STUDIES ON GARLIC FARMLAND EXTRACTION BY REMOTELY SENSED DATA

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ABSTRACT:

Garlic plant is an economic crop in Taiwan, and it's almost the most important seasoning food for everyday Chinese food cooking. The shortage of garlic production always causes social, economical or even political problems and its price could be very expensive. In that case, the Government might be forced to open the market for foreign garlic, and so the early knowledge of the planting area of garlic is important for the balancing and control of garlic farming and market. In this paper the growth spectra of garlic were measured with GER spectroradiometer and compared to corn and other seven food-crop spectra. An airborne multi-spectral scanner was also used for images acquisition to reckon the garlic parcels NDVI thresholds. And it's found that when the spectral reflectance curves of garlic were normalized with growth calendar, the correlation between ground and airborne measured NDVI curves was 0.76. It's also conjectured that most food plants may have their specific growth curves, and multi-temporal remotely sensed data have the potential for garlic parcels discrimination. Furthermore, we found out the specific cultivation behavior of paving straws on garlic field during the early growth period for keeping soil moisture can induce distinctive spectrum for identification, which paves the way for the feasibility of earlier estimation of garlic area using remotely sensed data. GIS polygons of the experiment farmland were used for assisting the segmentation of garlic parcels, which included a 1x1.2 km^2 area or about 202 parcels. Finally the threshold technique to recognize garlic plant site from AMSS images was developed. The results show that the accuracy is about 78% when one AMSS image is applied, while the accuracy rises to 87% when three AMSS images are applied.

1. INTRODUCTION

Garlic plant is an economic crop in Taiwan, and it's almost the most important seasoning food for everyday Chinese food cooking. The shortage of garlic production always causes social, economical or even political problems and its price could be very expensive. In that case, the government might be forced to open the market for foreign garlic, and so the early knowledge of the planting area of garlic is important for the balancing and control of garlic farming and market

The characteristic of synoptic view of remote sensing makes it suitable for large area monitoring. For the application in agriculture, the te chnology can be used for the monitoring of growth condition, nutrient deficiency, stress caused by illness or pest, area or yield estimation (Robert, 1997; Moran, 1997). . Fundamentally, the spectral signature and/or the derived vegetation indices of crops can be used to study the spatial and temporal variation of plants, and the information related to plant is then derived.

During the previous study, we have measured and studied the full-growth-period spectral response of garlic using a 704-channel GER3700 Spectroradiometer and SPOT satellite imagery, and it's found that when the spectral reflectance curves of garlic were normalized with growth calendar, the correlation between ground and space-borne measured NDVI curves was as high as 0.998. It's also conjectured that most food plants may have their specific growth curves, and multi-temporal remotely sensed data have the potential for plant discrimination. Furthermore, we found out the specific cultivation behavior of paving straws on garlic field during the early growth period for keeping soil moisture can induce distinctive spectrum for identification, which paves the way for the feasibility of earlier estimation of garlic area using remotely sensed data.

2. MATERIALS AND METHODS

2.1 Experiment Site

An experiment area of 1 km *1.2 km in Huwei Town, Yunlin County was selected for this study. In this area, there are 255 cadastral parcels, however, the number of parcels for practical farming is between 198 ~ 203, depending on various growing season. The GIS data of the cadastral maps were created for integrated analysis with remotely sensed data. Ground truth survey was also made to check which parcel was garlic crop, which is the basis for future comparison with the results derived from remotely sensed data.

2.2 Measurement of Spectral Response of Garlic Crop

A 704-channel GER 3700 spectroradiometer (380 nm ~ 2500 nm) is used for the ground measurement of spectral reflectance of garlic crop. The spectral radiance ($W/M^2/sr/nm$) of a standard white board is measured, and then the spectral radiance of the target is measured, the ratio of the two gives spectral reflectance of the target. During the full growing season of garlic parcel, the spectral reflectance was measured every two weeks if the weather condition permitted.

2.3. Airborne MSS Data Acquisition

The 11-channel DS-1260 AMSS data were adopted for the research on the recognition of garlic parcels. The AMSS data have better ground resolution than SPOT or Landsat data, for those reasons AMSS dada are deemed the best material for this study. During the garlic growing season in '00~'01 crop, four MSS flight mission were conducted , with altitude of 5000 feet and pixel size of 3.5 meters, over the experiment area on Oct. 22, Nov. 28, Feb. 08 and Mar. 22.

