Crop Maps and Yield Maps of Sugar Beets in the Tokachi Plains,Japan,Developed from Multitemporal Landsat TM Data

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Abstract

Crop maps were made using Landsat TM data of the Tokachi plains, Hokkaido, Japan, to investigate the relationship between soil organic matter content and planting ratio. Sugar content and root weight of sugar beets were also estimated using Landsat TM data obtained around harvesting time in 1986.

The study site was classified into 5-subclasses. Sugar beets, potatoes and wheat were distinguished with 95 per cent accuracy. Sugar content and root yield also could be estimated with accuracy using this method. Planting ratio and yield of sugar beets varied according to soil organic matter content. These results suggest that Landsat TM data are useful for constructing crop maps and for estimating sugar content and root weight for sugar beets. Application of this approach may increase productivity of sugar beets by improving fertilization.

1.Introduction

The main crop of upland field agriculture in Hokkaido, Japan is sugar beet. The purchase system of sugar beet changed in 1986, the producer price of sugar beets has been determined on a quality basis. However, prior to 1986 the price was determined by weight. Heavy fertilization resulted in excessively high nitrogen levels, which decreased the sugar content and the root weight. The farmers have become concerned about the current crop management plan and application of fertilizer because of the present soil environment.

It is necessary to collect data regarding sugar content and root weight per unit or grid to apply the fertilizer properly. Unfortunately, data for planted area and yield of each producer are combined in Japan. Neither data for individual fields nor grid data is available. Therefore, Landsat TM data was used to estimate root weight and sugar content of agriculturally grown sugar beets.

A TM sensor has been installed in the fourth Landsat satellite, which was launched in 1984. The number of bands and resolution have been improved. The TM data are available and have been put to practical use in the fields of agriculture, in addition to other fields in Japan.

As the first step in applying TM data, random selection of agricultural fields is necessary to estimate the yield and quality of the object crops. A crop map is required as foundation information. If root weight and sugar content of sugar beets can be estimated, cultivation management can be adjusted to nonuniform conditions.

In this study, a crop map was made using multitemporal Landsat TM data of the Tokachi area, Hokkaido, Japan, to estimate sugar content and root weight of sugar beets at the time of harvest. In addition, relationships between the yield of sugar beets and soil environment were surveyed.

2.Constructing a crop map using TM data

2.1 Study site and data

The study was conducted in the Tokachi plain, in the western portion of Hokkaido. This is an important agricultural region in Japan. The Landsat TM data of the Tokachi plain were acquired from 1985(May 24,July 27,August 12 and October 15) and 1986(July 30,September 16 and October 18). These data are computer compatible tape data.

Hand made crop maps of Nishisikari,Sinsei and Hokoku in the Tokachi plains were produced from the ground truth data. Maps of soil organic matter content for the Tokachi plain were used as soil environmental data. Soil data were reorganized for three levels of organic matter content; high, middle and low.

2.2 Procedure

The image analysis followed the flow chart shown in Figure 1. Mask files were created to remove pixels of the nonagricultural field such as the urban,forest and grass land. The fields of sugar beets, potatoes,wheat,corn and legumes were selected by the supervised classification method using the maximum likelihood decision rule. The logical operation then was applied to the selected fields. Because the boundary pixels of each selected crop contain some information such as adjoining crops and farming roads, the classified area of crops may be underestimated. In the next step, the neighboring pixel process was executed. For example, if at least one targeted crop's pixel in eight pixels were included, a center pixel was judged to be an object crop.

Finally, the files of each crop were overlaid to form the crop map. When one pixel contained two or more kinds of crops following the overlay process, then that pixel was unclassified.

