1-1-1979

Extraction of Soil Information from Vegetated Area

Michikazu Fukuhara

Shigechika Hayashi

Yoshizumi Yasuda

Ichio Asanuma

Yasufumi Emori

See next page for additional authors

Authors
Michikazu Fukuhara, Shigechika Hayashi, Yoshizumi Yasuda, Ichio Asanuma, Yasufumi Emori, and Joji Iisaka

Reprinted from

Symposium on Machine Processing of Remotely Sensed Data

June 27 - 29, 1979

The Laboratory for Applications of
Remote Sensing

Purdue University
West Lafayette
Indiana 47907 USA

IEEE Catalog No.
79CH1430-8 MPRSD

EXTRACTION OF SOIL INFORMATION FROM VEGETATED AREA

MICHIKAZU FUKUHARA, SHIGECHIKA HAYASHI,
Hokkaido National Agricultural Experimental Station

YOSHIZUMI YASUDA, ICHIO ASANUMA, YASUFUMI EMORI
Institute of Color Technology/Chiba University

JOJI IISAKA
Scientific Center/IBM Japan

ABSTRACT

Mix or influence of vegetation signal on soil information decrease the performance of soil identification and mapping. This paper describes a simple transformation to eliminate the mix or influence of vegetation reflectance on soil reflectance, and to enhance the soil information.

The usefulness of the transformation were investigated and shown by the channel selection based upon the statistical distance between soil classes and by multispectral pattern recognition. The simple transformation was considered to sensitive to the degree of the soil organic matter contents.

I. INTRODUCTION

On the application of remote sensing technique for identification and mapping of soil condition,there is a limitation that, in an area to be surveyed, only a portion of the soil exposed to aerial view. To maximize bare soil areas, it is necessary to collect the remotely sensed data in the spring,prior to substantial crop growth. Even then, there will be areas of perennial vegetation, winter crops, or cultural development for which no direct soil information will be obtainable from the remotely sensed data.

In order to extract soil information from the vegetated area and to analyze soil condition, the interaction of the vegetation reflectance on the soil reflectance should be eliminated. This paper describe a simple new ratio transformation technique to eliminate the influence of vegetation reflectance on the soil reflectance. The usefulness of the transformation on soil mapping is demonstrated.

II. THEORY

Variations of spectral characteristics due to vegetation growth change, vegetation cover change, and soil condition change can be two-dimentionally expressed by a relationship between red, R, and infra red, IR, spectral bands.

A IR/R reflectance ratio is sensitive to vegetation growth, biomass, and vegetation cover. The IR/R ratio, also, tends to normalize the effects of varying soil type, contents of soil organic matter, and soil moisture.[1]

A more important feature is that, according to increaseing of vegetation cover, the co-ordinate of each soil reaches to a co-ordinate of 100 percent vegetation cover;point P (x=PR, y=PIR), as shown in Fig. 1.[2] PR and PIR are red and near infrared reflectances of the vegetation, respectively. Red and near infrared relfectances, R and IR, of mixed area of soil and vegetation are approximately given as follows;

$$R = c\ PR + (1 - c)\ SR \quad \text{------ (1)}$$

$$IR = c\ PIR + (1 - c)\ SIR \quad \text{---- (2)}$$

where, SR and SIR is red and near infrared reflectances of the soil respectively, and c is vegetation cover. By elimination of c from the equations (1) and (2), following equation are derived;

$$\frac{R - SR}{PR - SIR} = \frac{IR - SIR}{PIR - SIR} \quad \text{----- (3)}$$

Let point P (PR, PIR) be the origin. Then, the equation (3) is rearranged as follows;

$$k = (PIR - IR) / (R - PR)$$

$$= (PIR - SIR) / (SR - PR) \quad \text{--(4)}$$

CH1430-8/79/0000-0242$00.75 © 1979 IEEE

(PIR - SIR)/(SR - PR) is constant for each soil type. Therefore, k can be considered to be an indicator of each soil type.

III. PROCEDURES

A. STUDEY AREA and LANDAST DATA

A test area for this investigation was selected in Tokachi district, Hokkaido (Figure 2). In early June, sugar beets, potatoes, corns, soybeans, azuki beans, winter wheat and grass are in the agricultural fields. The coverage of the grass was 100 percents and that of the winter wheat was 50 - 70 percents. The coverage of the other crops were 0 - 30 percents.

