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EXPERIMENTAL STUDY ON THE SPECTRAL REFLECTANCE OF PADDY SOILS IN THE FIELD SURVEY

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Abstract

It is well known that the spectral reflectance of soils varies with their moisture content. However spectral reflectance of soils has been studied only under non-submerged conditions. In this report, the spectral reflectance of paddy soils was determined under three conditions, i.e. air-dried soils, saturated and submerged soils. It was concluded that the analysis of spectral reflectance of soils under submerged conditions is useful for the identification of the soil-types. This observation emphasizes the utility of remote sensing data in fields in spring, under submerged conditions, when the fields are not fully yet covered with the rice.

Contents

I. Introduction

In Japan, paddy fields are plowed and covered with water and then the rice is transplanted in spring. The fields are drained, then the rice is harvested in autumn. The image data collected after harvest are useful in identifying soil-types of the fields by remote sensing techniques. However, as the image data collected in spring suffer from the great interference of water on the measurement of the soil reflectance, there are few studies on the soil reflectance under submerged conditions. In spite of that disadvantage, the image data collected in spring are still convenient for distinguishing the fields from different cover types such as forests and upland fields.

The aim of this report is then to make an investigation into the change of soil reflectances caused by covering with water and to discuss the utility of image data taken in spring. In this report, test soil samples of surface layer were collected and the soil reflectance of these samples was measured in the laboratory under three water conditions, i.e. the air-dried, saturated and submerged conditions. The cluster analysis was applied to the measured reflectances and the results of the analysis under each water condition were compared. This knowledge will help the remote sensing of soils by image data.

II. Description of the study area

The area studied involves the Aizu Basin which is located in the western part of Fukushima Prefecture in Japan. The Aizu Basin, an elongated central tectonic basin, covers about 12 km from east to west, and about 32 km from south to north. Table 1 shows the soil groups and each respective area in the Aizu Basin. Approximately the half of the soils of the paddy fields in this basin are gray lowland soils (grayish brown type) (corresponding to the fluvisols in the classification of "Soils of the World" published by FAO-UNESCO), which account for the most part of the center of this basin. Grey lowland soils (gray type) (corresponding to the fluvisols) are scattered over 25% of the paddy fields in this basin. The percentage area of thic humic wet andosols is about 8%. The aeral distributions of yellow soils (corrsponding to the cambisols), brown soils (corresponding to the cambisols), gley soils (corresponding to the gleysols) and muck soils (corresponding to the histosols) are sparse.

As mentioned below, since the grid sampling was carried out, this table actually represents the nature of the soil samples.

Table 1 Soil groups of paddy fields and the respective area

SOIL GROUP	AREA(ha)	(%)
HUMIC WET ANDOSOLS	1380	7.5
GRAY LOWLAND SOIL (BROWN TYPE)	1000	5.5
GRAY LOWLAND SOIL (GRAY TYPE)	4480	24.7
GRAY LOWLAND SOIL (GRAYISH BROWN TYPE)	10400	57.3
GLEY SOIL,MUCK SOIL	900	5.0

III. Measurement of spectral reflectance

1. Sampling of soils

One hundred fourty seven soil samples were collected for every 100 ha of paddy fields in the Aizu Basin. The Aizu Basin was subdivided into about 50 units, according to the geological and topographical parameters including the presence of rivers, the nature of soil series, etc. Depending upon the difference in the size for each unit, 2 to 4 separate soil samples were collected. Samples were collected only from those plowed layers that represented the spectral reflectance characteristics of the soil. After the soil had been air dried, the particles smaller than 2 mm in diameter were obtained by sieving.