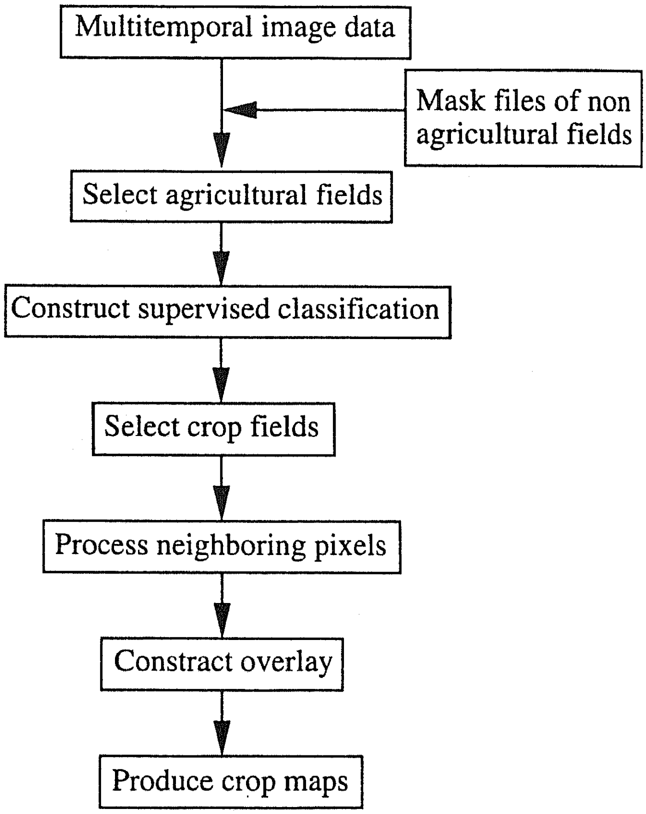

Figure 1 The procedure for constructing crop map.

2.3 Results and discussion

2.3.1 Evaluation of a crop map made from the TM data

The classification was evaluated at the Kamifushiko test field. In addition, the crop maps and the map of soil organic matter content were overlaid and the relationship of the planting ration according to the soil organic matter content were surveyed.

An example of a crop map made using 1985 multitemporal TM data is shown in Figure 2. The area of crop fields were estimated to be 29,353ha in 1985. This value was 34.5% of the total study site area. That area contained sugar beets, potatoes,wheat, corn and legumes at planting ratios of

24.3%, 29.7%, 17.2%, 15.3% and 13.5% respectively.

The black portion in Figure 2 contained urban areas, forests, grass land, river basins and unclassified areas. Unclassified areas included boundary regions of each crop field, another kind of vegetation fields, the self defense forces station and, established grounds for housing.