2.4. Normalized Difference Vegetation Index (NDVI)

During the growing period, the reflectance of a crop changes, and especially there are distinctive reflective property in NIR and red channels. NDVI is usually used to characterize the growth status of vegetation :

$$NDVI = \frac{R_{NIR} - R_{Red}}{R_{NIR} + R_{Red}}$$

R_{NIR}, R_{Red}: reflectance in NIR and Red channel

The NDVI of AMSS data is calculated by the above equation with their digital number (DN) derived IARR (Internal average relative reflectance), while the NDVI of spectroradiometer data is calculated by the integration of the reflectance of all channels within NIR and red channels.

3. RESULTS

Fig.2/3 show the response curves and NDVI of garlic and other crops. During the initial growing stage within 2 months after the seeding of garlic cloves, the spectral response dominated by straws and so the NDVI is lower. NDVI reaches the highest value on the 129 days of the growth calendar and then declines during the bulbing stage.

The initial spectral response of garlic field mainly comes from the contribution of bare soil, and the paving straws on garlic field for keeping soil moisture and preventing grass growth. This paves the way for earlier recognition of garlic parcels and estimation of planted area. Fig.3 explains this phenomenon clearly. During the middle stage of garlic growth, the straw is rotten, and the spectral response of garlic field is the combination of that from soil and garlic leaves. NDVI of rice straw ranges from 0.1 to 0.25, differs from the bare soil (<0.05) and any green plants (>0.3).

The relationship between airborne AMSS NDVI and ground measured NDVI was explored. In order to reduce the effects of atmosphere and sun illumination, the AMSS data were normalized with IARR,Internal Average Relative Reflectance, method, which constitutes the following steps: ①normalization of the DN value of each channel image, ②relative reflectance is obtained by dividing DN of each pixel by average DN. ③enhance the image to let the DN spans the range 0 ~ 255.

When MSS data were processed, their images were generated and ground truth are made by field checking, the following NDVIs of various crop fields were measured for ground data and calculated forms data (Table 1). When 1'st order polynomial equation was used to regressed the relationship of MSS NDVI on GER NDVI, the $R^2 = 0.76$ (Fig. 5).

Fig.4 shows the distribution of garlic and non-garlic NDVI distribution. It shall be mentioned that the NDVI in the figure has been transformed by the following equation(Fig. 5):

$$NDVI_{MSS\ IARR} = 0.2991 \cdot NDVI_{GER} - 0.0804 \qquad R^2 = 0.76$$

In Fig.4, the overlapped area of garlic and non-garlic NDVI distribution accounts for 17% of total area, in other words, when using only single MSS image for garlic parcels recognition, the error will be 17%, at least.

From Fig. 3, the values of GER NDVI from bare soil to garlic fields are between 0.1, 0.25, which is equivalent to the MSS NDVI range from -0.5, -0.0056, in other words, which are also the thresholds for garlic parcels recognition using single MSS image, and the error will be 17% which comes from overlay error owing to geometric distortion, deviation of cadastral map or other vegetations having the same NDVI with the early stage of garlic field. When 2000/11/28 MSS image was used for garlic parcels identification, 82.4 % of garlic parcels were identified and 75.2 % of non-garlic parcels were correctly classified, and the overall classification accuracy was 78%.(Table 2). Fig.6 give the actual garlic parcels and the classification map corresponding to Table 2.

Four images collected during the full growing period of garlic were adopted trying to improve the classification accuracy. The NDVI average of four images is shown in Fig. 7, showing the trend of NDVI distribution during the full growing period. It's found that during the late growing stage of garlic, the spectral signature isn't homogeneous, while it's fluctuated owing to that the garlic spectral response is gradually close to background response. Hence, the image acquired during later growing stage might be not good for garlic identification..

The concept used for multi-temporal recognition of garlic parcels is shown in Fig. 8. Following the procedures, the MSS data are geometrically corrected and registered to the map, the IARR reflectance is calculated, the NDVI index is calculated for every pixel and then the cadastral GIS data are referred for garlic field training, image classification is then done using the derived.

As shown in Fig. 9, when three images were used to classify garlic parcels, among them only two images were acquired in the initial growing stage, 91.2 % garlic parcels were recognized, and 83.1 % non-garlic parcels were also identified. The overall accuracy was 87 %, which might be able to be improved when more image acquired during the early growing stage are adopted..