2. Measurement of spectral reflectance

The spectral reflectance was determined using a portable photometer (PM-12A, Kimoto Co. Ltd.). The spectral reflectometer worked in 17 bands of wavelengths(Table 2). Both GaAsP and Si photoelectric cells were installed as the detecting sensors for the visible and the near infrared regions, respectively. The aperture of the spectral reflectometer could be adjusted to 2° or 10°. The ten degree aperture was used for this experiment. The measurement of reflectance was taken in the laboratory in order to keep experimental conditions constant. Two sets of

Table 2
Band wavelength

BAND	WAVELENGH
1	400nm
2	425nm
3	450nm
4	475nm
5	500nm
6	525nm
7	550nm
8	575nm
9	600nm
10	625nm
11	650nm
12	675nm
13	700nm
14	750nm
15	850nm
16	950nm
17	1050nm

metal halide lamps (Toshiba: 400W) were used for the light source because they display similar spectral characteristics to that of the sun. Two metal halide lamp stabilizers were used to reduce the fluctuations in the electric power supplied during the experiment. The incoming angle of the light source was adjusted to 32°, which was identical with the altitude angle of the sun when the LANDSAT image data were obtained. The spectral reflectances were measured at about 1.5 m directly above the soil sample with a thickness of 2 to 3 cm which was put in a tray. The inside of the tray was painted with black water paint to prevent possible diffused reflectance. In order to eliminate the interference of fluctuations of the illumination by reflected light, measurements were taken the soil sample and the standard white plate in turn. The spectral reflectance of soils is expressed by the following equation:

$$R(\lambda)=10^{-(V(\lambda W)-V(\lambda R))} \tag{1}$$

where $R(\lambda)$ is the spectral reflectance of soil, $V(\lambda W)$ is the logarithm of relative spectral energy distribution of the standard white plate and $V(\lambda R)$ is the logarithm of the spectral energy distribution of the soil sample. The following conditions were used during the measurements; air-dried, saturated with water, and covered with water. Water was added to the soil samples at a depth of 4 cm, taking into account of local conditions of the fields immediately after transplanting rice, when the LANDSAT image data were obtained.

IV. Data analysis

The cluster analysis applied in this study was the hierarchical clustering method proposed by Anderberg(1973), which included the 6 different components, i.e. the single linkage method, the complete linkage method, the average linkage between the merged groups, the median method, the centroid method and the Ward method. The factor for determining the linkage of clusters was the distance, D, which was expressed in Euclidean terms. The differences between the techniques mentioned above were due to the differences in the coefficient for the determination of D.

In order to derive the equation which defines the distance between clusters, D, cluster c consisting of clusters a and b, and cluster d which is different from cluster c were selected as shown in Fig.1.

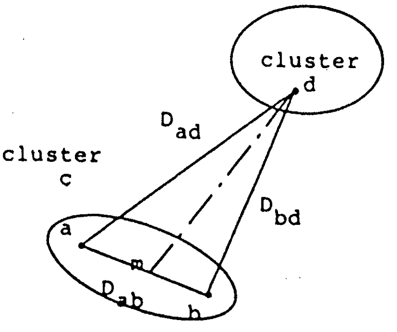


Fig. 1 Schematic diagram of the relationship among clusters

By expressing the distance between clusters a and b with Dab, distance between clusters c and d can be generally deduced by the following equation (2).

$$Ddc=\alpha a*Dda+\alpha b*Ddb+\beta *Dab+\gamma *|Dda-Ddb| \qquad (2)$$

where αa, αb, β and γ are constants which vary depending on the technique. Table 3 illustrates these relations. As for the distance between variables, euclidean distance was obtained from the normalized data using the reflectances of 17 wavelengths for each water condition. Special attention was paid to the normalization process in order to avoid any effect on the distance caused by the reflectance of any particular wavelength.

V. Results of the analysis

1. Availability for each clustering

As mentioned above, spectral reflectances have been analyzed by the six different clustering methods. The Ward method was found to be most suitable for analyzing the data. Fig.2 illustrates the schematic dendrogram obtained by the single linkage method and the Ward method.

In this analysis, one soil was separated from the others by applying the single linkage method, the average linkage method between the merged groups, the median method and the centroid method. As for the complete linkage method and the Ward method, the latter was applied in the report presented here because the results of the latter were easy to interpret, compared with the former method. In addition, this method affords a mathematical basis related to the information theory.