Most of agricultural fields in the area are covered with volcanic ash. The wet soil contains more soil organic matter. The following soils are included in the test area;

Black ando soil with above 15 percents organic matter (WV1)
Black ando soil with 10 - 15 percents organic matter (WV2)
Brown ando soil with 5 - 10 percents organic matter (DV)
Brown alluvial soil with 0 - 5 percents organic matter (AL)

Black ando soil is poorly drained type and has black surface soil and impermeable sub-soil. Brown ando soil is well drained type and has dark-brown surface soil and brownish-yellow sub-soil.

The other classes in the test area are grassland, pastures, marsh lands, needle-leaved forest, broad-leaved forest, sand,urban and water.

Multispectral data were collected over the study area by Landsat 2 MSS on June 11th, 1975. The MSS data had 4 spectral bands.

B. RATIO TRANSFORMATION and SOIL MAPPING

Trainning fields and classes were initially selected. The fields and the classes were refined by clastering. The statistical characteristics for each class were obtained. Figure 3 shows two dimentional plots of CCT counts of red and near-infrared bands (Landsat bands 4 and 7) for main classes. A broken line in the figure shows a loci of the bare soils.

The co-ordinate of the point P was determined by a co-ordinates of a grass field which was 100 percents vegetation cover and had the highest CCT counts in band 7 and the lowest CCT counts in band 5. The co-ordinates of the point P (PR,PIR) was x=10 and y=53 for this study.

Then, the new ratio transformation of equation (4), (53 - band 7)/(band 5 - 10), was computed from Landsat CCT. Additionally, three of ratio channels were also computed. The additional ratio channels were selected based upon our previous study.[3]
Table 1 shows 8 channels of a new work CCT. The channels 1,2,3 and 4 of the work CCT correspond to the Landsat bands 4,5,6, and 7, respectively. The channel 5 of the work CCT is the new transformed channel the equation (4) for enhancing soil types and conditions. The channel 6 is for enhancing vegetated area. The channel 7 corresponds approximately to the selected ratio, (V/IR), for mapping soil features.[4]

The best subset of 4 channels were determined with the theory of a statistical distance.[5] This sllows the assignment of priorities according to the need to correctly distinguish the soil types.

Finnally, a soil map was genetated by using computer-implemented pattern recognition technique, i.e.,supervised.[6] The computed soil map was evaluated with respect to their correspondence to conventional soil survey map.

IV. RESULTS & DISCUSSION

A. EFFECTS OF k ON SOIL ANALYSYS

A conventional soil survey map of the test area prepared by ground observation[7] is shown in Figure 4.

Figure 5-a is the photographic image of the channel 5 of the work CCT, i.e., the new simple ratio transformation for enhancing soil feature.
Figure 5-b is the photographic image of the channel 6 for enhancing vegetated area and vegetation cover.
Figure 5-c is the photographic image of the channel 7 for mapping soil feature.
In this image, the bare soil field were classified with some dependability.
But, the agricultural fields of corn and beet with low vegetation cover as 10 - 30 percents were not successfully identified.

The k values due to equation (4) decrease both with increasing of soil organic matter contents,and with increasing of soil moisture contents. The Landsat data used in this study were collected 6 days later from a rainfall of 40 mm.

At the time of the data collection by Landsat 2, the soil surfaces were dried enough. So, there is highly significant correlation between soil organic matter contents and the CCT counts of the channel 5 as shown in Figure 6.

Consequently, the photographic image of Figure 5-a agreed with a conventional soil map of Figure 4 in regard to agricultural field except the fields of grass land and pasture that are high vegetation cover over 70 percent.

A problem in using k, for soil mapping is that some classes such as water, forest, pasture, grassland and concreate cannot separate from the soil. Some soils have the same k value as water area and some water area have the same k value as a soil class. So, the k cannot solely be used for soil mapping. It is necessary for the mapping to use some other channels to extract the area of water, forest and field of high vegetation cover.

B. BEST CHANNEL COMBINATION FOR SOIL ANALYSIS

As the new ratio transformation by equation (4) decreases classification performances of water, forest and urban etc., the ratio should be used with combination of another channels. The best subset of four channels from the eight channels on the work CCT was determined due to the statistical distance among classes. Best twenty subsets of four channels for soil mapping were obtained on the basis of the minimum pairwise separation as shown in Table 2. When Landsat original bands (channels 1,2,3 and 4 in Table 2) were used for soil mapping, average separation was 1,738, but minimum pairwise separation was 335. This lower separability was between Brown alluvial soil (AL) and Brown ando soil (DV). This means that un-preprocessed original Landsat bands are not enough for soil mapping.