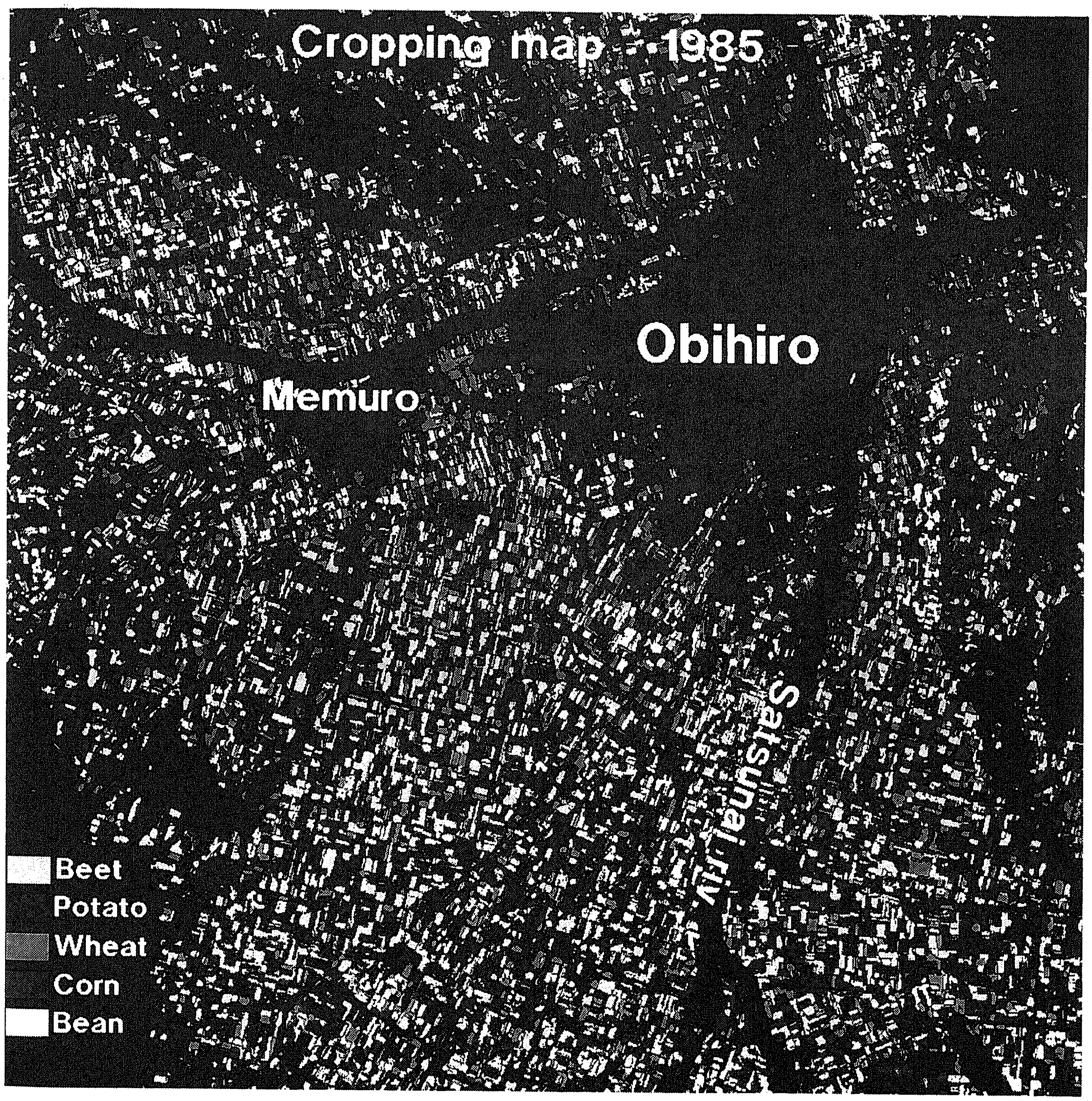

Figure 2 A crop map in Tokachi plains,Hokkaido,Japan, developed from 1985 multitemporal LANDSAT TM data.

Sugar beets, potatoes and wheat were distinguished with 95% accuracy in both 1985 and 1986 TM images (Table1). These results show that Landsat TM band ratios reflecting differences in the period of vegetation are effective in constructing crop maps in Japan.

The described method of constructing a map from Landsat TM data can be used in the Tokachi plain, Japan, where agricultural fields are wider than any other place in Japan. If the information of boundary pixels can be selected with precision the maps created will have high degree of accuracy.

Table 1. The classification accuracy of test fields (%).

1985

	Sugar beets	Potatoes	Wheat	Corn	legumes	unclassified
Sugar beets	100.0	0.0	0.0	0.0	0.0	0.0
Potatoes	0.0	95.6	0.0	0.0	0.0	4.9
Wheat	0.0	0.0	96.9	0.0	0.0	3.1
Corn	0.0	0.0	0.0	81.3	0.0	18.7
legumes	0.0	0.0	0.0	0.0	80.4	19.6

1986

	Sugar beets	Potatoes	Wheat	Corn	legumes	unclassified
Sugar beets	96.7	0.0	0.0	0.0	0.0	3.3
Potatoes	0.0	98.6	0.0	0.0	0.0	1.4
Wheat	0.0	0.0	98.6	0.0	0.0	1.4
Corn	0.0	0.0	0.0	88.4	0.0	11.6
legumes	0.0	0.0	0.0	0.0	88.1	11.9

2.3.2 Characteristics of planting ratio according to soil organic matter content

The planting ratio was calculated from the crop map and the map of soil organic matter content (Table2). The planting ratio achieves 100% with the levels of soil organic matter content. The planting ratio was higher for potatoes and sugar beets in soils with low and middle organic matter content in 1985. However, in 1986, the area planted in sugar beets increased in areas with high organic matter content.

These results were consistent with the findings of an actual investigation of the cultivation system executed near Memuro in the Tokachi plain. Cultivation of sugar beets has continued in areas of high soil organic matter content, to avoid water damage and the decrease of sugar content due to excessive absorption of nitrogen. Recently the planting ratio of root crops has increased due to improved drainage. However, cultivation of crops is not suited to the soil organic matter content. The farmers still believe their experiences. This satellite data can be used for large areas and agricultural fields which can be judged objectivity.

3.Estimation of sugar content and root weight of sugar beet

3.1 Study site and data

The study site for this analysis is the same area described in Section 2.1.

The TM data was collected on September 16 and October 18 in 1986 for the analysis.

Measured values of sugar content and root weight determined at the time of harvest represent an average increase each production association. Each association is composed of eight farms. The regression analysis was based on 22 data points and verification of estimated values was based on 15 data points.

