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# Development of method for estimating the components of upland soil productivities with accuracy and minuteness using Landsat TM data and improvement of upland soil management based on its information

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## Summary

Three subjects such as "High quality of products", "High production at low cost "and" Promotion of sustainable agriculture as well as preserve the environment" are exist in upland farming of Tokachi district located east-part of Hokkaido in the northern Japan. It is important to take countermeasures such as improvement project of the land basis, soil fertility management and fertilizing technology, crop rotation plan basd on the productivity of upland soil to cope with upper subjects.

For that purpose, in the first place, it is needs to estimate the irregular conditions of soil productivity as it is per unit field accurately and swiftly. Then it is also needs to estimate the soil productivity generally by overlaying the components and to establish the soil management techniques based on its result.

The present research have three aims as follows ; ① To develope the method for seizing the soil productivity components such as soil organic matter (OM) content, soil moisture chracteristics (SMC for example available moisture holding capacity etc), and gravelly layer's depth (GLD) over wide area and swifty using Landsat Thematic Mapper (TM) observational data. ② To develope the "Agricultural Information System of Tokachi" which is capable to give the high degree's information gained by overlaying the few primary data such as OM, SMC and GLD for soil management. ③ To indicate a new support concerning to soil management on upland farming on both level of fermar's unit field and wide area.

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## Ⅰ. Method for estimating the OM content of upland soil.

The method for estimating the OM content of upland bare soil using Landsat TM data, recorded in May 1984 and 1985, in the southern part of Tokachi district was examined. These two TM data was observed under different soil moisture conditions. Amount of precipitation in May was 95.5 mm in 1984 and 21.0 mm in 1985. Therefore, upland soils were kept under wet conditions in 1984 and under dry conditions in 1985. It was found that band TM3 (wavelength:630-690nm) could be used effectively for estimating the OM content of surface soil plowing and hallowing in the depth of 25cm and correlation coefficient were higher in dried condition of surface soil. Therefore, next experimental equation was gained.

$$LOG(OM\%)=1.6112-0.0120TM3(1985)$$

$$( r=-0.924,\ n=30 )$$

Where, TM3 is the CCT counts of band 3 observed in 1985.

On the other hand, the method for

estimating the OM content of vagetation-covered soil was examined. As the result of examination, the OM content of vagetation-covered soil was estimated from the CCT counts of TM band 3 on the soil line transformed by soil index method (Fig.15).

Therefore, we estimated OM content both bare soil and vagetation-covered soil such as wheat field and new developed pasture field by using transformed TM band 3 data. Next experimental equation was gained (Fig18).

$$\text{Transformed TM3}=247.772-125.540\text{LOG (OM\%)}$$
$$(r=-0.977,\ n=28)$$

## Ⅱ. Method for estimating the soil moisture characteristics of uplandsoil.

### 1. Soil moisture tension and content.

The relationship between Landsat TM data and soil moisture tension (kPa and pF) and moisture ratio (Volume%:Mv and Water content by weight:Wc) measured in the depth of 10cm at 7 locations in 1984 and 1985 was examined.

As the result of examination, in the case of soil moisture tension, it was found that multiple regression equations (MRE) used TM1, TM2 and OM content could be useful to estimate kPa, and MRE used TM1, TM4 and OM contennt for pF. In the case of moisture rario, MRE used TM2 and OM content could beuseful to estimate Mv, and MRE used TM1, TM4 and OM content for Wc. The following experimental equations were gained.

$$\text{kPa}=132.82-1.9563\text{TM1}+2.8468\text{TM2}-26.881\text{LOG(OM\%)}$$
$$(r=0.926,\ R^2=0.857,\ n=14)$$
$$\text{pF}=3.5215-0.0160\text{TM1}+0.0176\text{TM4}-0.3729\text{LOG(OM\%)}$$
$$(r=0.934,\ R^2=0.873,\ n=14)$$
$$\text{Mv}=104.73-1.2551\text{TM2}-4.3390\text{LOG(OM\%)}$$
$$(r=0.961,\ R^2=0.924,\ n=14)$$
$$\text{Wc}=34.534-0.1188\text{TM1}-0.2664\text{TM4}+43.633\text{LOG(OM\%)}$$
$$(r=0.987,\ R^2=0.975,\ n=14)$$

Where, kPa and pF are soil moisture tension, and Mv and Wc are soil moisture ratio. TM1, TM2 and TM4 are the CCT counts of band1, band2 and band4 observed in 1984 and 1985 respectively. OM content is value on dry soil basis.

### 2. Reducing rate of soil moisture content (RRSMC) in drying process of soil.

In order to know the difference of RRSMC of upland soil covered wide area, we calculated RRSMC values of soils per day (dkPa, dpF and -dMv) by using the data of kPa, pF and Mv measured in the depth of 10cm at 7 farmers' field. The values of dkPa, dpF and -dMv are mean data of 7 days under the condition of drying process of soil respectively and then are used for regression analysis with Landsat TM data.

