Study on Plant Damage Caused by Mt. Usu Eruption Using Remote Sensing

Shigeru TAKAHATA, Kazuya MIYAMA

Abstract

The present paper deals with the plant damages caused by ash-fall from Mt. Usu (Hokkaido island, Japan). The data were obtained with multispectral scanner in an aeroplane at an altitude of 3,650m, and were analyzed with the Program for Image Analysis (PIA). Analysis of large area observation led to a classification of plant damages into three grades; heavy, medium and light. The total classification performance was 70.3 %. The digital analysis of aircraft multispectral scanner data is concluded effective for plant demage survey.

Preface

Mt. Usu is located in the south of Hokkaido island, and erupted during 7th to 13th of August, 1977. Volcanic ash and pumice spread 12,000 m in height and 300km in width and accumulated several centimeters over the close surrounding areas. The piedomont of Mt. Usu had been covered with thick forest which had regrown since the last previous eruptoio in 1910. The forest vegetation consisted of deciduous broad leaved trees, mainly Populus maximowiczii, Quercus crispula Tilia japonica and Acer mono. The plantation of Abies sachalinensis and Larix Kaempferi extended widely on the hill areas near Mt. Usu.

Toya Village (10km north of Mt. Usu) has 13km^2 of agricultural fields, and produces mainly potato, corn, red been, vegetables and paddy rice.

Mt. Usu has shown periodic activities . In recent years, it erupted in the years 1663, 1769, 1822, 1853 and 1910. The first eruption the 1977 activity occurred at 9:30, August 7. The wind was blowing north at 10 m/s. Thus the volcanic ash and pumice from this eruption fell thick over the southern foot of Mt. Usu. The second big eruption occurred at 15:00 the next day. Since strong south wind was blowing at that time, ash was carried far toward the northern foot of Mt. Usu. Rain started soon after the eruption and carried down fine ash with rain drop. The ash adhered onto leaves of plantation like mortar.

Fig 1 illustrates damages of plants caused by volcanic action of Mt. Usu.

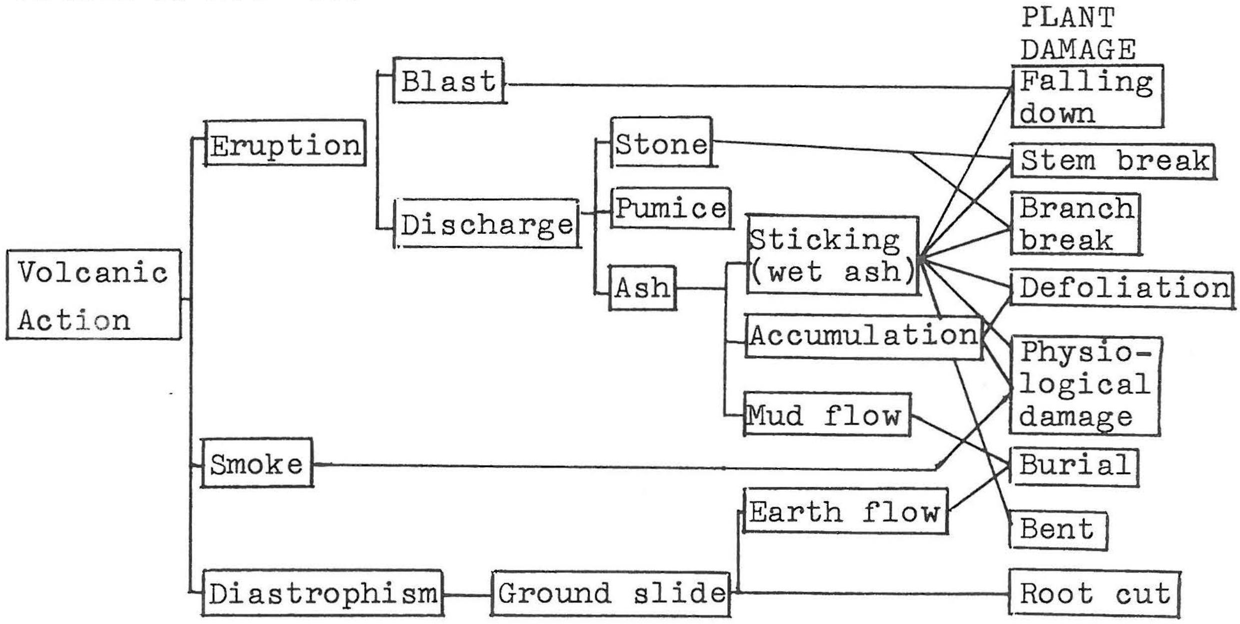


Fig 1 Relation of Volcanic Action and Plant Damage

Method

The process of analysis is illustrated in Fig 2. Classification was carried out by the most likelihood method.

