having altitude of 492m at that time are now reduced to 270m as shown in **Fig. 4**. Presently the summit area of Mt. peak 1 is about 360,000m^2.

In the Kawara Mountain, the impact of monsoon and the flow of sunshine are different in the east and west sides. This difference leads to the growth of different group of trees in the east and west part of the mountain. East side slope contains mostly *Quercus glauca* (oak) trees that is also called evergreen tree, and the west side *Carpinus turczaninovii* trees (birch) which is also called deciduous tree. Both of these trees are very common in limestone mines.



(a) 1930 (b) 2003

Fig. 4. Comparison of Kawara Mountain between 1930 and 2003.

Mt. peaks 2 and 3 of Kawara Mountain have the highest concentration of trees in Fukuoka Prefecture. Moreover, in Kawara Mountain many plants peculiar to the limestone mine are growing. Also *Miscanthus sinensis* (bamboo grass) and *Pleioblastus chino* var. *viridis* (Japanese pampas grass) are seen abundantly in north half side of summit of Mt. peak 2, and the whole of Mt. peak 3. No measures are yet taken to cut or burn them, which is hindering the growth of other plants in the area.

4. Results

Fig. 5 shows yearly change of the average value of NDVI of Mt. peak 1, Mt. peak 2 and Mt. peak 3. In Mt. peak 1, the NDVI value is low as compared to Mt. peaks 2 and 3. Both Mt. peaks 2 and 3 are showing almost the same NDVI value. Moreover, Mt. peaks 1, 2 and 3 all are showing the same trend of yearly change in NDVI.

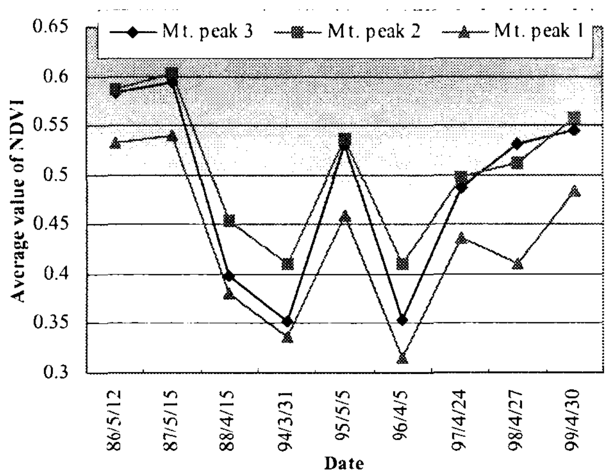


Fig.5. Yearly change of the average value of NDVI.

However, the difference of NDVI of Mt. peaks 2 and 3 is getting larger in 1988, 1994 and 1996. About yearly flow of change, decrease tendency is observed from 1987 to 1994. Then, although it increases in 1995 and decreases in 1996, increase tendency is seen afterwards.

Fig. 6 is the subtracted images of NDVI of the whole Kawara Mountain in 1986, 1995, and 1999. Reduction of an overall NDVI value can be seen in 1986 and 1995. Although the NDVI value is decreasing in the east side in 1986 and 1999, it is increasing in the western part of the mountain. The increase in an overall value of the NDVI can be seen in 1995 and 1999. Especially, the increase in western side is large.

5. Discussion

From the results of the yearly change in NDVI value, it is observed that in Mt. peak 1, which is an open-cut mining ground, vegetation activities are lower compared to Mt. peaks 2 and 3. Due to open-cut mining and discharge of mine waste, the land system of the Mt. peak 1 is destroyed. This had led to the abrupt reduction of trees and vegetation consequently. On the other hand, Mt. peaks 2 and 3 have lot of birches and thus also having a positive impact on the vegetation activation of the mountains.

The big difference had appeared in NDVI value of Mt. peaks 2, and 3 in 1994 and 1996. Furthermore, in Mt. Peak 2 there is difference in NDVI value between the east and west, but Mt. peak 3 shows comparatively uniform yearly change. Since the images are taken in between March – April, when the evergreen trees still have the leaf, the NDVI value got higher in places where more of these trees are available.