The best subset of four channel combination for soil mapping was channels 2,4,5 and 6 on the work CCT. By using the new ratio transformation ,channel 5, for soil enhancement and a ratio, channel 6, related to vegetation enhancement, the lower separabilities between Brown alluvial soil (AL) and Brown ando soil (DV), and between Black ando soil with very rich humus (WV-1) and Black ando soil with rich humus (WV-2) are improved. In the best subset (Table 2), value of minimum pairwise separation was 1,901 and average separation was 1,997.

All subsets in Table 2 contain channel 5. This means an usefullness of the new simple ratio transformation for soil analysis.

Channels 2 and 4 on the work CCT are Landsat bands 5 and 7, respectively, as shown in Table 1. Channels 5 and 6 are transformed from the Landsat bands 5 and 7. This shows a capability of soil mapping with data of red spectral band and near infrared band and their transformations.

C. SOIL MAPPING

Soil maps were computed by using LARSYS installed in TOKYO. Figure 7 shows a computer classified soil map of study area. There is reasonable good agreement between the soil survey map and computer generated map. In the soil map in Figure 7, soils were mainely classified in regard to soil organic matter contents. Agricultural fields which had 0 - 50 percent vegetation cover were successfully classfied into correct soil classes.

A half of wheat fields of 50 - 70 percents vegetation cover were classified into the correct soil classes. But, remaining half of wheat field were classified into another class of marsh. The vegetation cover of about 60 percents is considered to be a limitation of the new ratio transformation for soil mapping.

Table 3 shows performance of training fields. 68.3 percents of average performance by soil classes was obtained. Table 4 shows, as a reference, performance of training fields when channels 1,2,3 and 4 were used for soil mapping. The average performance by soil classes was 56.1 percents.

V. CONCLUSIONS

In order to extract soil information from a vegetated area and to analyze soil condition, influence of vegetation reflectance on soil reflectance should be eliminated. For this purpose, a simple ratio transformation, k=(PIR-band7)/(band 5-PR), were theoretically derived, where PR and PIR were derived from a co-ordinate of 100 percents vegetation cover. PR and PIR were 10 and 53, respectively, for this study.

The k is considered to sensitive especially to degrees of soil organic matter contents. A problem in using k for soil mapping is that classes of water, forest, grass and urban etc. had the same value of k as soil classes. Therefore, the soil classes and the other classes cannot be distinguished by k values only. For soil mapping, the channels of the k must be used with combination of another channels. The best subset of four channels was channels 2 (Landsat 5), 4 (Landsat 7), 5 (the new transformation), and 6 (Landsat (7-5)/(7+5)) on work CCT. By using those four channels, agricultural fields which had 0 - 50 percents vegetation cover were successifully classified into the correct soil classes.

REFERENCES

1. Colwell, J.E. and G.H.Suits, "Yield prediction by analysis of multispectral data," NASA-CR-141865, ERIM 109600-17-F, p57 (1974).
2. Fukuhara, M., et al, "Remote sensing of agricultural area by using multiband phtography," Proceedings of 1st Remote sensing Symposium, p.13, Tokyo, Nov. 25, 1975. (in Japanese)
3. Fukuhara, M., et al, "Extraction of soil Infomation from Vegetated Area," Proceedings of 12th International Symposium on Remote Sensing of Environment, pp1707-1716, (1978)
4. Kristof, S.J., et al, "Mapping soil features from multispectral scanner data," Photogrammetric Engineering, vol.40, p1427 (1974)
5. Swain, P.H., et al, "Comparison of the divergence and -distance in feature selection," LARS Information Note 020871 (1972)
6. Lindenlaub, J.C., "Guide to multispectral data analysis using LARSYS," LARS Information Note 062873 (1973).
7. Kikuchi, K., et al, "Soil map of Tokachi district," Tokachi Agricultural Experimental Station, (1972), (in Japanese)