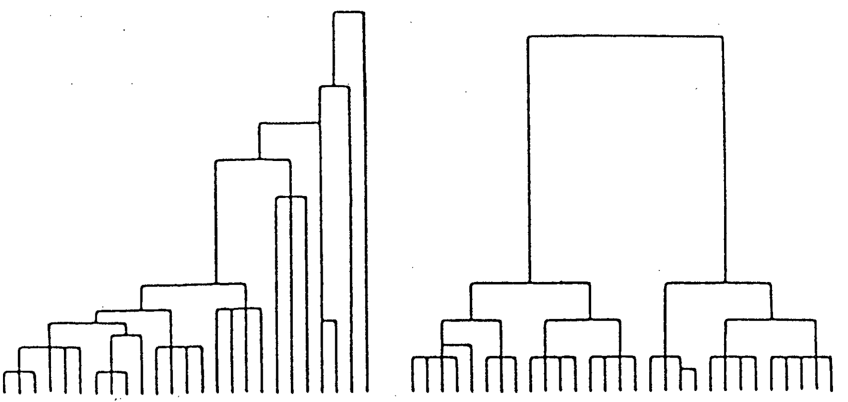
2. Grouping map of soil under air-dried conditions

Fig.3 shows classified areas by symbols, i.e. the open circle, the open triangle and the open square, based on the spectral reflectance of soils under air-dried conditions. This type of figure showing classified areas was referred to as "a grouping map". First, eight groups were generated at a distance level in the dendrogram by the Ward method. Secondly, the three kinds of clusters are illustrated. In the north-western side of Kitakata City, the clusters that are shown by open squares formed a small mass. This area corresponds to a given soil series on an ordinary soil map. The small mass of the cluster was found to be located in the north-western side of Aizuwakamatsu City, too. This area corresponds to either one of two soil series on an ordinary map. In the western side of

Table 3 Coeffecients of each clustering technique

METHOD \ COEFFECIENT	αa	αb	β	γ	LEFT SIDE OF EQ.(1)
SINGLE LINKAGE METHOD	$\frac{1}{2}$	$\frac{1}{2}$	0	$-\frac{1}{2}$	D
COMPLETE LINKAGE METHOD	$\frac{1}{2}$	$\frac{1}{2}$	0	$\frac{1}{2}$	D
AVERAGE METHOD	$\frac{1}{2}$	$\frac{1}{2}$	$-\frac{1}{4}$	0	D
MEDIAN METHOD	$\frac{na}{nc}$	$\frac{nb}{nc}$	$-\frac{na \cdot nc}{nc^2}$	0	D^2
CENTROID METHOD	$\frac{na}{nc}$	$\frac{nb}{nc}$	0	0	D^2
WARD METHOD	$\frac{nd+na}{nd+nc}$	$\frac{nd+nb}{nd+nc}$	$\frac{-nd}{nd+nc}$	0	D^2

na, nb, nc and nd represent number of elements in the cluster indicated by the each suffix.



(a) The dendrogram by single linkage method

(b) The dendrogram by Ward method

Fig. 2 Schematic dendrogram indicating the utility of clustering technique

Aizuwakamatsu City, the cluster shown by an open square formed a large mass across the Agano River. This area corresponds to any one of three soil series on an ordinary soil map. In the south of this area, the small mass of the clusters shown by the open triangles corresponds to either one of two soil series on an ordinary soil map and was identified as belonging to the humic wet anodosol group.

3. Grouping map of soil under saturated conditions

The groups were combined as described according to the soil reflectance under air-dried conditions. As shown in Fig.4, the cluster that is represented by the open triangle forms a small mass in the south-eastern side of Kitakata City. A relatively large mass of the cluster, shown by the open squares, can be recognized on both sides of the Agano River. Small masses of the open traingles surround it in the western side of Aizuwakamatsu City. The area along the Agano river is the same that was described in the grouping map of the soil under air-dried conditions, but it is less wide.

4. Grouping map of soil under submerged conditions

The grouping map of soil under submerged conditions is represented in Fig.5. First, six groups were identified on a distance level in the dendrogram of reflectances of soil under submerged conditions and each of the two kinds of groups were combined into one cluster. A mass of the cluster can not be recognized in the northern part of the basin, but the same pattern as that observed in grouping map of soil under air-dried conditions can be found in the southern part.

