NIRとGISを活用した効果的なサトウキビ営農支援情報システム

An Effective Information System to Assist the Sugarcane Farming Using NIR and GIS

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Abstract: An information system was developed to assist the sugarcane cultivation by precisely grasping the conditions of soil, crop and others. Near Infrared Reflectance (NIR) spectroscopy for evaluating the cane quality in the current payment system was employed as an effective data collecting system. Sugar content and unit yield obtained automatically in the payment system were used to make a database. The function of NIR measurement system was extended to evaluate the components of cane juice and soil. It was confirmed that sucrose, glucose, P, K, Mg and other minerals could be measured within a certain accuracy level. A large volume of data collected by the system enabled us to make a database with quite low cost. A model information system equipped such data collecting system was installed into the sugarcane production system in Minami-Daito Island. Spatial analyses on the unit yield and sugar content were carried out using Geographic Information System (GIS) in order to achieve the purpose of the system. Combination of NIR and GIS was quite effective to analyze the structure of sugarcane production system. The availability of the system to improve the farming and management of individual farm was demonstrated by some case studies.

Key words: NIR, GIS, information system, quality information, data collecting system, precision farming

Introduction

Sugarcane is a major crop in Okinawa with 50% of farmland and 70% of farmers engaged in its production. The yield and income in Okinawa reach about 0.9 million tons and 18 billion yen respectively. Recently, some factors such as extreme aging of farmers and a relative decrease in income have resulted in a serious reduction in output. However, sugarcane is still valued as an indispensable crop in Okinawa because of its superior qualities such as its economical effect on rural society especially small islands, the high productivity of its bio-mass, toughness to typhoon and drought, preservation of environment and so on. In addition, the payment system of sugarcane has turned to evaluate from the weight to the quality i.e. content of cane sugar since 1994/95. Farmer's income depends on both weight and quality. The price within the range in 13.1-14.3 % sugar content is set 20,190yen/ton, and the change of 0.1 % of it deduces increase/decrease of 130 yen in the outside of the range, so farmers are compelled to improve their farming.

To overcome such severe situations, new production systems should be established to realize not only high-yield, high-quality and high-efficiency, but low input and sustainable agriculture[1)]. The systems execute precise control for cultivation and management according to the conditions of the farmlands and crops by systematically using various kinds of information. In this study, an information system in order to carry out the production assistance was constructed. For the success of the information system, effective data collection with low cost is dominantly important. The quality-oriented payment system can be regarded as the data collecting system. Therefore, a numerous volume of quality data can be automatically obtained using the system. NIR works as a sensor to detect the sugar content in the system. NIR has a potential to measure various kinds of components at the same time if calibration equations are prepared. New functions were installed to the NIR system for measuring the mineral contents in cane juice and soil.

Minami-Daito Island was selected as a model area to found such information system. Basic concept and constitution of the system and its application were discussed by focusing on the production system of the is-

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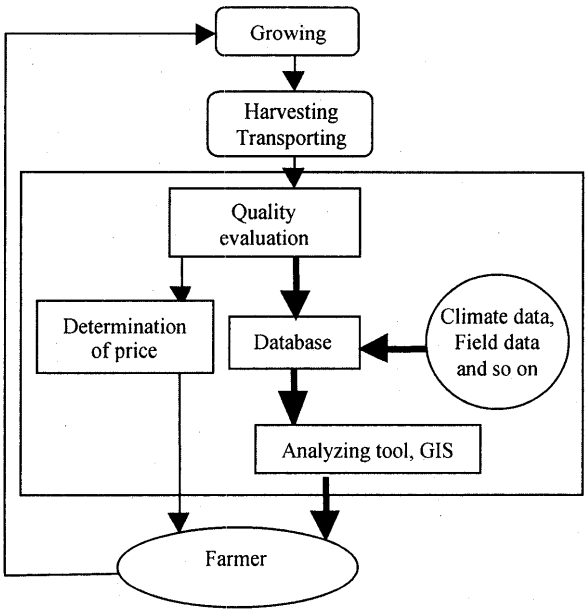

Fig. 1. Structure and concept of the infomation system.

land. Distributions of the unit yield and sugar content were analyzed, and the effects of cropping type and variety were examined, and some distinct properties were made clear. Sugar content increased continuously during the harvest season especially in the latter half of it. Such tendencies could be described by a parabolic curve or linear line. Geographic information system (GIS) was employed as a powerful tool to manipulate the data attached onto the farmland. In addition, GIS worked as good viewer and analyzer for the spatial distribution of data. The maps of sugar content and unit yield were made using the GIS, and some of spatial analyses were carried in order to obtain useful information for precision farming. The availability of the information system was confirmed by some case studies in order to improve the cultivation and management of individual farms.