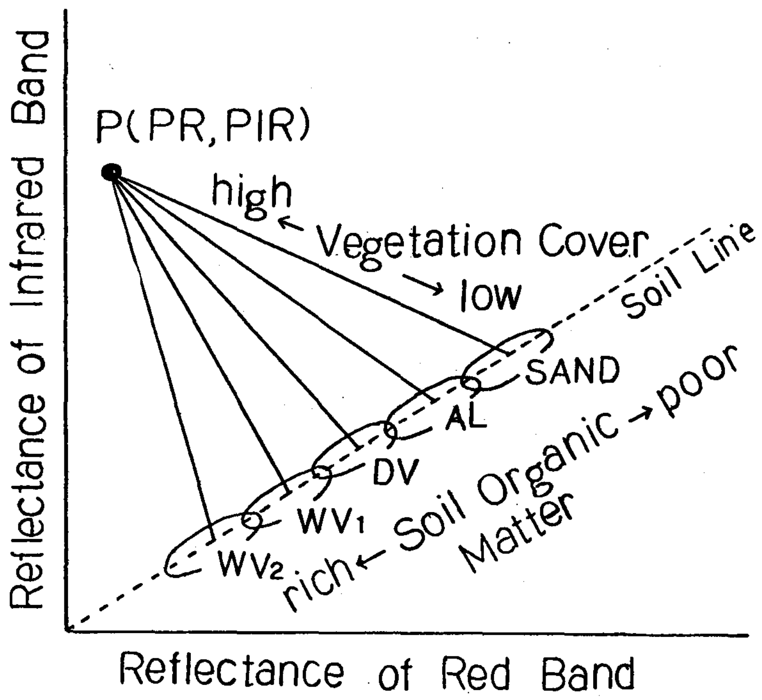

Figure 1. Ilustration of relationship between soil types and vegetation covers in a space of red and infrared spectral bands. According to increasing of vegetation cover, the co-ordinates of each soil reaches to a co-ordinates of 100 percent vegetation cover:point P(x=PR,y=PIR).

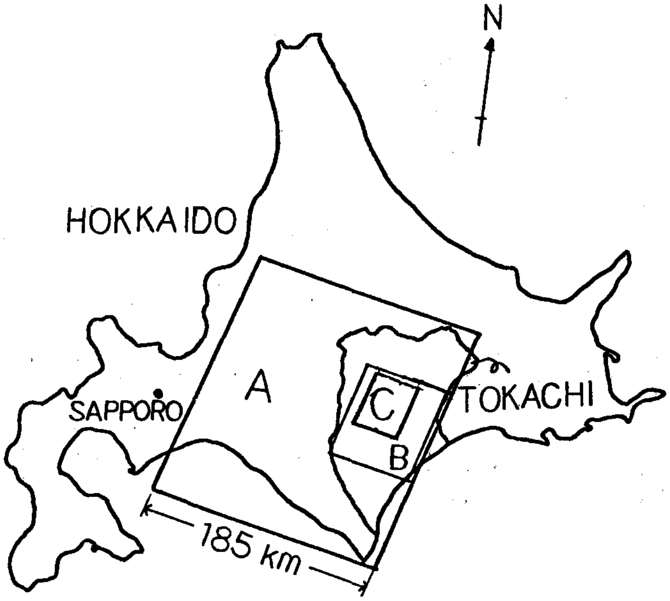

Figure 2. Location of test area in Tokachi district, Hokkaido. A=Whole area of Landsat image. B=Test area. C=Area of computer classified soil map in Figure 7.

