The Application of Multi-Temporal Spectral Data Classification to Identify Rice Fields

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Abstract: The evaluation of land resources has been greatly facilitated by recent advanced development in information science and computer technology. In this study, the Global Position System (GPS) and Geographic Informaiton Systems (GIS) were used to identify the field experimental sites. The multi-spectral reflectance images from rice field and rice growth physical characters were collected throughout growing season, and the images were classified to identify rice field. CERES–Rice model, a computer-based biological simulation model was used to evaluate the land use effects from different management practices for rice production environment simulation, which was linked to a Geographic Information Systems to set up a spatial information system that could assign and visualize the model inputs and outcomes into homogenous polygons. An application of spatial information system was presented for rice production simulation to understand the optimal irrigation strategy on Nan-ton districk, Taichung, Taiwan.
Key Words: Spatial Information System, Geographic Information Systems, Remote Sensing.

Introduction

The past thirty years have been a time of rapidly evolving industrialization and commercialization in Taiwan. It makes a huge change impact to agricultural land use especially when rice fields have to transfer into industrial or residential land uses from the agricultural land management. Resoure planners must be able to evaluate the potential of land use under the association with various management options and environmental impacts.

In recent years, the developments of GIS and modeling have been a useful tool and technique that shift the conventional agricultural land use which evaluation rely on pencil and paper into most up-to-date information age. It allows decision makers to make different land use plans, which contains various managements in particular regions to analyze and compare with other land use plans. A GIS that incorporates appropriate predictive capabilities can explore a wide variety of 'what if' question, which is of paramount importance to agricultural and environmental planning and management and helps to reduce uncertainty in decision making (Beinroth et al., 1998). An example of this approach can be found in Engel and Jones (1995) who combined widely-used GIS software with DSSAT (Decision Support System for Agrotechnology Transfer) to produce a desktop computer tool for analyzing and viewing simulated results over regional spatial scales. Hansen et al. (1997) presented a study that applies systems simulation, optimization and GIS to evaluate economic and environmental impacts of alternative agricultural uses of sugarcane land on the south coast of Puerto Rico. In this paper we combined GIS to CERES (Crop-Environment Resources Synthesis)-Rice model to understand the productive potential of rice land in the connection between alternative irrigation scenarios and variety soil types.

The CERES-Rice Model

The CERES-Rice model is a process-oriented, management-level model of rice crop growth and development (Singh et al., 1993) that is developed to predict the duration of growth, the average growth rates, and the amount of assimilate partitioned to the economic yield components of the plant (Ritchie et al., 1998). The simulation processes of model are dynamic and are affected by environmental and cultivar specific factors. The environmental factors can be separated into the aerial environment and the soil environment. The aerial environment information comes from a record of weather conditions such as temperature and solar radiation. The soil environment information must come from synthesized approximations of the soil water status, the avilability of soil nitrongen and other nutrients, the aeration status of the soil and the spatial distribution of the root system (Ritchie et al., 1998).

The potential biomass yield of a crop can be thought of as the product of the rate of biomass accumulation times the duration of growth. The rate of biomass accumlulation is principally influenced by the amount of light intercepted by plants over an optimum temperature range. The duration of growth for a particular cultivar, however, is highly dependent on its thermal environment and to some extent the photoperiod during floral induction (Ritchie et al., 1998).

Therefore, the model requires input data such as daily weather data, initial soil conditions, crop management and crop cultivar information. The daily weather data includes solar radiation, precipitation, maximum and minimum temperatures. Initial soil conditions involve drainage and runoff coefficients, initial soil water, rooting preference factors, organic nitrogen and carbon contents. Crop management contains the planting and emergence date, row spacing, plant population, amount and timing of fertilizer application, and irrigation applications. The output data for each model simulation run encompasses the results of simulated daily growth and development, carbon balance, soil water balance, nitrogen balance, and mineral nutrient aspects.

The Spatial Information System

The simulation of CERES-Rice model is based on a specific point and time that predicts the crop growth in an independent of location, management and cultivar, however, the reality of agricultural environment contains soil, climate and human activity variabilities. In order to expand the scope of model analysis from a site to an area, GIS, GPS and remote sensing (RS) technologies are used to collect field spatial information as model input data that enable model to evaluate the land resource on region scale.