Methods

1. *Information system and data collecting system.*

The values of sugar content and unit yield are automatically collected from all of the sugarcane growing fields through the quality-oriented payment system. A large volume of data is systematically collected every day and every year as long as growing sugarcane. Although such data is just a numerical value to determine the price, systematic collection and analyses turn it to useful information. The system brings us a big chance to establish a large size database with quite low cost, because various kinds of data can be obtained through the system. Thus, a research project has started to utilize effectively such database and to found information systems for production supporting. Such data is combined with the various kinds of information to realize more sophisticated methods for fertilizer application and farming management. Figure 1 shows the concept and outline of the information system based on the payment system.

NIR system is a powerful tool to analyze chemical components, and it has been used to measure the sugar content in the payment system. The process of measurement is as follows; At first, sample cane about 5 kg is picked up using a core-type sampler from every transport truck at the entrance of the sugar mill. Clean cane is separated from trash, and shredded into small pieces and pressed with constant pressure and duration. The juice obtained is filtered and supplied to NIR system using an automatic liquid supplier. The temperature of juice is kept constant in the measurement. Sugar content i.e. Pol in cane is measured and the price of the sugarcane is determined in the system. New functions are added to measure the contents of N, P, K and other minerals in the cane juice simultaneously at the sugar content measurement for more useful applications. At first, 100-200 sampling fields were selected in Minami-Daito Island in order to carry out more detail analyses and develop NIR calibration equations for measuring the mineral contents. Juice, bagasse, soil and leaves were sampled from these fields since 1996 to 1999. Mineral contents were measured by ICP and HPLC in order to establish of calibration equations for NIR measurement.

The obtained data enables us to improve the farming technology. It means that the quality-oriented payment system can be used as a monitoring system of sugarcane fields[2, 3] as shown in Fig. 1. The analysis of its database is equivalent to the large scale field test carried out under various and natural conditions. This function is regarded as a "Virtual Experiment Farm", which is called "Dehji Farm" by the authors. It seems to be available to many studies for example the selection test in breeding. GIS plays very important roll to represent effectively the data and to analyze the spatial distribution. Almost data belongs to the farmland, therefore GIS is quite useful in order to achieve the purpose of information system.

2. *Outline of Minami-Daito Island.*

Minami-Daito Island is chosen in order to construct a model system, which locates about 400 km east far from Naha City. The width is about 6 km to North-South and 5 km to East-West. The periphery of the island is relatively high and the central zone hollows like an ashtray. There are many ponds in the

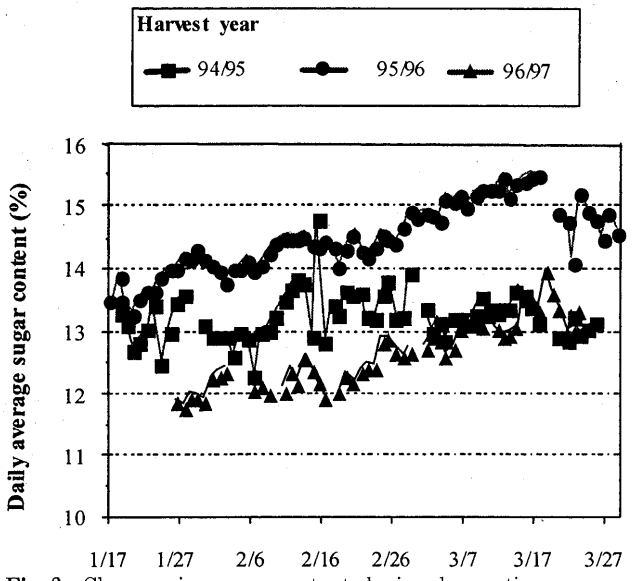

Fig. 2. Changes in sugar content during harvesting season.

central zone. Topographical feature, soil-type, variety of sugarcane and farming manner are almost uniform in the island. Main crop is sugarcane rather monoculture. The farming land is about 1,800 ha and about 250 farmers engage into sugarcane cultivation. The full-mechanized farming system has been established. Harvest area reached to maximum in 1964, about 1400 ha. The change in harvest area was not so large during 30 years, but the ratio of cropping types varied remarkably. Total and unit yields altered up and down in the period, which were mainly affected by climate conditions such as typhoon and draught. Total yield in the decade of 1960 was about 90,000 tons, however, it reduced to about 50,000 tons in recent. These values became seriously low level during 1979/80 to 86/87 harvest seasons. A weak tendency that these values decreased linearly was observed before the duration. Burn-type harvesting system and soil compaction by heavy machines were regarded as main causes of the yield reduction. In addition, nematode and inadequate farming influenced to the yield. Recently, total and unit yields recovered to a certain level, however, many subjects remain in realizing a high-efficient and stable production system.