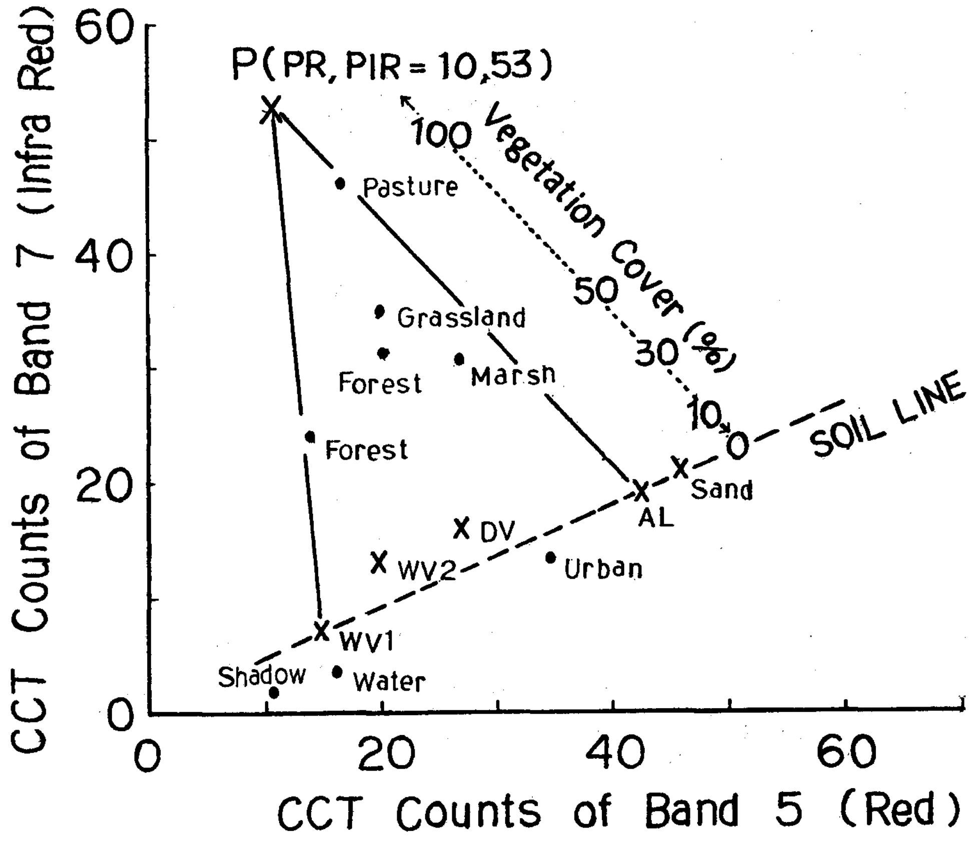

Figure 3. Two dimentional plots of CCT counts of red and near-infrared bands(Landsat Bands 4 and 7) for main classes.

Table 1. CCT channels for analysis.

CCT Ch. No.	Spectral Band & Ratio
1	Landsat band 4 (0.5 - 0.6 um)
2	Landsat band 5 (0.6 - 0.7 um)
3	Landsat band 6 (0.7 - 0.8 um)
4	Landsat band 7 (0.8 - 1.1 um)
5	(53 - band 7)/(band 5 - 10)
6	(band 7 - band 5)/(band 7 + band 5)
7	(band 4 + band 5)/(band 6 + band 7)
8	(band 4 - band 5)/(band 4 + band 5)

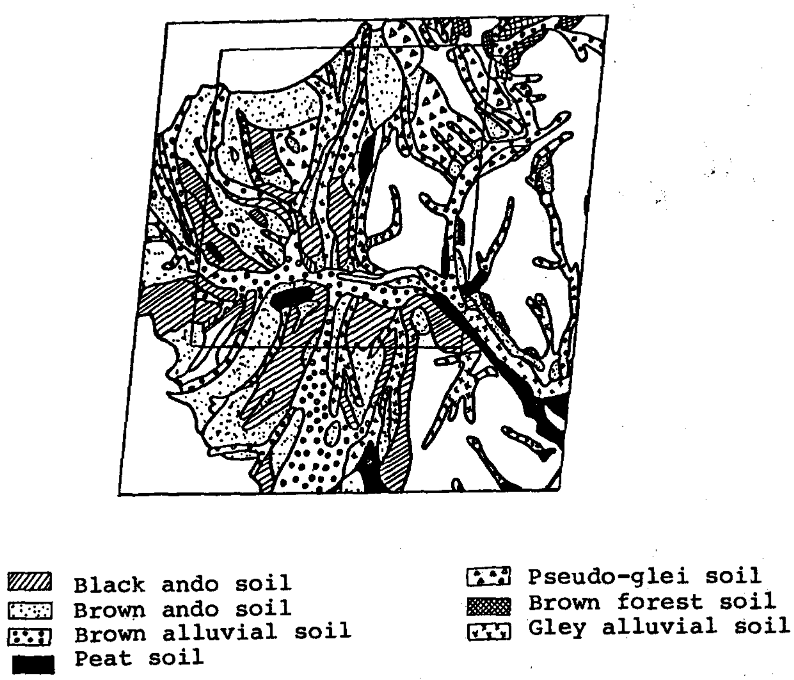

Figure 4. Conventional soil survey map of the test area.[7]