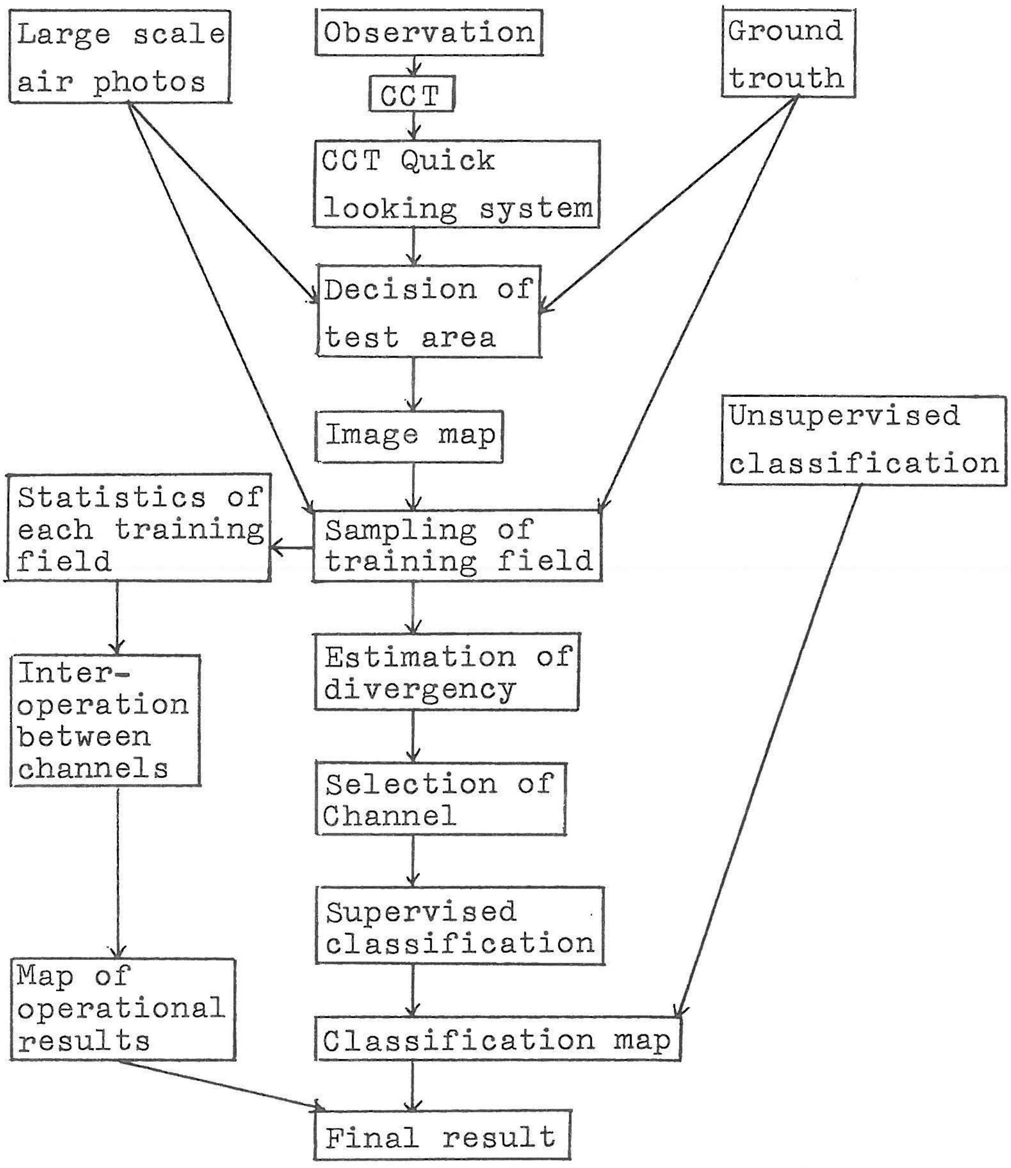


Fig 2 Study Flow

Date Acquisition

We acquired the following data which we used for the analysis of plant demage.