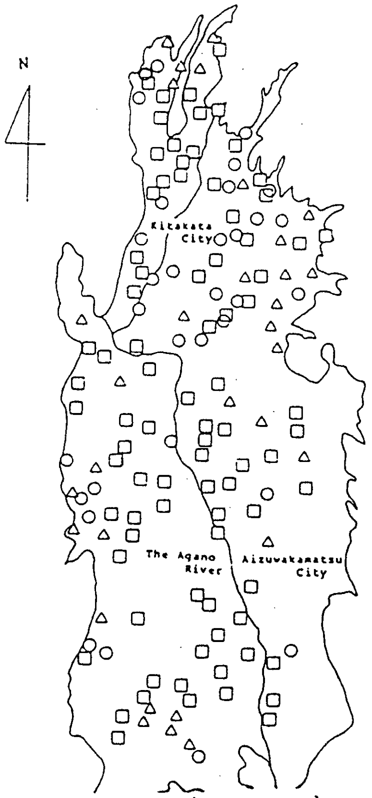


Fig. 3 Grouping map under air-dried conditions

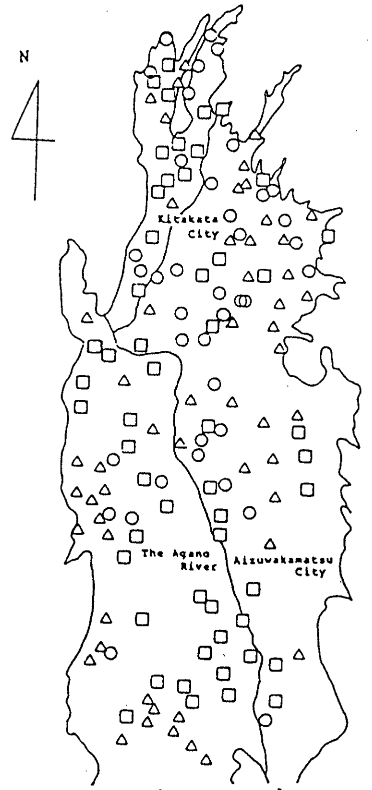


Fig. 4 Grouping map under saturated conditions

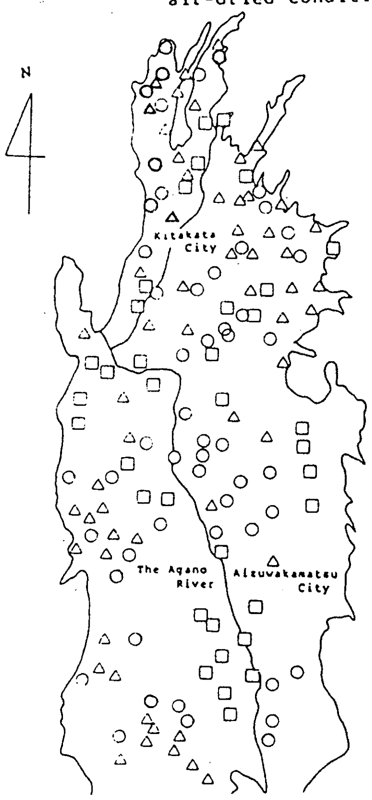


Fig. 5 Grouping map under submerged conditions

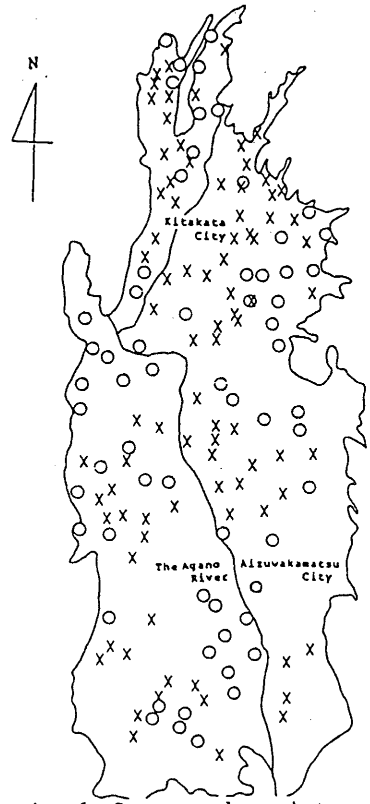


Fig. 6 Correspondance between two grouping maps

However, it is interesting to note that the large mass of the cluster shown by the open circles could be recognized in the north-western side of Aizuwakamatsu City.