In this study, a SPOT High-Resolution Visible (HRV) multispectral (xs) image is collected over the research area. The rice gowth physical characters data and several spectral pattern diagnostics are also gathered as reference data, GPS technology is employed to better locate rice fields as training sites during the process of image classification. The supervised classification with maximum-likelihood algorithm is used to classify the image and identify rice fields, then transfer them to a vector format and assign a field level for each homogeneous polygon to build rice land coverage. Futhermore, we utilize GIS as a tool to create climate, soil and policy boundary coverages for research area, each uniform polygon within the coverages is defined a specific ID number.

Through overlaying rice land, soil, climate and administrative coverages, the attribute databases for these coverages are integrated to create practice layers. It contains soil and weather varieties in every rice field polygon; besides, the different crop management practices such as irrigation strategies, fertilizer applications and cultivar characters are added into each layer. Then, the internal field levels from this layer are used as a linkage between GIS and CERES-Rice model that allow decisionmakers to perform alternative model simulations directly from GIS, moreover, the simulated results can be linked back to the layer that they can be displayed as thematic maps. They also can compared and analyzed the potential productivity under various practice conditions. Figure 1 shows the overall process.

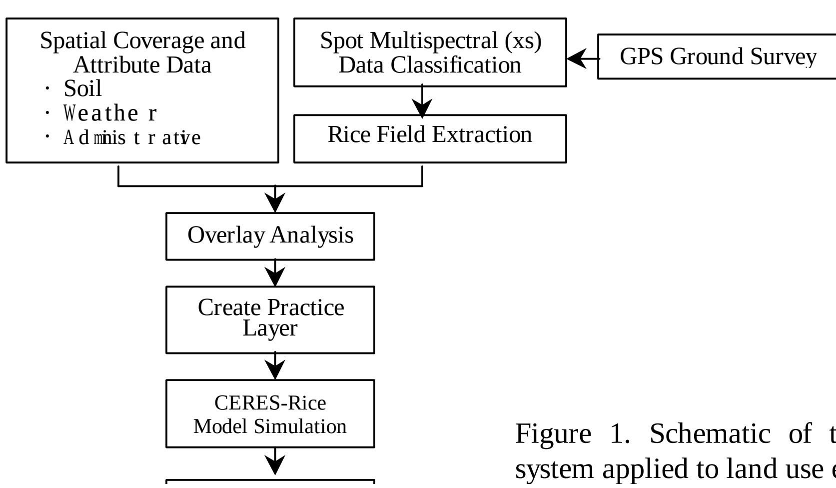

Figure 1. Schematic of the spatial information system applied to land use evaluation.

Application of Spatial Information System

In Taiwan, there is an abundant mountain, a steep topography, and short and rush rivers flows. Although the average precipitation is approximately 2510 mm per year, it concentrates on a summer period (from July to September) that is difficult to store and be used. On the other hand, the remarkable industrial and commercial developments have enhanced the urgent demand for water resources in recent years. Therefore, the rice plant, a main agricultural production in Taiwan is often shortage in irrigation resouces. For the government, due to the poor-resource information, it is difficult to make a suitable land use decision on time.

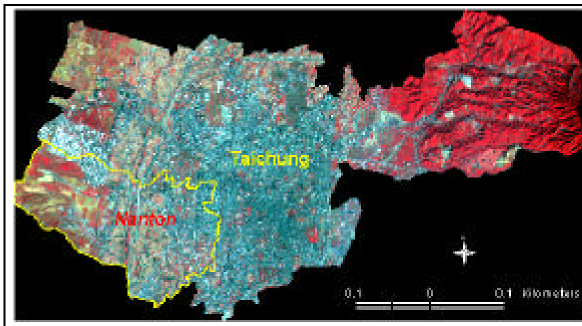

Figure 2. SPOT Multspectral (xs) image on study area (Nanton, Taichung).