	Date	Agency	Code Name of Operation	Scale	Type
Before Eruption	8.21, 1972	NASA	LANDSAT 1		MSS
	7.01, 1973	NASA	LANDSAT 1		MSS
	5.30, 1977 6.04, 1977	Geographical Survey Inst.	CHO-76-12 CHO-76-8	1: 10,000	Color photo
After Eruption	8.12, 1977	NASA	LANDSAT 2		MSS
	8.14, 1977	KOKUSAI Aerial Survey Ltd.	K-773	1: 20,000	MBC
	8.30, 1977	JAFSA			MSS
	9.17, 1977	NASA	LANDSAT 2		MSS
	9.22, 1977	ASIA Aerial Survey Ltd.		1: 8,000	Color photo

Table 1 Data

Large scale color photographs were used to interprete the ground conditions. In the midst of eruption at August 12, LANDSAT 2 had just passed over the Usu area. We could recognize the smoke from Mt. Usu on the LANDSAT 2 data, but we could not observe the ground conditions on account of thick cloud. Just after the eruption, multi-band photographs were taken over the Usu area and we could observe the damaged surface by means of an additive color viewer. Japan Foundation for Shipbuilding Advancement (JAFSA) takes an air-borne MSS data which were recorded on 21st and 30th of August.

Results

1. Interpretation of Aerial Photographs

The ground trouth can be uncovered by correct interpretation of the large scale aerial photographs. We were able to identify the kind of crops in the color photographs, eventhough they are buried under the ash (Table 2).

Table 2 General Key to Identification of Ash-covered Fields (Color Photography, Scale 1:10,000)

Symbol	Crops	Key to identification by means of color and texture of photography and field size
A	Red been	Dark gray, smooth texture, small size
B	Sugar beet	Light gray, smooth texture, large size
C	Corn	Light dark gray, distinct and vertical crop line
P	Potato	Light gray, clear couble trace of tractor wheels
As	Asparagus	Light dark green, distinct outline of field, located along river
K	Kidney been	Greenish gray, rough texture, medium size
Y	Vegetables	Light gray, gradual density pattern caused by different harvesting time, small size
G	Pasture	Light gray spotted with dark patches, flat texture
Z	Bare soil	Yellowish brown

2. Classification of Damaged Fields by MSS Digital Analysis

An area of 1km X 1km in Kagawa district was se;ected as a test area. This is a typical, flat farmland. Using data from channels 5,7, 8, 9, 10 and 11 the ground conditions were classified into five categories by the unsupervised most likelihood method. According to this classification, the damaged fields correspond to three of them: 1) Those which partially retains green --- paddy rice, asparagus (damage especially light), sugar beet (quick regrowth) and kidney been (supported by props); 2) Those which shows no sign of green --- potato (completely buried); 3) Those which looks impure green --- corn, red been (harf buried).

Other two are "Lake" and "Residental area or Bare soil". The supervised, most likelihood classification method was applied using twelve categories. The optimum combination of channels were decided as that of 7, 9 and 11 based on the interclass divergence. Average performance of the classification was 75.5 %.

Table 3 Performance of Classification, Kagawa district

Category	Number of pixels	Training field											
		Performance %											
		1	2	3	4	5	6	7	8	9	10	11	12
1. Beet	109	(89.0)	0.9	4.6	4.6	0.9	0	0	0	0	0	0	0
2. Rice	12	0	(91.7)	0	8.3	0	0	0	0	0	0	0	0
3. Asparagus	37	5.4	0	(83.8)	8.1	0	2.7	0	0	0	0	0	0
4. Kidney been	73	1.4	8.2	2.7	(87.7)	0	0	0	0		0	0	0
5. Corn	63	0	0	1.6	0	(60.3)	23.8	7.9	0	0	6.3	0	0
6. Red been	65	0	0	1.5	0	27.7	(64.6)	0	0	0	4.6	1.5	0
7. Potato	275	0	0	0	0	9.5	0.7	(83.6)	1.8	0.7	3.3	0.4	0
8. Bare soil	134	0	0	0	0	0	0	3.0	(84.3)	7.5	1.5	3.7	0
9. Residences	45	0	0	0	0	0	0	2.2	28.9	(53.3)	6.7	8.9	0
10. Forest (flat)	18	0	0	0	0	5.6	16.7	5.6	5.6	11.1	(55.6)	0	0
11. Forest (slope)	270	5.6	0	0.7	1.5	3.7	1.5	5.9	8.9	8.1	11.9	(51.9)	0.4
12. Water	9	0	0	0	0	0	0	0	0	0	0	0	(100)

3. Classification of Toya District by MSS Digital Analysis

An area of 5.5km X 9km, located about 10km north of Mt. Usu was chosen as the test area. This area suffered 1 to 10cm of ash-fall. The unsupervised classification failed to identify different degrees of ash-fall. This is because the classification of field and forest crossed each other. The supervised classification method worked by using 7, 8 and 10 channels. Table 4 shows successful classification of different degrees in damage caused by ash-fall.