Table 2. Planting ratio according to soil organic matter content (%).

1985

Crops	Soil organic matter content (%) < 5	5~8	> 8
Sugar beets	26	27	22
Potatoes	37	34	24
Wheat	8	12	24
Corn	19	16	14
legumes	10	11	17
Total	100	100	100

1986

Crops	Soil organic matter content (%) < 5	5~8	> 8
Sugar beets	21	22	28
Potatoes	28	30	25
Wheat	26	21	16
Corn	19	19	19
legumes	6	8	12
Total	100	100	100

3.2 Procedure

The image analysis is described in Figure 3. The fields of sugar beets were selected from a crop map which was made using multitemporal Landsat TM data.

The CCT average for sugar beet fields were calculated based on increased production for each association. The analytical data of CCT value, sugar content and root weight were used for multiple linear regression. The sugar content and root weight maps were based on estimation equations. The relationships between sugar content, root weight and soil environment were evaluated.

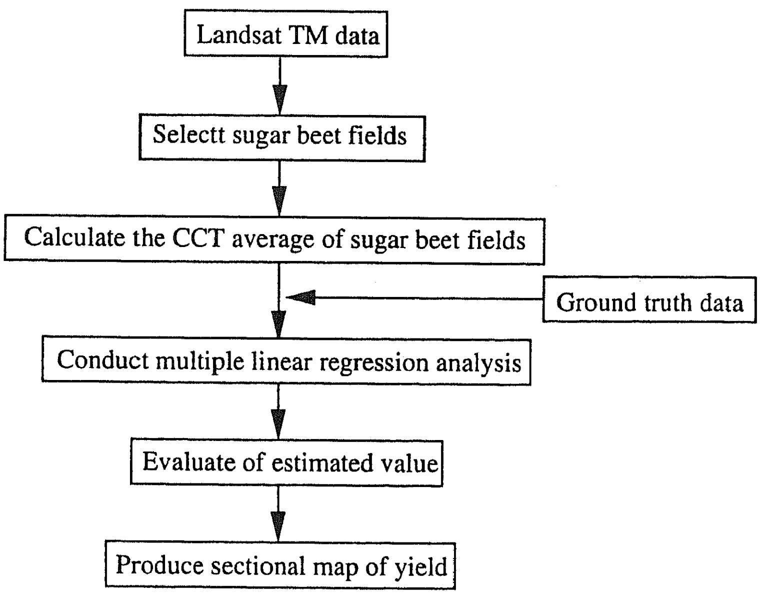

Figure 3 The procudure for constructing sectinal map of yield.

3.3 Results and discussion

Correlation coefficients between sugar content and CCT values of each band were higher in October than in September (Table 3). Conversely, correlation coefficients between root weight and CCT values of each band were higher in September than in October (Table 3).

Table 3. Correlation coefficients between sugar content (SC), root weight (RW) and CCT values of each band on September 16 and October 18 in 1986.

	9.16		10.18	
Band	SC	RW	SC	RW
TM1	-0.01	0.69**	0.65**	-0.12
TM2	-0.07	0.44**	0.60**	-0.28
TM3	-0.09	0.58**	0.72**	-0.26
TM4	-0.52	-0.06	-0.26	-0.25
TM5	-0.45	0.11	-0.10	-0.36
TM7	-0.36	0.20	-0.44	-0.10

** Indicates $P<0.01$

The following equations were derived to estimate the sugar content and root weight successfully:

$$\text{sugar content}=0.172TM1o+0.342TM3o-3.013 \quad (r=0.83^{**})$$

$$\text{root weight}=2.664TM1s+0.849TM4s-1.395TM5s-198.839 \quad (r=0.91^{**})$$

Where TM1o and TM3o are Band1 and Band3, respectively, derived from TM data on October 18. TM1s, TM4s and TM5s are Band1, Band4 and Band5, respectively, derived from TM data on September 16.

The fields producing sugar beets with low sugar content and low root weight were detected frequently on the soil rich in organic matter, while the fields with soil low in organic matter tended to produce sugar beets with high sugar content and high root weight (Figure 4,5).