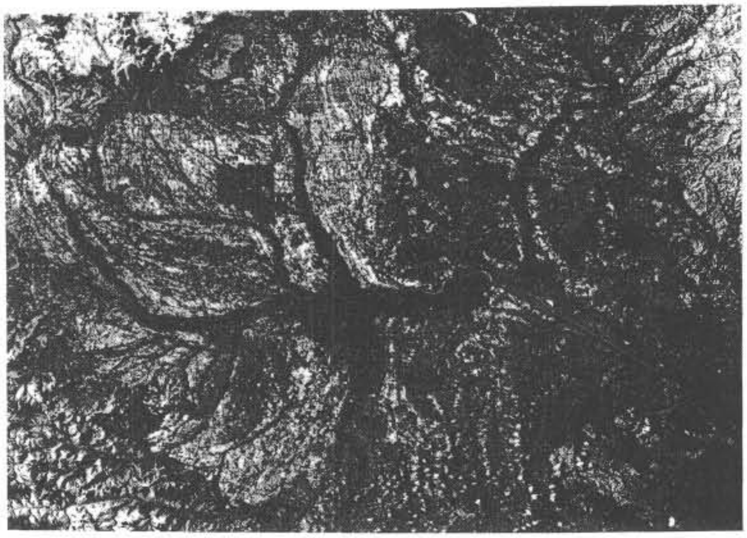

Figure 5-a Output of the channel 5 of the work CCT, i.e., the new simple ratio transformation for enhancing soil feature.

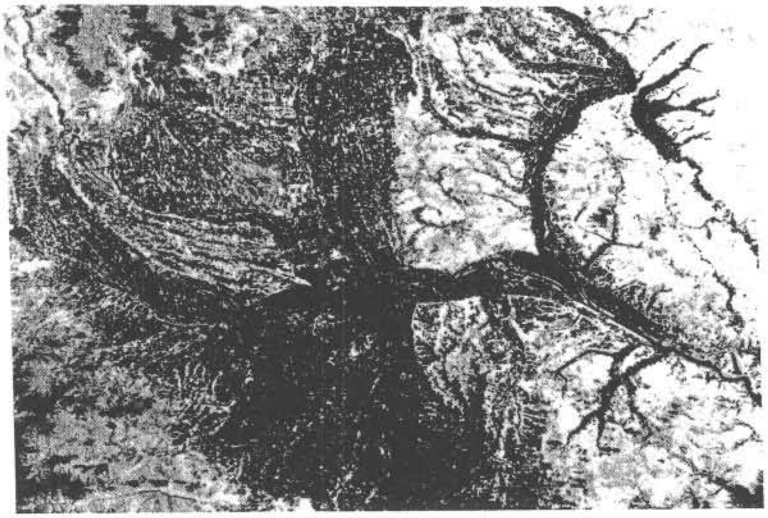

Figure 5-b Output of the channel 6 for enhancing vegetated area and vegetation cover.

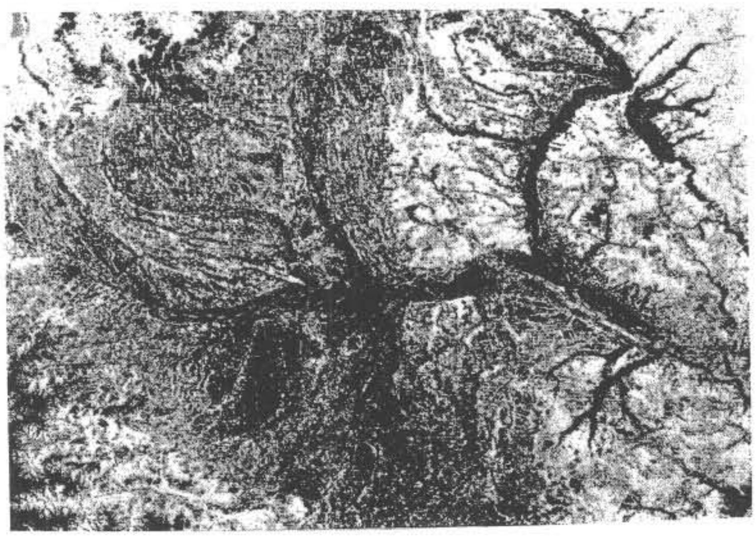

Figure 5-c Output of the channel 7 for mapping soil feature. Agricultural fields with low vegetation cover were not successfully identified.

