Industry note: Application of remote sensing in agriculture of Taiwan

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1 Introduction

Taiwan is a small-scale farm structure area, the farmland parcels are small, and the mixed cultivation and batch cultivation of crops in the same crop growth period are common. Traditionally, due to the limitations of remote sensing satellite image resolution technology, the phenomenon of the same object with different spectrum or different objects with the same spectrum and mixed pixels is common. Using a single remote sensing satellite image method to measure the spatial distribution of crops, the results of total accuracy of the interpretation of each crop is difficult to exceed 85%. However, in recent years, the European Space Agency has provided free images or some abundant and cheap commercial satellite resources on the market, which has made great progress in image analysis technology, including: the application of multi-temporal classification, the method of combining multi-source sensors and other remote sensing technologies, and combined with the supervised classification method of ground-truth sampling techniques; at present, more than 35 crops (the fourth and fifth classification of the land cover system) can be distinguished and their distributions can be mapped.

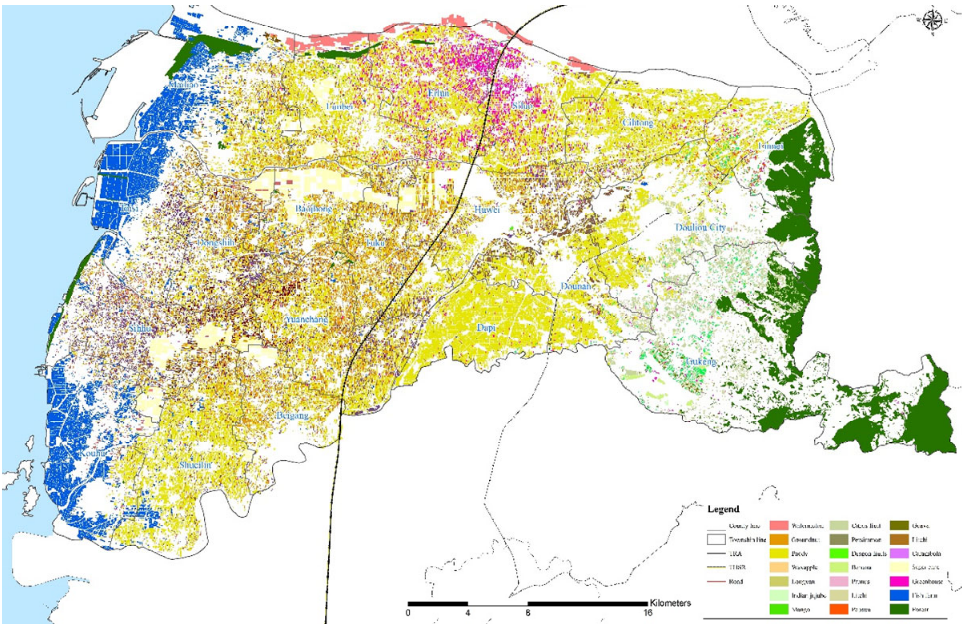
It has systematically applied aerial photo images for crops monitoring by Taiwan Agricultural Research Institute of the Council of Agricultural, the Executive Yuan since 2002. The framework of the system is based on the agricultural GIS system, with manual operation of GIS software supplemented by stereo technology to analyse aerial photos from aircraft and drones. In the process, semi-automatic artificial stereoscopic image interpretation or the most approximate theory is used to develop supervised classification to discriminate the distribution of various crops and assist in predicting the yield of various crops. A total of 22 kinds of fruit trees and a total of 72 main crops can be identified. Although manpower is combined with image analysis software and on-site survey results, it relies on accumulated technology and experience, and is too labour-intensive and time-consuming. The attempts are made to develop AI analysis methods to achieve automated crop judgment. On the fruit industries, the analysis results can only be used to monitor the location and area of orchards, and cannot monitor individual fruit trees. The monitoring results are only suitable for agricultural departments to grasp the current trend and have limited practical application in the fruit tree industry.