Results and discussions

1. *Analyses using the database*

(1) Time series of sugar content during the harvest season.

Figure 2 showed the time series of the daily average of sugar content within three harvest seasons. The tendencies of the time series were different each other. Daily average increased slightly in the latter half of the harvest season day and day in any years. The difference of it

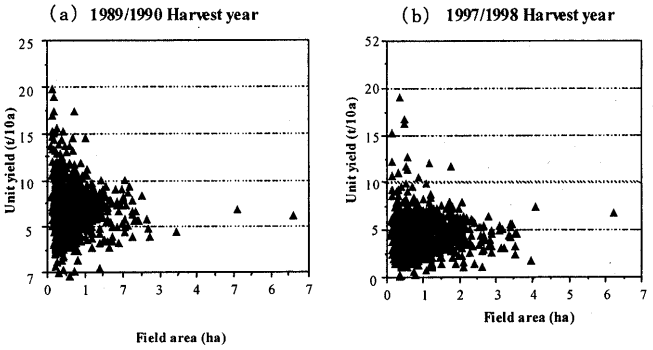

Fig. 3. Distributions of field size and unit yield of ratoon cane.

during the season reached to about 2 % in maximum, which was equivalent to 2,800 yen/t. The time series could be approximated by a quadratic equation or a linear equation. The daily average in 94/95 changed with small width through the season. It seemed that the damage of severe draught caused the tendency. The sugar content in 96/97 harvest season was quite low especially at the beginning of season, however it increased largely at the latter end. The tendency was caused to the damage of typhoon at the late of November, 1996.

(2) Effects of unit yield and field size.

Density of cane plant is not uniform in the field due to various reasons so that the control of the density seems easy for small size farm rather than large one. In other words, the farm size affects on the unit yield. The influence of size to the unit yield was investigated for every cropping type. Unit yields of ratoon cane were plotted to the field size as shown in Fig. 3. Unit yield scattered with wide range when the size was small, and gradually converged to a certain value with the increase of size. The distribution in 89/90 harvest season was looked like a triangle which was a typical pattern. Although upper bound of the triangle decreased with the increase of size, there was no correlation between size and unit yield. The cause to draw the triangular distribution could not make clear. When the unit yield was totally low, the triangle deformed as shown in the pattern of 97/98. Similar tendencies were observed for summer plant cane and spring plant cane. In the viewpoints of precision farming, the wide distribution at the small size field should minimize and bottom up.

(3) Distribution of sugar content and unit yield.

Figure 4 showed the distributions of harvest area, total yield and unit yield of all ratoon cane fields in the island during nine years. The distribution of harvest area coincided to that of management size. There were two distinctive points at about 5 ha and 8.5 ha. Total yield distributed to draw a smooth reductive curve. Unit yield represented a single peak curve. These distributions

