Estimation of sugar beet yield based on soil type through analysis of satellite data

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Abstract

In order to assess the feasibility of developing an efficient sugar beet cultivation support system to effectively reduce the costs of beet cultivation, beet collection and sugar production using an agricultural spatial information, and also to predict the root yield of sugar beet three months before the harvesting season, an analysis of satellite data and meteorological data was carried out in this study.

For predicting the root yield of sugar beet, the analysis of the growth was conducted around the town of Memuro, Hokkaido, Japan. The cumulative temperature (T), cumulative rainfall (P) and cumulative solar radiation (R) from the end of April to the middle of July were selected as the predictors of the root yield (RY) prediction formula.

$$RY=0.043675R+0.02783T-1.09513P-39.634(r^2=0.87^{**})$$

The predictive error was 3. 8t/ha, that was the result calculated by the farmers group, after weighted to the predicted root yield using NDVI which was derived from SPOT5 satellite data. The results suggest that it was possible to predict the root yield before three months of harvesting season. By providing such result to sugar companies in much earlier before harvesting, the sugar beet collection and sugar production efficiency will be increased.

Keywords **:** root yield prediction, precision agriculture, cost reduction

1. Introduction

The production of beet sugar in Hokkaido is about 640,000 tons, which is 3/4 of the total national production (Ministry of Agriculture, Forestry and Fisheries, Japan 2006). The Japanese government is implementing a "New policy on sugar beet crops and other sweet resources" policy, through which it aims to reduce the cost of the production and manufacturing processes.

In order to assess the feasibility of developing an efficient sugar beet cultivation support system to effectively reduce the costs of beet cultivation, beet collection and sugar production using an agricultural spatial information, and also to predict the root yield of sugar beet three months before the harvesting season, an analysis of satellite data and meteorological data was carried out in this study.

2. Methods

2.1 Study site

This study was conducted around the town of Memuro located in the middle west of the Tokachi plain, Hokkaido, Japan (longitude 143.1°E, latitude 42.9°N) (Fig. 1). The area of the test site in this study is 22.6km from east to west and 35.4km from north to south, in which large-scale agricultural management is performed. The acreage of sugar beet cultivation is 3,505ha in Memuro, and the average cultivation area of sugar beet per farmer is 6.9ha(Ministry of Agriculture, Forestry and Fisheries, Japan 2007). The test site can be divided into three geographical types: lowland, low, middle and high terraces (Koji Kikuchi 1981).

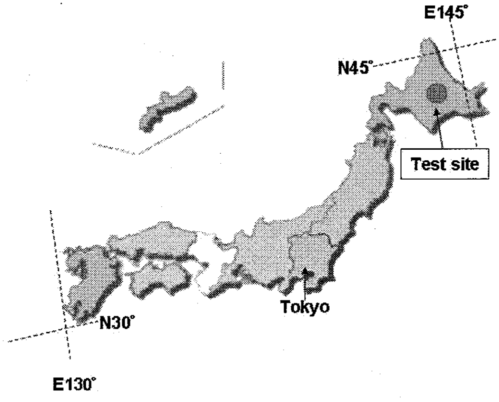

Fig1. Study site

2.2 Ground truth data

Sugar beet field observation data was prepared to analyze the relationship between beet tops and root yield. To measure the plant height, leaf color (SPAD: Soil & Plant Analyzer Development), root yield and sugar concentration, investigation points were set in 56 different locations each with an area of 3 rows×7 plants (Fig 2). The field survey was performed from June to October in 2006 and 2007. In addition to these data, the annual average root yield in Memuro from 1990 to 2007 were prepared, which was compiled by Hokkaido Government Tokachi Subprefectural Office.

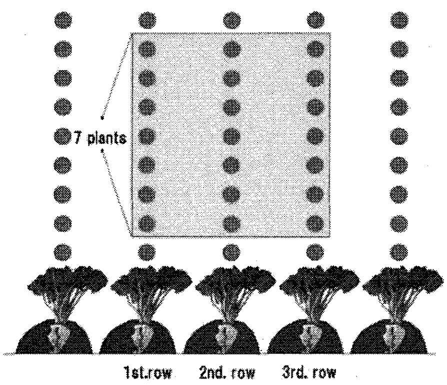

Fig .2 Outline of a ground observation point

2.3 Meteorological data

Data on cumulative temperature, cumulative rainfall and cumulative solar radiation from the end of April to the middle of July was collected from Obihiro meteorological observatory and Memuro observation site.

2.4 Satellite data and GIS data

SPOT data was acquired on July 27, 2006 and July 27, 2007. GIS data of 2006 and 2007 was used to identify sugar beet fields from the satellite data.

2.5 Procedure

The procedure for predicting the root yield is described in Figure 3.

To derive the root yield prediction equation, multiple linear regression analysis was executed using the data on cumulative temperature, cumulative rainfall and cumulative solar radiation from the end of April to the middle of July from 1990 to 2005. The average root yields of Memuro town in 2006 and 2007 were predicted using the yield prediction equation.

Secondly, the digital values of sugar beet fields derived from the satellite data were converted to surface radiance values, and the majority value of the NDVI was calculated from the radiance values of all sugar beet fields in Memuro.

The predicted yield obtained from the meteorological data and the majority value of NDVI are presumed to be equal, and the NDVI values of whole sugar beet fields were transformed into a absolute root yield value after calculating the predicted yield value in proportion to the NDVI value.