As the result of examination, MRE used TM1, TM5 of 1985 and OM content could be useful to estimate dkPa, and MRE used TM1, TM4 of 1985 and OM content for dpF, and MRE used TM1, TM3 of 1985 and OM content for -dMv. The following experimental equation were gained.

$$\text{dkPa}=0.0118\text{TM1}_{85}-0.0507\text{TM5}_{85}-0.1229\text{LOG(OM\%)}+10.375$$
$$(r=0.939,\ R^2=0.881,\ n=12)$$
$$\text{dpF}=[5.903\text{TM1}_{85}-3.842\text{TM4}_{85}+17.69\text{LOG(OM\%)}-284.4]\times10^{-3}$$
$$(r=0.965,\ R^2=0.932,\ n=12)$$
$$-\text{dMv}=0.1249\text{TM1}_{85}-0.1075\text{TM3}_{85}+0.4107\text{LOG(OM\%)}-5.4217$$
$$(r=0.965,\ R^2=0.932,\ n=12)$$

Where, dkPa and dpF are rising rate of kPa and pF per day, and -dMv is reducing rate of Mv per day. $\text{TM1}_{85}$, $\text{TM3}_{85}$, $\text{TM4}_{85}$ and $\text{TM5}_{85}$ are the CCT counts of band1, band3, band4 and band5 observed in 1985 respectively.

### 3. Available Moisture Holding Capacity (AMHC) of soil.

The relationship between Landsat TM data and AMHC values measured at 20 locations was examined. As a result of application a regression analysis process, it was demonstrated that the AMHC values could be estimated by using the subtracted CCT counts of two TM data observed under different soil moisture conditions. Also it was found that the AMHC values showed a linear and positive correlation with a high accuracy with the subtracted CCT countsof band 5.

Experimental equations were derived by using the subtracted CCT value from band 5 for EAMHC and TAMHC, and using common logarithmic data of the subtracted CCT value from band 5 for NGAMHC. The measured AMHC values showed a one-to-one correspondence with the estimated AMHC values from the experimental equations. It was confirmed that these relationships were obtained in an area different from the study area. The following experimental equation were gained.

| AMHC | Soil depth(cm) | Experimental equation |
|---|---|---|
| W1 | 15 | LOGW1(mm) = 0.318+0.565LOG(⊿TM5) |
| | 30 | LOGW1(mm) = 0.513+0.630LOG(⊿TM5) |
| | 50 | LOGW1(mm) = 0.526+0.747LOG(⊿TM5) |
| W2 | 15 | W2(mm) = 9.62+0.748(⊿TM5) |
| | 30 | W2(mm) = 18.78+1.464(⊿TM5) |
| | 50 | W2(mm) = 23.78+2.311(⊿TM5) |
| W3 | 15 | W3(mm) = 13.96+0.906(⊿TM5) |
| | 30 | W3(mm) = 27.50+1.778(⊿TM5) |
| | 50 | W3(mm) = 36.41+2.844(⊿TM5) |

Where, W1 is Normal Growth Available Moisture Holding Capacity, and W2 is Easily Available Moisture Holding Capacity, and W3 is Total Available Moisture Holding Capacity. (⊿TM5) is the CCT counts of band 5 which subtracted the CCT counts of 1984 from the CCT counts of 1985.

## Ⅲ. Method for estimating for Gravelly layer's Depth (GLD) of soil.

The relationship between Landsat TM data and GLD measured at 30 locations was examined. As a result of a regression analysis process, it was found that TM2, TM4, TM5 and TM7 could be used effectively to estimate GLD of upland soil, and correlation coefficient were higher in 1985 than that in 1984. This relationsihp are confirmed at 12 locations of upland soil in an area different from the study area, and correlation coefficient was 0.995 between estimated GLD values and measured GLD values. Therefore, next experimental equation was obtained using the GLD values at 42 locations.

$$GLD=4.565TM2_{85}-5.754TM4_{85}+6.265TM5_{85}-6.417TM7_{85}-126.85$$

$$(r=0.972,\ R^2=0.944,\ n=42)$$

Where, $TM2_{85}$, $TM4_{85}$, $TM5_{85}$ and $TM7_{85}$ are the CCT counts of band 2, band4, band 5 and band7 in 1985 respectively.

## Ⅳ. Development and utilization of "Agricultural Information System" and improvement of soil management based on its information.

1. The translation of each pixel in TM data into OM content, moisture ratio, moisture tension, RRSMC, TAMHC, EAMHC, NGAMHC and GLD by using the above experimental equations enabled to construct classification maps respectively. These method has characters that devided value in classification maps is able to change optionally since TM data consisted of figures from 256 steps ranging from 0 to 255 in the CCT.
2. We developed "Agricultural Information System" (AGRIST) which enabled to utilize the classification maps concern to OM

content, moisture chracteristics, and GLD as primary and high degree's information on computer sysytem.

The classification maps prepared for AGRIST were consist of 8 items such as moisture ratio (Volume%) map, moisture tension (pF) map, RRSMC (dpF/day) map, TAMHC (mm) map, EAMHC (mm) map, NGAMHC (mm) map, GLD map and OM content map. In AGRIST, four functions are prepared such as ①Data input function: renewal of geographical data; data addition, ②Information visual function: visualization of map; accumulation, expansion and squeezing of information; visualization of position, ③Information edition function: color change of map; formation of new high degree's map by overlaying the two primary map, ④Print out function: Print out map on optional size.

3．How to utilize the classification maps such as OM content map, soil moisture chracteristics map and GLD map were discussed from viewpoint as follows; ①how to utlize each classification maps on cultivation of main crops and soil management, ②how to utilize the new high degree's map by overlaying the primary map.

4．The factor strenght on OM content, AMHC and GLD is set. Also it was discussed overall whether any soil condition could be useful to cultivate main crops in Tokaci district, and whether what kind of assistance could be on operating upland farming.