2 Agricultural land cover classification and monitoring

Using Sentinel-2, LandSat-8, Rapid Eye, KomSAT, aerial photo and UAV images as materials, applying remote sensing techniques, imagery analysis, geographic information system (GIS) and ground-truth sampling techniques to update the farmland land cover temporal and spatial information in plain and hill land region of Taiwan three times per year. Remote sensing technology seems prepared to have an even bigger impact on planning organisations and land management initiatives involved in monitoring land-cover and land-use change at a variety of spatial scales, especially when combined with the ready availability of historical remote sensing data, the reduction in data cost, and the increased resolution from satellite platforms (Rogan and Chen, 2004).

The species categories that can be interpreted and mapped for agricultural crops are as follows: rice, groundnut, sweet potato, cabbage, burdock, red bean, edamame, garlic, wheat, radish, corn, potato, carrot, onion, water spinach, buckwheat, mustard greens, watermelon, strawberry, onion, chayote, water taro, lotus, water bamboo shoots, ginger, pineapple, citrus, pear, star fruit, betel nut, papaya, lemon, guava, red dragon fruit, mango, lychee, grape, longan, India Dates, coffee, peaches, plums, plums, coconuts, custard apples, avocados, bananas, persimmons, tea, livestock farms, poultry farms, bird or ostrich farms, other livestock and poultry farms and slaughterhouses or meat markets, garlic, shallots, cauliflower, mustard, leek, water chestnut, pomelo, Indian jujube, lotus mist, loquat, betel nut, etc. 72 kinds of crops are updated. The overall accuracy of individual crops is 90.2~99.82%, and the KAPPA value is 0.75~0.98.

Figure 1 Land cover classification map of Yunlin (see online version for colours)

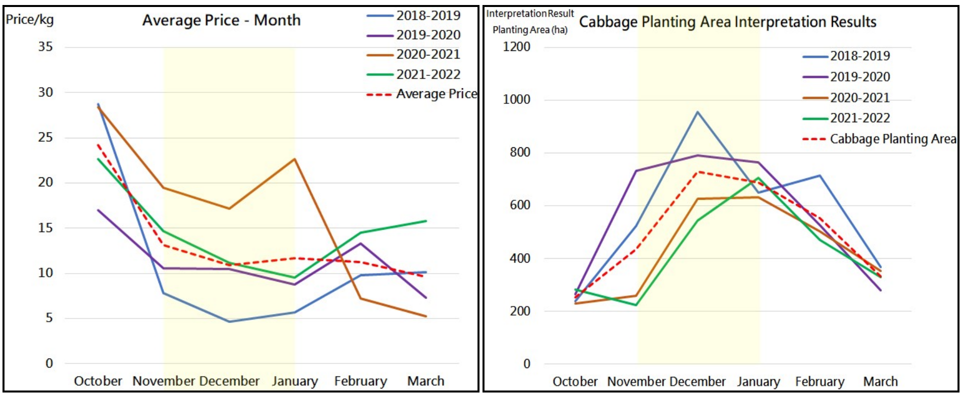


3 Forecast harvested area of cabbage crops

The frequently happening overproduction and shortage of cabbage in winter causes market prices fluctuations and is one of the indicators of success or failure in agricultural governance. To estimate the area of cabbage that can be harvested by farmers in the next month, multi-period satellite images and image analysis technology can be used to build crop distribution maps over the years with the farmland land cover database (Kim and Eun, 2021). The output results are then compared with the planting area of the same season and the same region of the previous year, and then the fluctuation of the crop planting volume in the latest season is estimated, thereby providing early warning information. Chang-Hua to Tainan Plain is the main monitoring area for cabbage production in winter, and the forecast period is from October to March of the next year.

To predict the growth and decline of cabbage planting area, Rapid Eye and Sentinel-2 satellite images have been used to predict long-term cabbage harvested area. The analysis process is based on selecting the appropriate spectral of phonologic characteristics of the monitored crops, and multi-temporal image interpretation, for the extraction of variation information between temporal-spatial images, to identify the location and growth period of cabbage. In addition, the low-altitude UAV took the sampling sites and the ground truth with GPS camera of the field surveyors are used to determine the accuracy of the data, and to improve the accuracy of the s interpretation results. Verification indicators include: producer accuracy, user accuracy, overall accuracy, Kappa value, etc., to understand the degree of omission and misjudgment in the cabbage result data, correct or adjust the harvest area, and provide decision-making levels with reference to the credibility of the interpretation results.