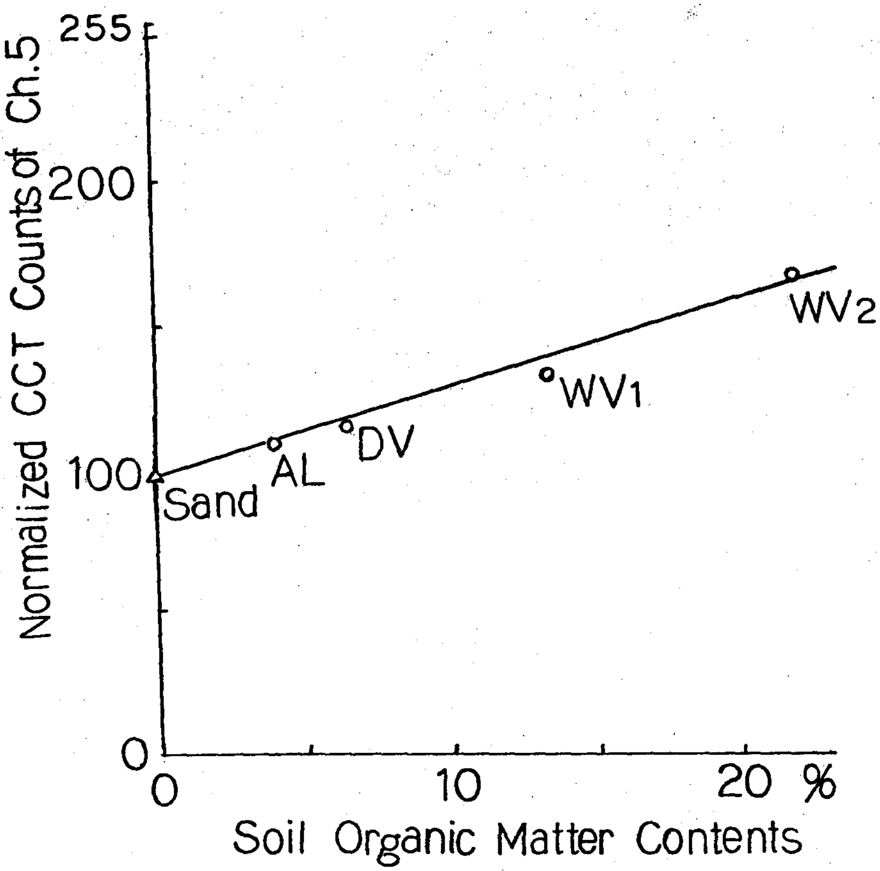

Figure 6. Relationship between soil organic matter contents and CCT counts of channel 5.

Table 2. Results ordered according to Divergence(Minimum)

	Channels				D(Min)	D(Ave)
1	2	4	5	6	1901	1997
2	2	4	5	7	1599	1978
3	4	5	6	7	1518	1979
4	1	2	5	8	1503	1968
5	2	5	6	7	1483	1966
6	1	4	5	6	1456	1976
7	4	5	7	8	1421	1968
8	1	4	5	8	1410	1967
9	3	5	6	7	1406	1958
10	1	5	6	7	1400	1953
11	4	5	6	8	1390	1975
12	2	4	5	8	1378	1966
13	1	5	7	8	1376	1960
14	1	2	4	5	1371	1966
15	1	3	5	8	1369	1951
16	3	4	5	7	1366	1960
17	2	3	5	7	1362	1961
18	1	5	6	8	1356	1961
19	2	3	5	8	1323	1949
20	1	2	3	5	1322	1949
	1	2	3	4	335	1738