4. DISCUSSION

1. The garlic spectral curves during the full-growth-period were built and studied, and its found the unique cultivation behavior and significant spectral characteristics during the early growing stage making the early recognition of garlic parcels become feasible

2. The relationship of remotely sensed and ground measured garlic spectra were analyzed with NDVI (Normalized Difference Vegetation Index) curves, and the correlation coefficient between airborne MSS (AMSS) spectral curve and ground measured was derived with $R^2 = 0.76$.

3. The semi-automatic technique for garlic parcels recognition was developed. The accuracy is about 78% when one AMSS image was applied. On the other hand, the accuracy rises to 87% when three AMSS images acquired during garlic growing period were used, which shows the future potential of using remotely data for garlic parcels identification.

4. The recognition accuracy should be improved when more images acquired during the initial growing stage are used for classification, and also, the decision rule for garlic recognition should be refined and applied to a township level farmland, in order to verify the feasibility of the technique.

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Figure 1: Garlic growth in farmland at different stage; left: new planting with straws paving (2000/10/23); center: straws carbonized and stems grew up (2000/11/23); right: stems dried up and garlic started bulbing (2001/2/9)

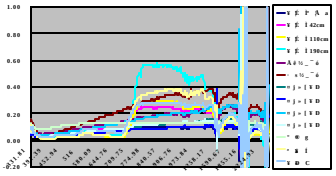

Figure 2: The reflectance spectra of Garlic and other crop farmlands

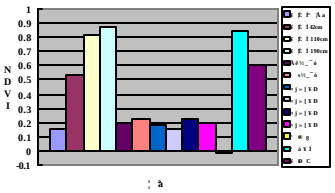

Figure 3: The NDVIs derived from GER measurements of garlic and other crop farmland

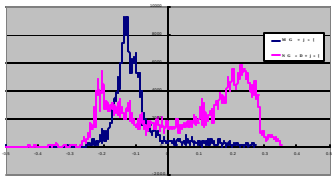

Figure 4: NDVI histogram of AMSS IARR image; blue curve represents the garlic farmland and red curve represents the other crop and bare soil farmland.

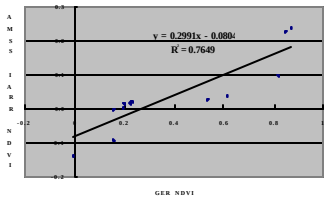

Figure 5: AMSS NDVI to ground measured NDVI, the R^2 of linear model is 0.76.

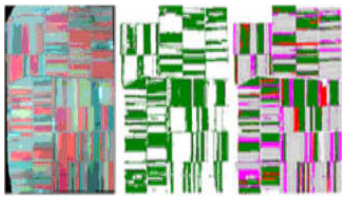

Figure 6: Left is AMSS image in pseudo color; green blocks in center represent the classified garlic farmland and right is the comparison with ground truth (color assigned as Tab. 2).

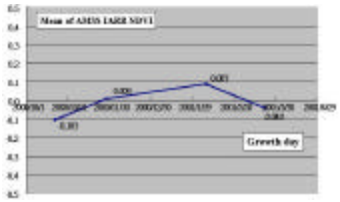

Figure 7: NDVI averages of garlic farmland in AMSS IARR images change with growth date

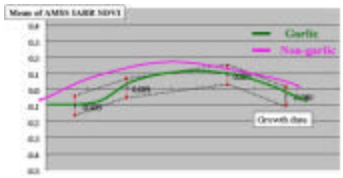

Figure 8: "AND" condition for NDVI threshold of multi-temporal AMSS images

Figure 9: The classification precision by three AMSS images (2000/10/22,2000/11/28 and 2001/2/8), color index assigned as Table 3

Table 1: NDVIs derived from ground measurement by GER3700 and from AMSS data competed IARR													
NDVI derived from	Corn 20cm	Corn 42cm	Corn 110cm	Corn 190cm	Garlic 1	Garlic 2	Garlic 3	Straw 2	Garlic 4	Straw 1	Dry soil	Peanut	Green manure
GER measurement	0.16	0.53	0.82	0.87	0.16	0.19	0.19	0.19	0.22	0.23	-0.01	0.85	0.61
AMSS IARR	-0.002	0.03	0.09	0.24	-0.09	0.002	0.02	0.02	0.02	0.02	-0.14	0.23	0.04

Table 2 Precision of classification by one AMSS image		Ground truth	
		Garlic	Non garlic
Classified	Garlic	82.4%	24.8%
	Non garlic	17.6%	75.2%

Table 3: Precision of classification by three AMSS image		Ground truth	
		Garlic	Non-garlic
Classify	Garlic	91.2%	16.8%
	Non-garlic	8.8%	83.1%