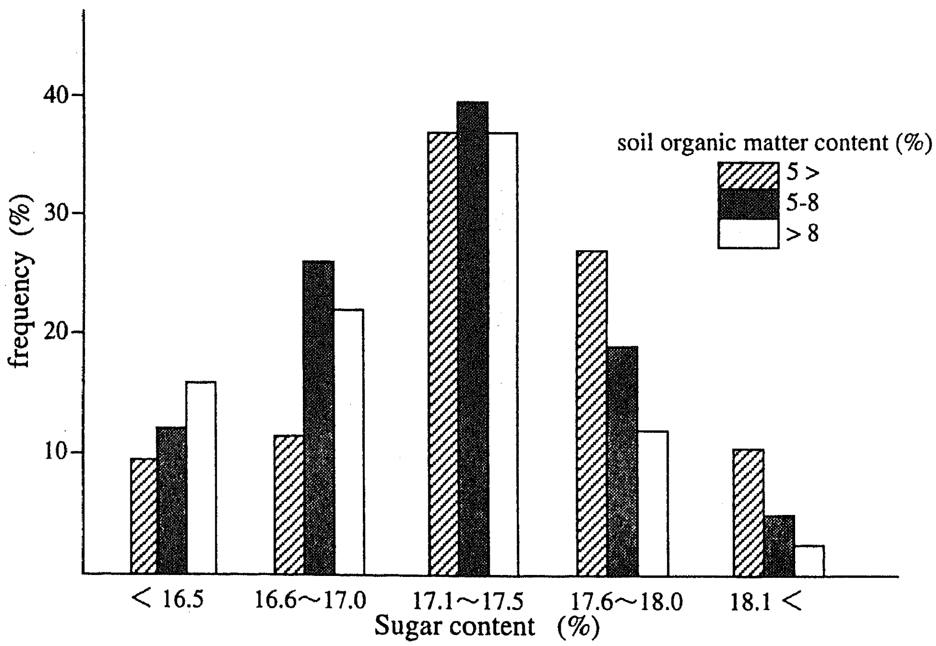

Figure 4 The frequency of sugar content of sugar beet caltivated with three levels of soil organic matter content.

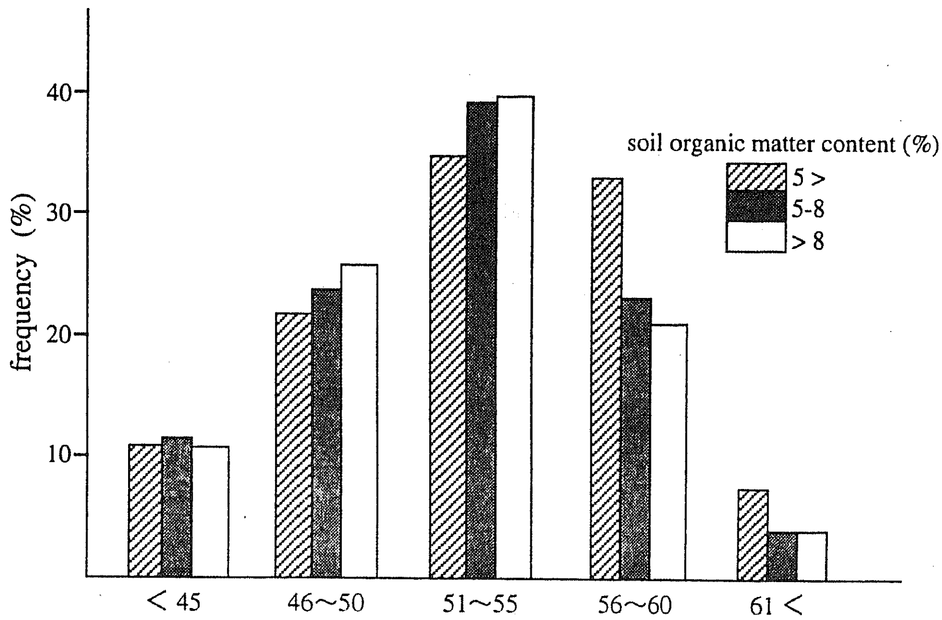

Figure 5 The frequency of root yield of sugar beet caltivated with three levels of soil organic matter content.

It was possible to estimate the sugar content and root weight of sugar beet for large areas using Landsat information. This facilitated an understanding of the relationship between soil environment and yield. However, yield of sugar beets is affected not only by the amount of nitrogen supplied from soil but also by the amount of chemical fertilizer and compost added to the soil.

In the future, it will necessary to consider weather conditions, nutrient uptake availability, planting history and topography during the analysis process.