VI. Discussion

1. Comparison of grouping maps under the different soil conditions

In order to dertermine how water conditions influence soil identification, grouping maps of the soils under air-dried and submerged conditions were compared. (Fig.6) In Fig.6, the open circles indicate the points (Ca.48%) where the cluster of one grouping map corresponded to the cluster of the other grouping map and the cross marks indicate the points (ca.52%) where the cluster of one grouping map did not correspond to the cluster of the other grouping map. As is implied by Fig.6, there are few points with correspondance in the nothern part of this basin, unlike in the central and southern parts. The mass with the points showing correspondance in the western side of Aizuwakamatsu City involves an alluvial fan. The mass of the southern side of this area consists of humic andosols. The mass of points with correspondance can be recognized in the central western part of this basin. On an ordinary soil map, this area does not consist of only one kind of soil series as in the western or southern side of Aizuwakamatsu City, but consists of various kinds of soil series. Thus, grouping map of soil based upon spectral reflectance under air-dried conditions can be achieved , even if the surface soil is covered with water.

2. Soil reflectance curve of each cluster

First, the effect of soil types and water depth upon the reflectance curves was studied in selecting four kinds of soils with different colors, i.e. whitish sandy soil, gray-colored soil, reddish Kanto loam and black volcanic ash soil. Soil reflectance was determined under seven sets of conditions, i.e. air-dried conditions, saturated conditions and water depth of 1 cm, 2 cm, 3 cm, 4 cm and 5 cm. The results obtained are shown in Figs. 7 (a),(b),(c) and (d). Except for the reflectance of the Kanto loam and the volcanic ash soil at 1050 nm region under air-dried and saturated conditions, the sandy soil shows the highest reflectance values, followed by the gray-colored soil, the Kanto loam, while the volcanic ash soil exhibits the smallest reflectance values regardless of the wavelength. As air-dried soils change into saturated soils, reflectance values of each soil decrease to about half regardless of the wavelength. However the pattern of the reflectance curve of each soil was preserved. Namely, in the case of the sandy soil, reflectance values suddenly increased within the 400-650 nm region, gradually increased and markedly increased at the 1050 nm region again. In the case of the gray-colored soil, reflectance values tended to increase with the increase of the wavelength. While in the case of the Kanto loam, reflectance values gradually increased within the 400-650 nm region and tended to increase slowly above the 650 nm region. In the case of the volcanic ash soil, reflectance values gradually increased below the 625 nm, remained almost constant within the 625-750 nm region and increased agin above 750 nm region. Though there was a difference in values among different soils, the reflectance values once decreased at the 950 nm region and clear differences were obtained between air-dried and saturated conditions. From this observation, it is considered that specific absorption of spectra by water molecules occurs at the 950 nm region. However, the pattern of each soil reflectance curve under air-dried and

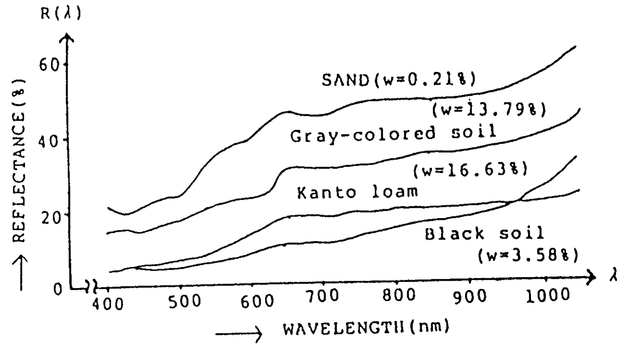


Fig. 7(a) Representative soil reflectance curves (in the case of air-dried conditions)

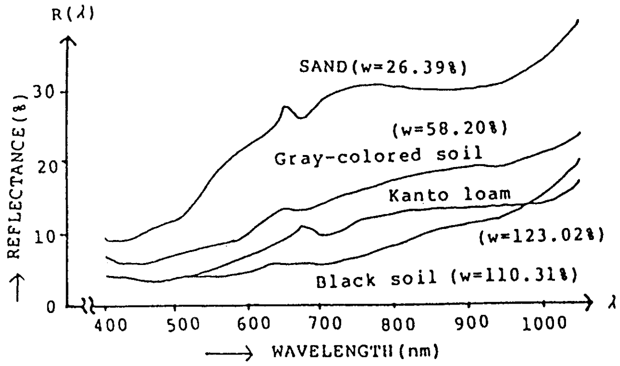


Fig. 7(b) Representative soil reflectance curves (in the case of saturated conditions)