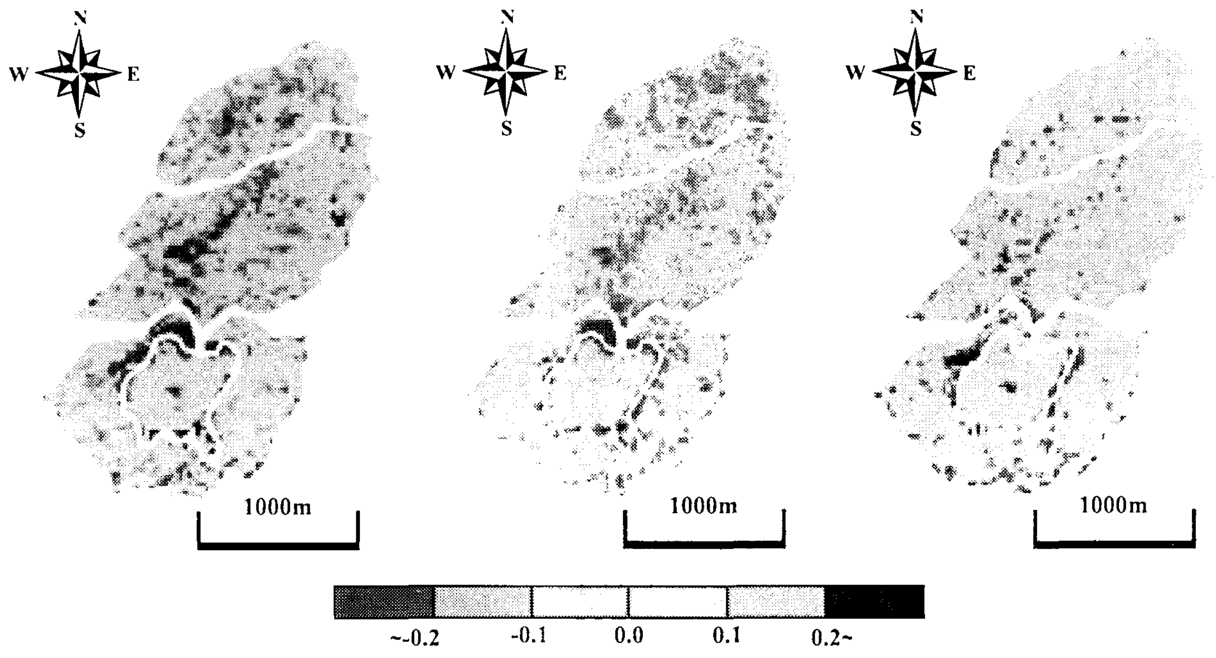


Fig.6. Subtracted images of NDVI (left: 1986-1995, center: 1986-1999, right: 1995-1999).

The NDVI value showed an increasing tendency from 1997 to 1999 in all of the mountain peaks. It should be pointed here that value of the NDVI was decreasing in 1988, 1994 and 1996. This happened not only in case of the Kawara Mountain but also in the surrounding area the NDVI value was lower at that time. Thus this fall in NDVI value might be due to the difference in observation period of satellite images.

Regarding the whole Kawara Mountain, the NDVI image shows that vegetation activity was increasing in the west side and decreasing in the east side. The Kawara Mountain has different type of trees growing in the east and west sides of the mountain. Again in the north half side of summit of Mt. peak 2, and the whole of Mt. peak 3 there are Japanese pampas grass which are not burned or cut down to help the growth of other trees. This had negative impact on the vegetation activities of these areas.

6. Conclusion

In this study we tried to monitor the environmental changes of the open-cut mining ground using satellite remote sensing. As the open-cut mining activities are conducted by the mining company, it is their responsibility to monitor the environment surrounding such mines. However, we can use satellite remote sensing for monitoring such vast area with lower comparative cost. In this respect the increased use of remote sensing for the monitoring of open-cut mining is expected in future.

References

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