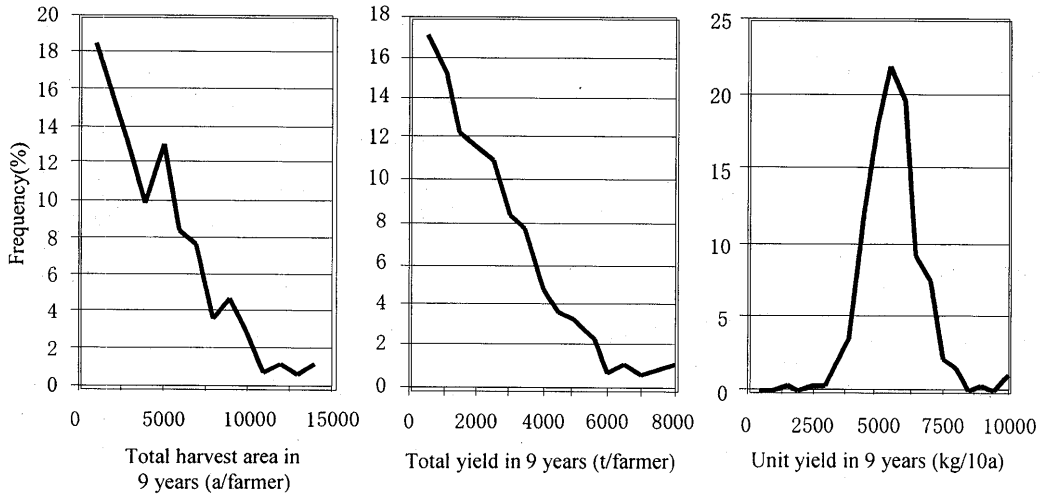

Fig. 4. Distributions of harvest area, yield and each farmer.

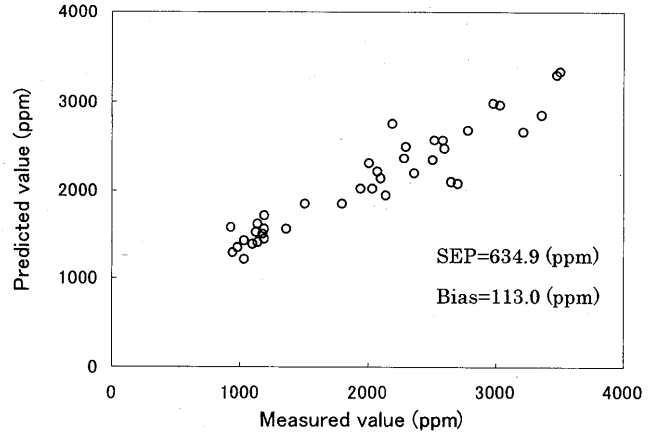

Fig. 5. Evaluation of NIR prediction of K content in juice.

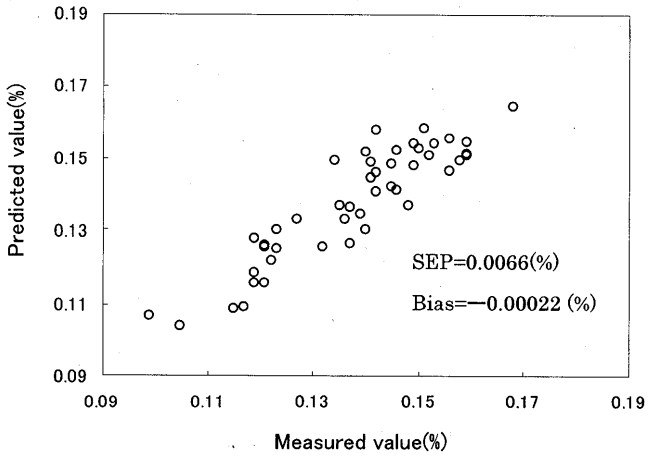

Fig. 6. Evaluation of NIR predication of TN in dried soil.

exhibited the productivity and management feature in the island. There were clear differences among the cropping types in the unit yield, i.e., summer plant cane, ratoon cane and spring plant cane in order. A part of spring plant cane showed higher value than that of summer plant cane, because the unit yield of a part of summer plant cane was quite low. If the reason of it was clarified by the view points of field conditions and weather conditions, it was useful to improve the farming manner. The order of sugar content was ratoon, summer plant and spring plant, even though the differences were not so clear. The productive efficiency of ratoon cane was highest with respect to unit yield, sugar content and growing duration.

2. *Potential of NIR measurement for minerals in cane juice and soil.*

A detailed analysis for the precise fertilizer application is possible by evaluating N, P, K contents in cane juice and soil. Whether NIR is effective or not for mineral measurement is an important subject. If NIR measurement is available, a large volume of data is obtained rapidly and easily. The relationship between the predicted values using NIR and the measured values of K content in juice showed good agreement as shown in Fig. 5. It was statistically confirmed that sucrose, glucose, P, K, Mg, S, Si, fructose, Na were able to measure within a certain level of accuracy. Some of them should be improved by collecting samples with more wide range. Fig. 6 shows the relation between the predicted values and measured values of total nitrogen (TN) content in the soil. The values of pH, Total Carbon (TC), moisture and K in the soil were also measured.

3. *Analyses using GIS.*

GIS is an effective tool to express and to analyze spatial distribution of the quality data. GIS can also be applied to the optimum scheduling of cultivation taking into consideration the next season's production. The digital maps of all fields were made using 1/5000 scale paper map and the air photography of Minami-Daito Island. The total number of fields was about 1800.