Figure 2 Cabbage planting area interpretation results and average price (see online version for colours)



The same method is also applied to the second crop of groundnut and winter season garlic. The estimated area also has a very high level of reliability. The long-term observation data on the cultivated area of cabbage has a very high correlation with the market price. Some traces of weather and human disturbance can also be observed.

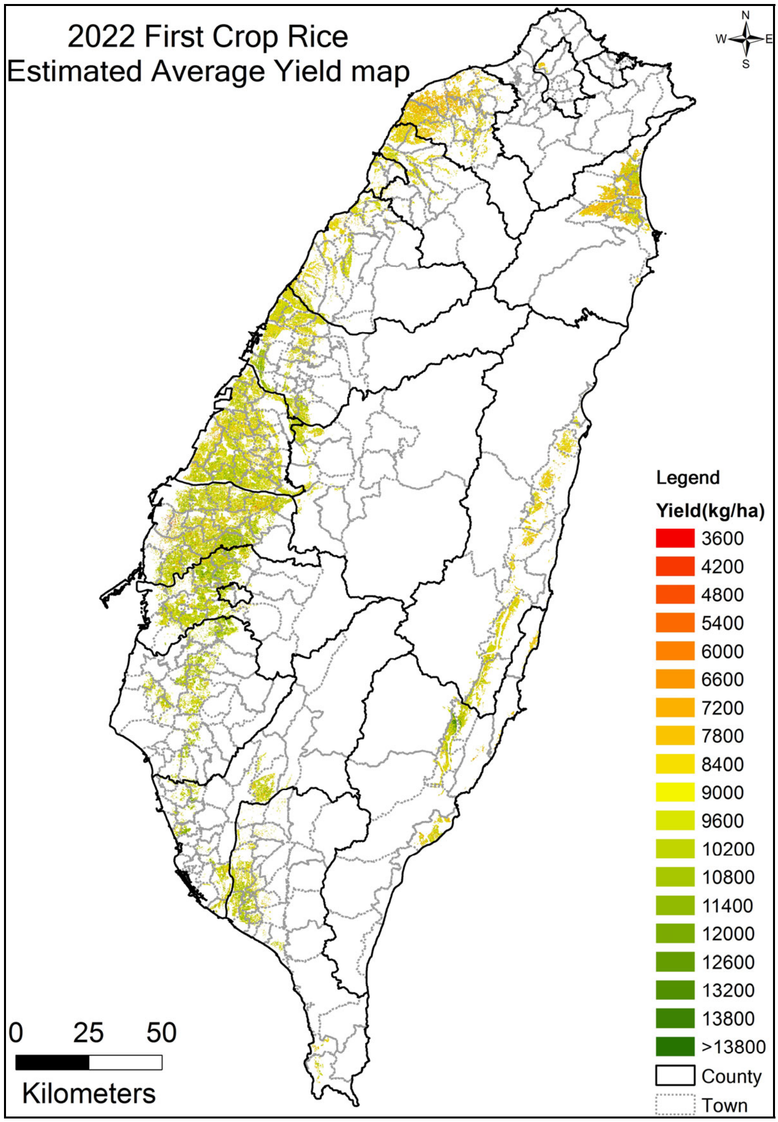
4 Mapping rice yields map in the western part of Taiwan

Yield mapping is the first step in precision agriculture. Rice is the largest crop in Taiwan. Traditional rice production surveys are conducted by selecting sample fields and using the hundred-straw-cut sampling method. The yields of the sample points in the same field are calculated as the average unit area, which is then multiplied by an administrative unit of acreage is used as an estimate of its overall yield.

Since 2018, the Taiwan Agricultural Research Institute has used rice harvesters equipped with RTK-GNSS signal devices and grain weighing devices to obtain relevant data such as time, location, and weight of the harvesting process, and then transmit the data every second back to the base. After sorting out each harvest field, the whole data sequence of the individual harvest field can be obtained, and then converted into spatial information with harvesting time series and harvesting trajectory, so as to understand the harvesting behaviour, harvesting weight, area and scope in detail. Data collection for sample fields in the western half of Taiwan from Ping-Tung to Tao-Yuan is completed in each issue of the year.