Table 4 Performance of classification, Toya District

Category	Depth of ash-fall	Dmage grade	Number of pixels	Performance %								
				1	2	3	4	5	6	7	8	9
1. Field A	5cm	Heavy	84	(61.9)	11.9	0	19.0	3.6	0	0	3.6	0
2. Field B	2	Medium	105	13.3	(58.1)	14.3	1.0	2.9	8.6	0	1.9	0
3. Field C	1	Light	60	0	20.0	(78.3)	0	0	0	1.7	0	0
4. Forest A	10-5	Heavy	84	13.1	0	0	(64.3)	2.4	0	0	20.2	0
5. Forest B	3	Medium	75	6.7	0	0	0	(88.0)	2.7	2.7	0	0
6. Forest C	1	Light	96	2.1	4.2	2.1	0	0	(91.7)	0	0	0
7. Forest F	2	Medium	78	0	0	6.4	0	1.3	0	(92.3)	0	0
8. Town	5		40	2.5	0	0	20.0	0	0	-	(77.5)	0
9. Lake			60	0	0	0	0	0	0	0	0	(100)

The spectral value of ch. 7 and 10 was converse in connection with the depth of ash-fall. Fig 3 shows this relation. The difference in spectral values of channels 10 and 7 has a highly negative correlation with the depth of as-fall.

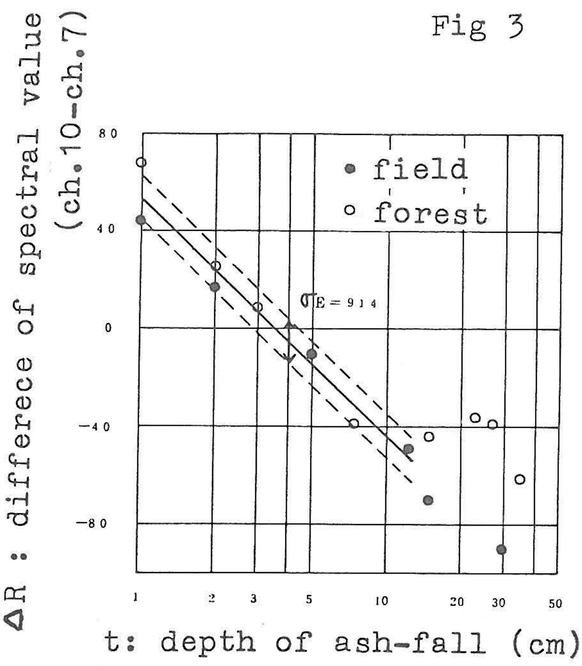
$$\Delta R = -97.5 \log t + 53.8 \quad (1 < t < 12.5\text{cm}) \qquad r = -0.976$$

ΔR : Difference in CCT counts of ch. 10 and 7.

t : Depth of ash-fall (cm)

r : Correlation coefficient

Fig 3   correlation with spectral value (ch.10-ch.7) and ash-fall depth



Conclusions

We often suffer from the natural disaster such as volcanic activities, floods, typhoons and droughts. It is most important to recognize the extent of disaster immediately and extensively as soon as it happens. For this purpose, the remote sensing technique is effective. In the caurse of this study, we prepared a map of plant damages baced on the MSS data, and the map was utilized in the planning of restration and also in the compensation problems.

The reliability of damage map depends on the timing of observation. If we can obtain the data immediately after the incident, the result of analysis is most accurate. We emphasize the necessity of establishing a dynamic system which can handle the emergency without loss of time.

References

1)Hokkaido Agric. Exp. Sta. (1978); Report of Surveying on the Agricultural Disasters Caused by the 1977 Eruption of Usu Volcano, Hokkaido, Japan.

2) Maesaki, T., Suzuki, H. (1979); Classification of Forest Tree Damage Caused by the Eruption of Usu Volcano Using MSS Data, Bulletin of Hokkaido Forest Exp. Sta. , No 17.

3) Takahata, S., others (1978); Studies on the Agricultural Damage Caused by Mt. Usu Eruption Using Remote Sensing, Res. Bulletin of Hokkaido Agric. Exp. Sta. No123.

4) Miyama, K., Takahata, S.and Fukuhara, M. (1979); A Digital Analysis of Agrecultural Damage Caused by Mt. Usu Eruption Using Aircraft MSS Data, Journal of the Japan Soc. of Photogrammetry, Vol 18, No 1.