Finally, to validate the root yield prediction results of 2006 and 2007, the predicted root yields of the farmers' groups were compared with the observed root yields by calculating RMSE.

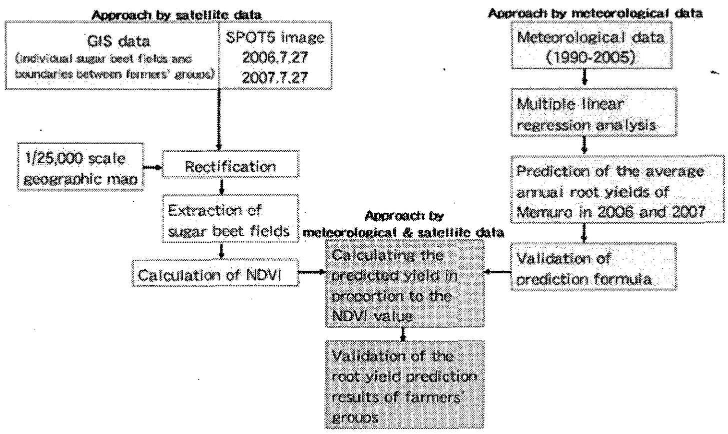

Fig. 3 Procedure of image analysis

3. Results and discussion

The relationship between SPAD×plant height and the root yield was investigated. There is positive correlation between [SPAD×plant height] on July 12 and the root yield on October 4, 2007. The coefficient of determination is 0.64.

The result shows that sugar beet with a larger amount of leaf and stem in July has a higher root yield in the harvesting season, and it is also suggested that the root yield in the harvesting season is determined by the growth status of beet tops in July. Moreover, there is positive correlation between [SPAD×plant height] and NDVI on July 27, 2007 (r^2=0.6). Through these results, it may be possible to estimate the root yield of sugar beet about three months before the harvesting season.

For predicting the root yield of sugar beet, the analysis of the growth was conducted around the town of Memuro, Hokkaido, Japan. The cumulative temperature (T), cumulative rainfall (P) and cumulative solar radiation (R) from the end of April to the middle of July were selected as the predictors of the root yield (RY) prediction formula. The root prediction formula derived from these predictors is as follows:

RY=0.043675R+0.02783T-1.09513P-39.634(r2=0.87**)

The coefficient of determination of the prediction formula is 0.87, which is significant at the 1% level. RMSE is 3.2t/ha, which is calculated from the predicted root yield and observed root yield.

In our previous research, we reported that there was a positive correlation between the root yield at the harvesting season and the amount of beet top in July and that was possible to estimate the root yield by analyzing the SPOT5 satellite data acquired in July(Chiharu Hongo et al. 2006a), 2006b), 2008,).

However, the absolute root yield value cannot be obtained before the harvesting season even if the satellite data in July is applied to this prediction approach because it is necessary to know the ground observation root yield data of October, which is input into the prediction formula to derive the absolute root yield value. Thus, we focused on the relationships between the beet top biomass and NDVI in July and root yield in October, and the absolute root yield value was derived using the following prediction procedure.

The root yield predicted using the formula is replaced by the majority NDVI value of the beet fields cultivated in the study site. The predicted average root yield is converted to the root yield of individual sugar beet fields in proportion to the NDVI value. Finally, the average root yield of each farmers' groups was calculated from the yields of individual sugar beet fields.

The scatter graph in Figure 4 shows the relationship between the prediction root yield and the observed root yield in 2007. The ground observed root yield data was collected from the observation points on farmers' fields, each of which consisted of three rows of 7 plants. The RMSE of the predicted value relative to the observed root yield was 4.8t/ha, corresponding to an error of about 6.8% against the observed value of 70.54t/ha. However, the RMS error of the predicted value was 3.8t/ha after eliminating the fields with the brown lowland soils.

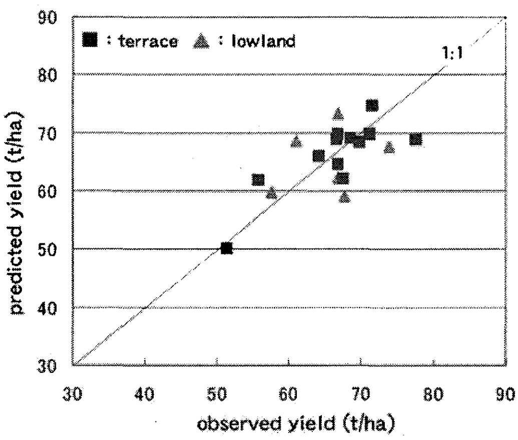

Fig.4 Relationship between predicted yield and observed yield of the field observation points (2007)

4. Conclusion

To assess the feasibility of developing an efficient sugar beet cultivation support system to effectively reduce the costs of beet cultivation, beet collection and sugar production using agricultural spatial information, and also to predict the root yield of sugar beet three months before harvesting season, analysis of satellite data and meteorological data was carried out in this study.

The results show that it is possible to predict the root yield with high accuracy using the meteorological data and satellite data. In this study, we have constructed a new yield prediction method using the average root yield in region predicted from meteorological data replaced by the majority of NDVI value of the beet fields.

By providing such results to sugar companies much earlier before the harvesting, the efficiency of sugar beet collection and sugar production is expected to increase substantially, which will lead to economic and environmental benefits.

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