In addition, using synthetic aperture radar (SAR) data is not affected by the weather and can stably and continuously carry out the growth process of rice (Phan et al., 2018). Analyse the classification of rice irrigation periods to find out different rice transplanting times; according to the grouping of different transplanting periods, the harvest data of the sampling field corresponds to the time-series of dB of the SAR image group obtained 60 days before the harvest of the field. Regression analysis was carried out between the rice harvest and the dB value of the radar image, and the calibration curve was established to estimate the rice yield of each parcel in the western part of Taiwan by the value of the pixels of the radar images.

Figure 3 2022 first crop rice estimated average yield map (see online version for colours)



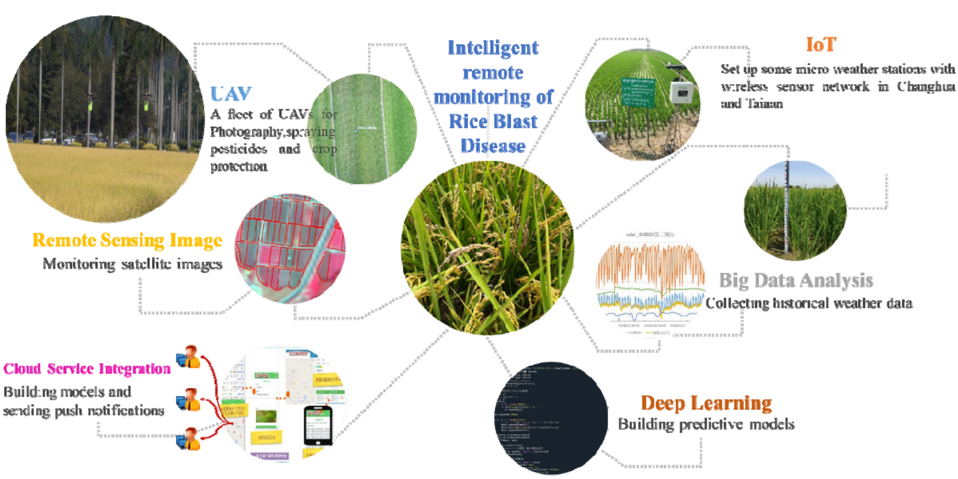
The results can be used as a reference for the distribution of rice yield throughout Taiwan. The obtained data can also show the variability of rice yield in the different time of the same parcel. After accumulating for a period of time, the temporal-spatial distribution and difference of yield data can be further research. At present, the R^2 value of the correlation between the estimated value of remote sensing and the measured value of the harvester is 0.66–0.89. In the future, more efforts of yields estimated data are verified and needed to ensure the stability of the model.

5 Application of remote sensing monitoring and sensors for early warning of rice blast

Global food security is being threatened by rice blast, a devastating fungal disease of the rice plant (*Oryza sativa L.*) (Asibi et al., 2019). The Taiwan Agricultural Research Institute established a regional IoT micro-meteorological data network, setup equipment and data collection in major paddy fields in Taiwan. Cooperate with the on-site meteorological data collected by the IoT weather station and record the disease history of leaf blast and ear blast with cameras to obtain accurate data for accurate big data analysis operations. The IoT micro-weather station is used to collect temperature, humidity, rainfall, soil temperature and humidity, light radiation value, illuminance and leaf humidity at a fixed time and frequency, and a rice blast incidence prediction model is established through artificial intelligence deep learning to quantify the probability of disease incidence.

In the future, TARI will continue to improve the rice blast prediction model, identify the key variables of weather for early warning predicting of rice blast, and cooperate with ground image monitoring and AI recognition technology to determine symptoms, UAV and satellite images are used to map area that farmer is fond of over dozing nitrogen fertiliser application, reducing the uncertainty of prediction model. Applying remote sensing, terrain relief information and planting time, meteorological data will be used to estimate the onset point, and farmers will be notified to spray pesticides and pay attention to the use of nitrogen fertilisers, so as to reduce the incidence or spread of leaf rice blast and strengthen the work of early warning information release for the farmer.

Figure 4 Forecasting and early warning of agricultural crop disease (see online version for colours)



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