Figure 7 showed the distribution map of sugar

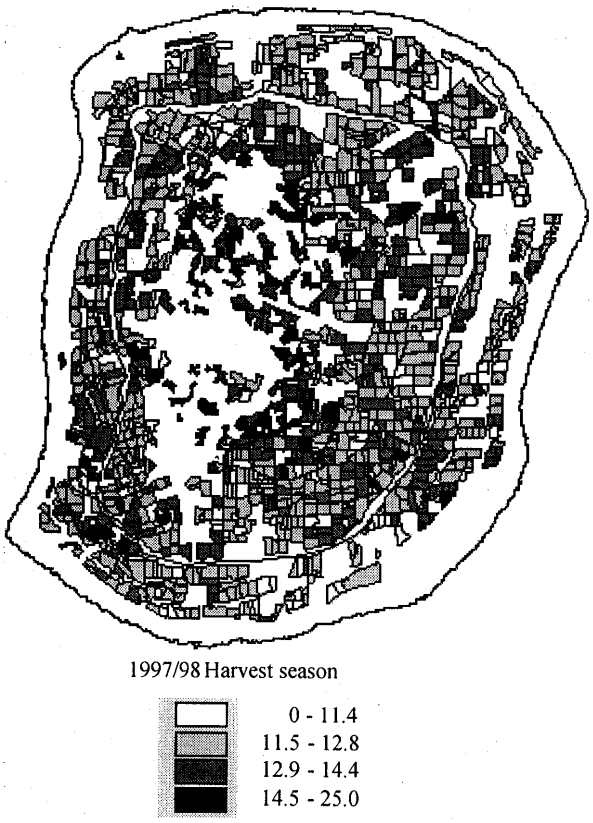

Fig. 7. Distributions of sugar content of all fields.

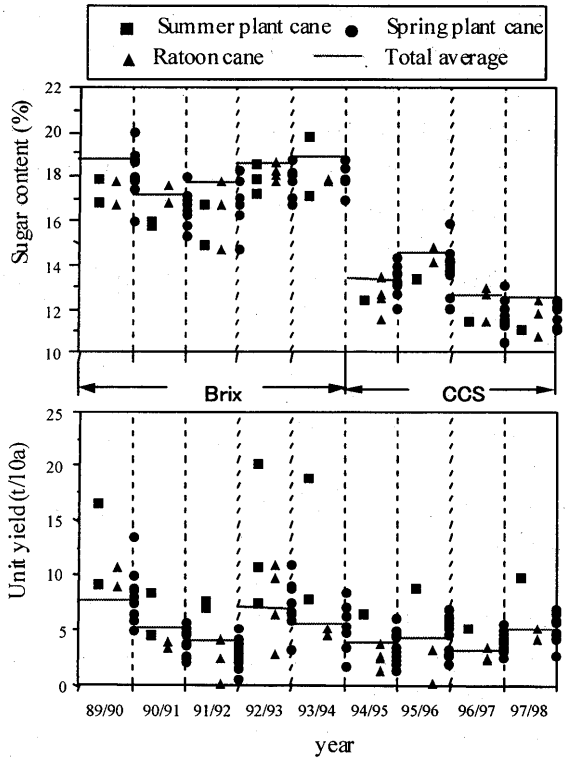

Fig. 9. Changes in production of a farmer.

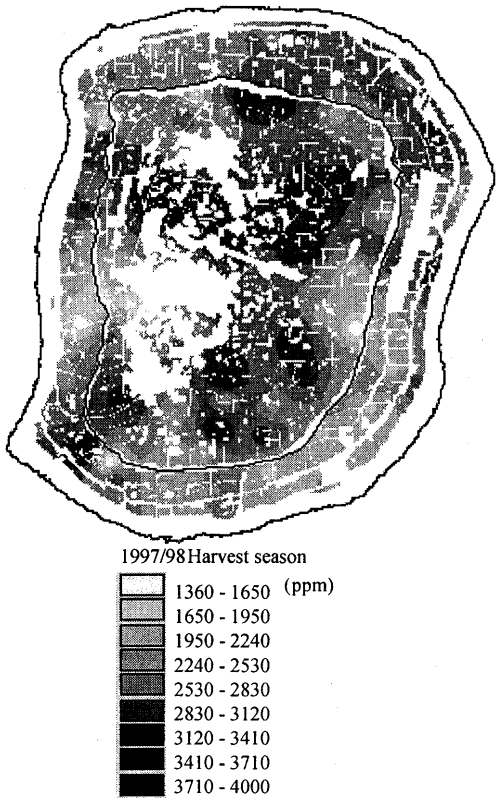

Fig. 8. Distributions of K- content in cane juice.