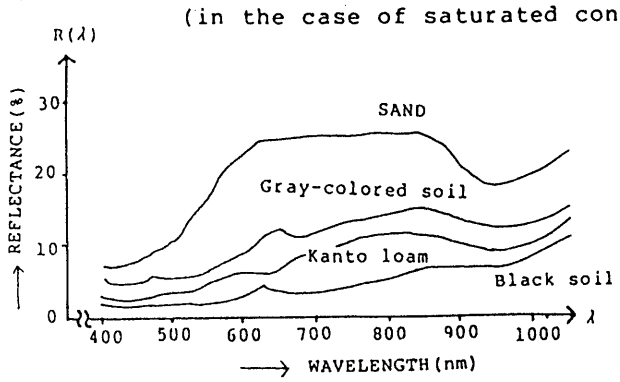


Fig. 7(c) Representative soil reflectance curves (in the case of water depth 1 cm)

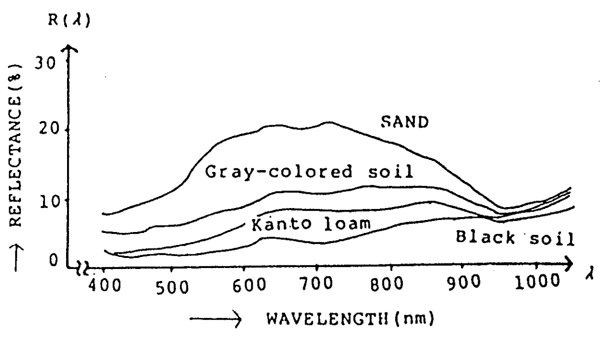


Fig. 7(d) Representative soil reflectance curves (in the case of water depth 5 cm)

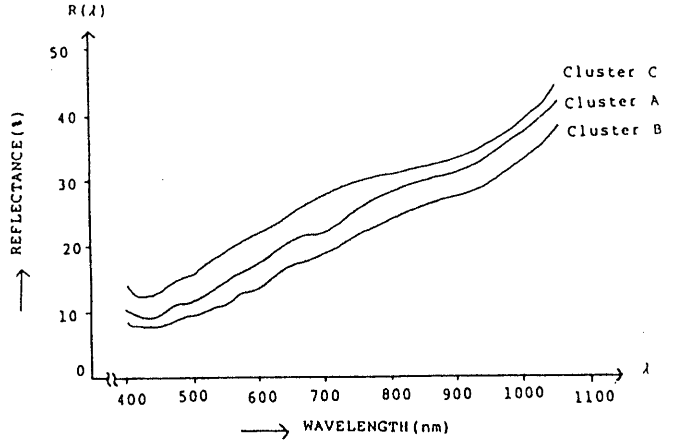


Fig. 8(a) Average reflectance curve of each cluster (in the case of air-dried conditions)

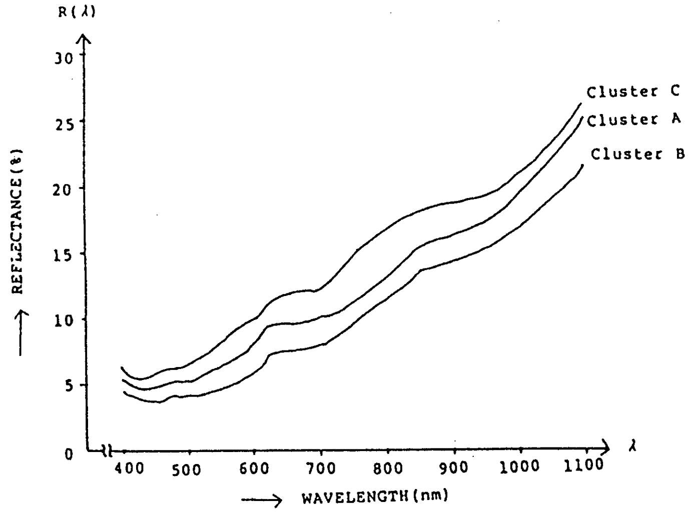


Fig. 8(b) Average reflectance curve of each cluster (in the case of saturated conditions)