Study Area

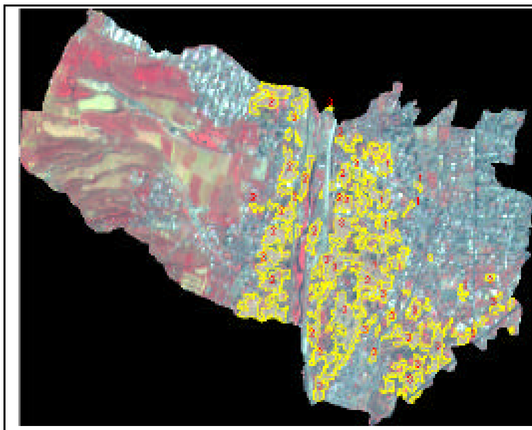
Figure 3. Rice areas on Nanton, Taichung.

The Nanton area is a south district of Taichung-city located in the center of Taiwan (Figure 2). This area is one of the main rice plant regions in Taichung, however, during the process of urban expansion, a mass of rice fields in this area are transfered to residential or business use that also increase the restraint of irrigation demands for agricultural land.

In this study, the spatial information system is used to understand the connection between rice fields grown and soil types under four alternative irrigation conditions in the research area.

Rice Field Extraction from Satellite Image

For this study, SPOT High-Resolution Visible (HRV) multispectral (xs) data is collected on December 14, 1997 which is used to inventory the rice field distribution. The image is first radiometrically and grometrically corrected and two-dimentsional resampled geocoding using Ground Control Points (GCPs) from digital terrain model.

The training sites for supervised classification are identified from GPS surveying points and 1:5000 aerial photomaps. These training sets are used in a maximum likelihood algorithm for the classification of the Nanton study area. The rice land identified from supervised classification is then transferred to a vector format and assigned a specific field ID for each polygon, the result is shown in figure 3.

Figure 4. The soil map on Nanton, Taichung.

Spatial Input Data for CERES-Rice Model

Soil Map

The soil profile map is digitized into a GIS coverage, which contains three soil types: Dilhuviun Red Soils, Sandstone-Shale Older Alhrvial Soils and Sandstone-Shale Noncakareous Younger Alhrvial Soils (Figure 4). Each polygon within the coverage are defined an ID_soil item, this item is a linkage between soil profile characteristics and CERES-Rice model.

Weather Data

For a particular simulation, the weather file contain data collected from before planting to after maturity (Hunt L A and Boote K J, 1998). The historical daily weather data for solar radiation, maximum, and minimum temperature, and precipitation is collected from 1961 to 1998 in Nanton area, it is also combined to the field polygon attribute table by WSTA item.

Cultivar Data

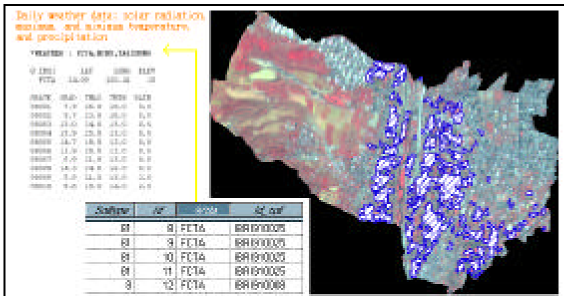

Figure 5. The linkage between weather attribute data and spatial information.

The cultivar information required for CERES-Rice model operation is designed as an input data, it document the genotype characteristics. These genetic coeffcients are listed as bellow (Ritchie et al., 1986):

1. P_1: thermal time required for the plant to develop after emergence to the end of the juvenile stage.
2. P_2R: rate of photoinduction.
3. P_2O: optimal photoperiod.
4. P_5: thermal time for grain filling phase.
5. G_1: conversion efficiency from sunlight to assimilate.
6. G_2: single grain weight.

In order to acquire the genetic coefficients, we collect field data from National Chung-Hsing University, Taichung in 1988. Daily weather data, soil profile and management pratices from experimental fields are also gathered for model calibration and evaluation, the outputs from model simulation are compared with the observed data to explore the coefficients. The relationship is defined by the regression equation, Y=-83.6+0.63y with R^2=0.934. Moreover, the weather data and crop yields from 1982 to 1990 are also used to simulate and compare with CERES-Rice model; with R^2 = 0.707. The cultivar data are then extracted as P_1: 770.0, P_2R: 50.0, P_5: 600, P_2O: 14.0, G_1: 72.3, G_2: 0.025.