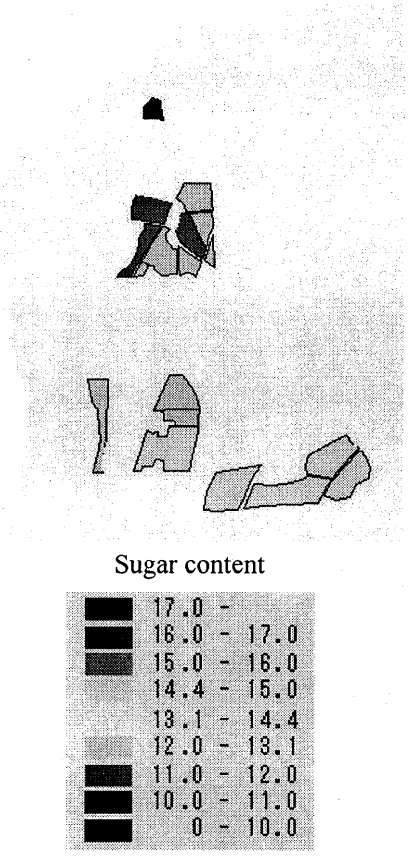

Fig. 10. Location of fields of the farmer.

content. There were many fields that the sugar content was low at the North-East region. On the other hand, high sugar content fields were located mainly at the neighborhood of ponds in the central zone. High sugar content and low unit yield produced the low sugar yield at the neighborhood of ponds. Low sugar yield was produced because of the low sugar content and unit yield

at the North-East region. Thus, more detail analysis can be executed with respect to the geographical features and the surroundings. Therefore, mapping is useful to carry out the precision farming. A distribution of K content in cane juice was shown in Fig. 8 in 97/98 harvest season using surface map. There was a negative correlation between the K content and the sugar content. Therefore, we can find out effectively the spots or the fields to improve the content of fertilizer.

4. *Application to consulting for farmers.*

Detailed analysis was applied to consulting farmers. Here, two farmers were listed as samples. One of them was a superior farmer with unit yield and sugar content as shown in Fig. 9. His fields located at the Northern part (see Fig. 10) and inside of the peripheral plateau. The fields had almost same size about 0.3 ha. Ratoon cane was the main cropping type. His average sugar content was higher than that of all farmers in the Island after introducing the new payment system.

Conclusions

Information system to support the precise farming was founded using a large volume of data obtained from the quality-oriented payment system of sugarcane. Quality database and map database were constructed. The system exhibited a superior potential to improve farming technology and to carry out optimization of the production system. The structure of production system was made clear using the database of quality data. Distribution characteristics of unit yield and sugar content were analyzed. As a simple case study, the productivity of farmers was evaluated using nine years data in the database. NIR was effective as a data collecting system to measure mineral contents in cane juice and soil. GIS showed powerful function to analyze the spatial distribution and to pick up the fields to be improved. It could be concluded that the NIR-GIS combined information system was quite effective to improve the farming manner for all farmers.

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NIRとGISを活用した効果的なサトウキビ営農支援情報システム

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要 約

土壌状態や作物状態を詳細に把握してサトウキビ栽培を支援する情報システムを開発した．現行の品質取引で品質評価に利用されている近赤外分光分析装置（NIR）を効果的なデータ収集装置として使用した．品質取引において自動的に得られる糖度と単収をデータベース化した． NIR測定システムの機能をジュース成分と土壌成分の評価もできるように拡張し，ショ糖，グルコース，P，K，Mgおよび他のミネラル成分を一定精度内で測定できることを確認した．本システムで得られる大量のデータによってデータベースを極めて低コストで作成できることを示した．南大東島のサトウキビ生産システムにこのようなデータ収集システムを備えたモデル情報システムを組み込んだ．さらに，このシステムの目的を実現するために地理情報システム（GIS）を用いて単収と糖度の空間分布の解析を行った．NIRとGISの組み合わせはサトウキビ生産システムの構造を解析するのに非常に有効であることが明らかとなった．いくつかの事例研究によって個々の農家の栽培と経営の改善におけるこのシステムの有用性を示した．