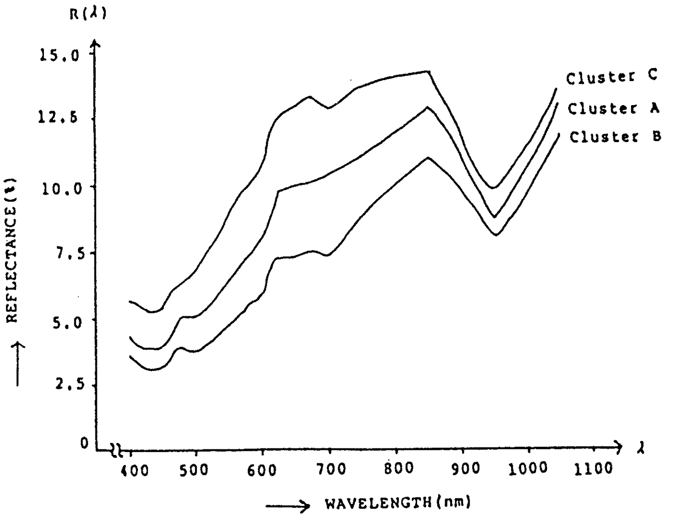


Fig. 8(c) Average reflectance curve of each cluster (in the case of submerged conditions) saturated conditions was preserved in the other wavelength region. As the water depth increased, the values of spectral reflectance gradually decreased as a whole. But, basic pattern remained and it appeared that the water depth did not influence significantly the soil reflectance curve for a depth of 1-5 cm.

Secondly, the reflectance curves of each cluster were compared. Fig. 8(a), (b) and (c) show the average reflectance curves of each cluster indicated in Figs. 3, 4 and 5. Clusters A, B and C correspond to the open circle, triangle and square mark respectively. Regardless of water conditions, reflectance values of cluster C were the largest and those of cluster B were the smallest. In each cluster, reflectance values were gradually increased with the wavelength as described in the gray-colored soil. Under submerged conditions, reflectance values of each cluster suddenly increased within the 400-625 nm region, but the rate of increase was less conspicuous within the 625-850 nm region. Each cluster showed a distinctive increase rate within the range of these wavelengths. The reflectance values once decreased at the 950 nm region and increased again above the 950 nm region, as observed in the gray-colored soil.

VII. Conclusions

The usefulness of spectral reflectance of soil under submerged conditions for distinguishing soil-types has been examined and the following conclusions have been reached.

1. A specified area, for example, the alluvial fan along the Agano River can be recognized by the values the spectral reflectance under submerged conditions.

2. If the soil is coverd with water, reflectance values decrease

markedly at the 950 nm region. However, since even under submerged conditions, the pattern of the curve obtained under air-dried condtions is preserved, it is therefore suggested that it would possible to distinguish soil-types by applying the spectral reflectance methods under submerged conditions.

3. As for the image data collected in the paddy fields under submerged conditions, it is a great convenience to use the spectral reflectance within the 600-800 nm region.

Reference

1) M.R.Anderberg(1973);"Cluster Analysis for Applications", pp.132-156, Academic Press, (1973).

2) T.Ishida and T.Hoshi(1984);"Spectral Reflectance of Paddy Soil under Different Water Conditions", Proc. of Annual Conference'84, Society of Photogrammetry and Remote Sensing, pp.111-114, May. 1984.

3) T.Ishida,T.Hoshi and T.Maruyama(1984);"Influence of Water on Soil Reflectance", Proc. of Annual Conference'84, Japanese Society of Irrigation, Drainage and Reclamation Engineering, pp.306-307, Aug. 1984.

4) T.Hoshi and T.Ishida(1984);"Study on The Relationship between Spectral Reflectances and Physical and Chemical Properties Using Cluster Analysis", Journal of Society of Photogrammetry and Remote Sensing, 1984. (in press)

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SUPPLEMENTARY NOTES