Crop Management

Four irrigation management practices are defined in the irrigation control depth on 0.1m with irrigation threshold level: 40% according to rice growth stage: the nutrition growth stage, the reproduction growth stage and the maturity stage. These applications include auto-irrigation, auto-irrigation at vegetative stage, auto-irrigation at reproductive stage and rainfed scenarios.

Auto-irrigation scenario means the model will re-fill the field to the depth of 0.1m with each irrigation practice when soil water content drops to the threshold level during the whole growing season. Auto-irrigation at vegetative stage practice means the model would automatically irrigated during the vegetative growth stage. Auto-irrigation at reproductive stage practice means the model would automatically irrigated during the reproductive growth stage. Rainfed practice means the model used only rainfed strategy.

Model Simulation

An application of spatial information system is demonstrated for potential rice productivity analysis from above irrigation practices, weather, crop cultivar and soil types in Nanton, Taichung. For this application, the CERES-Rice model is integrated into this system to evaluate rice growth including yield, biomass and irrigation requirement for each spatially unit of soil and weather data using the defined irrigation management practices. The process of CERES-Rice model simulation is shown in figure 6.

From simulation, the results can be joined to rice field coverage that enable decision maker to display yield, biomass and irrigation directly in a regional scale. Figure 7 shows an example of a rice yield result and irrigation demand in Nan-ton area.

Table 1 describes outputs of simulated rice yield and irrigation under three soil types and four irrigation practices in Nanton area. The result shows that the option of auto-irrigation at vegetative stage practice and auto-irrigation at reproductive stage practice require less water than that of auto-irrigation scenario. The highest rice potential productivity is obtained from the Sandstone-Shale Noncakareous Younger Alhrvial Soils.

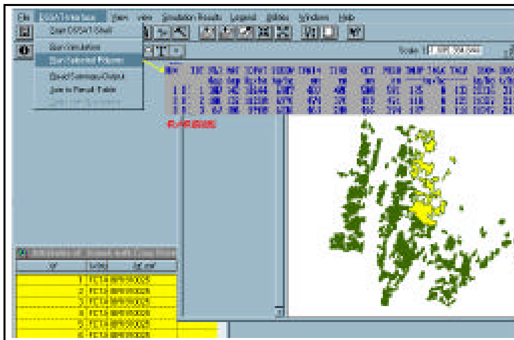

Figure 6. The process of CERES-Rice model simulation for potential rice productivity.

Conclusions

The temporal multi-spectral images enable us to identify spatial patterns of rice growth area, especially with the wide availability of GPS and GIS which could enhanced the accuracy of image classification. Through a combination of RS, GIS and CERES-Rice model, the spatial information system could expand the model application for evaluating rice productivity with different strategies from single site to a regional scale. This assist resource managers with more information to make an optimum land use decisions.

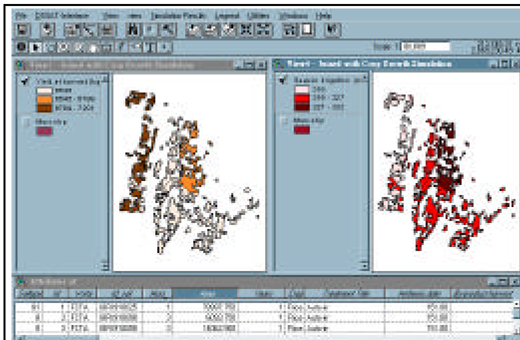

Figure 7. Rice yield result and irrigation demand map in Nan-ton area.

Table 1. Outputs of simulated rice yield and irrigation under three soil types and four irrigation practices in Nanton area.

Irrigation Practices / Soil Types	Auto-irrigation Management		Auto-irrigation at Vegetative Stage Management		Auto-irrigation at Reproductive Stage Management		Rainfed Management
	Yield (kg/ha)	Irrigation (mm)	Yield (kg/ha)	Irrigation (mm)	Yield (kg/ha)	Irrigation (mm)	Yield (kg/ha)
Sandstone-Shale Noncakareous Younger Alhrvial Soils	7095	464	7098	255	7058	247	7021
Diluviun Red Soils	6752	468	6737	248	6376	252	6260
Sandstone-Shale Older Alluvial Soils	6720	463	6622	251	6290	251	5971

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Acknowledgments

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