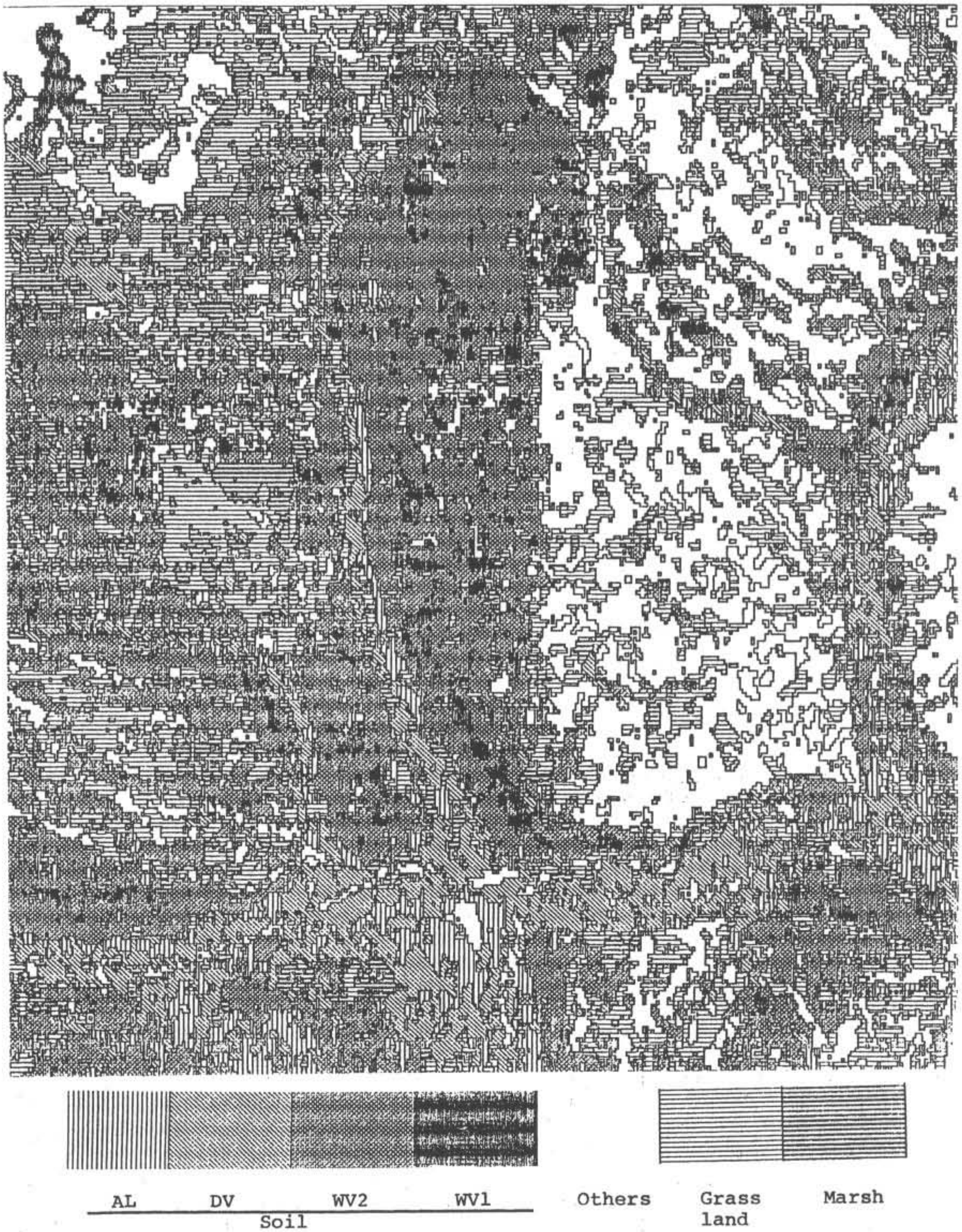

Figure 7. Computer classified soil map of study area.

Table 3. Performance of training fields classified by using best four channels (channels 2,4,5 & 6 of work CCT)

	Class	No of Samples	Percent of Samples into WV1	WV2	DV	AL	Sand	Urban	Pastr	Grass	Marsh	Forst
1	Soil WV1	48	60.4	33.3	2.1	4.2	0	0	0	0	0	0
2	WV2	50	28.0	64.0	0	0	0	0	0	0	0	8.0
3	DV	30	0	6.7	80.0	13.3	0	0	0	0	0	0
4	AL	48	0	2.1	12.5	68.8	2.1	0	0	4.2	10.4	0
5	Sand	96	0	0	0	0	93.8	0	0	3.1	0	3.1
6	Urban	12	0	0	0	0	0	100.0	0	0	0	0
7	Pasture	24	0	0	0	0	0	0	66.7	12.5	8.3	12.5
8	Grass land	108	0	0	0	0	0	0	0.9	80.6	5.6	13.0
9	Marsh	138	0	0	0	2.2	0	0	0	15.9	81.9	0
10	Forest	80	0	0	0	0	0	0	8.8	1.2	0	90.0

Table 4. Performance of training fields classified by using original four channels (Landsat bands 4,5,6 & 7)

	Class	No of Samples	Percent of Samples into WV1	WV2	DV	AL	Sand	Urban	Pastr	Grass	Marsh	Forst
1	Soil WV1	48	85.3	8.3	4.2	2.2	0	0	0	0	0	0
2	WV2	50	52.0	26.0	6.0	2.0	0	0	2.0	0	0	12.0
3	DV	30	6.7	0	56.6	23.3	0	6.7	0	0	0	6.7
4	AL	48	0	0	16.7	56.3	20.8	2.1	0	2.1	2.1	0
5	Sand	96	0	0	5.2	4.2	87.4	3.1	0	0	0	0
6	Urban	12	0	0	0	16.7	8.3	75.0	0	0	0	0
7	Pasture	24	0	0	4.2	6.5	0	0	43.5	16.7	8.3	20.8
8	Grass land	108	0	0	0	2.8	0	0	11.1	38.0	38.0	9.3
9	Marsh	138	1.5	0	0	0	0	0	0	11.6	86.3	0.7
10	Forest	80	0	0	0	0	0	0	1.3	0	0	98.7