Cropland classification from MODIS-Landsat fusion data

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ABSTRACT: Crop mapping requires information of crop phenology regarding the high spatiotemporal resolution satellite data. This study aims to develop an approach integrating the Moderate Resolution Imaging Spectroradiometer (MODIS) data and Landsat-8 data for rice crop mapping in western Taiwan. Images of MODIS and Landsat-8 taken in 2013 were processed through five main steps: (1) data preprocessing to account for geometric and radiometric errors of Landsat-8 data, (2) MODIS‒Landsat data fusion using the spatial–temporal adaptive reflectance fusion model (STARFM), (3) construction of the smoothed time-series perpendicular vegetation index (NDVI), (4) image classification with the fusion data for estimating rice crop area, and (5) accuracy assessment. The comparisons between mapping results and ground reference data indicated satisfactory overall accuracies and Kappa coefficients. This study demonstrates the applicability of MODIS‒Landsat data fusion with STARFM in rice crop monitoring.

1. INTRODUCTION

Rice is a major crop and planted throughout in Taiwan, but rice fields are generally small. Acreage computation is usually based on the interpretation using aerial photo sets which requires intensive manpower, and its time consuming. In recent years, crop management using temporal remotely-sensed satellite data (8 - days) has been proposed (Feng *et al*., 2006), and high spatial resolution satellite data (30 m) is additionally expected to detect small segments of rice fields in Taiwan. However, it’s difficult to acquire imagery data with both high spatial resolution and temporal resolution. A potential solution is to fuse remotely-sensed data form multiple sources.

The spatial and temporal adaptive reflectance fusion model (STARFM) is developed by NASA to produce high spatial and high temporal resolution imagery data, and it is expected to provide more information than using single sensor data (Dongjie *et al*., 2013). Practically, STARFM can fill in “missing days” of long-visit satellite data by using short-visit satellite data (Dongjie *et al*., 2013). STARFM has been proven to have the capacity if blending Landsat images and Moderate-resolution images to simulate the daily surface reflectance at Landsat spatial resolution (30 m) and MODIS temporal frequency (8 - days).

The research checked the accuracy assessment with two pairs and five pairs based on rice phenology and used the Landsat8 and MODIS data to blend the imagery with high spatial and temporal resolution. Due to the Landsat8 images in Taiwan started on 25/5/2013, the study add the Spot5 data and Formosat2 data in the heading date and harvested date. The accuracies compared between the 2 pairs and 5 pairs predicted data in 2013.

2. METHODOLOGY

STARFM data processing includes three major steps: (i) one or more pairs of fine-resolution reflectance and land cover data are used for the selection of spectrally similar neighbor pixels; (ii) the weighting function is based on the temporal spatial and spectrum parameters; and (iii) the weighting and conversion coefficients are applied to the available coarse-resolution reflectance to produce the fine-resolution reflectance (Dongjie et al., 2013).

2.1 Study Areas

The study areas are located in two counties (Yunlin and Changhua county) in west Taiwan (Figure 1), [a] is the forest region located in Changhua, [b] is the crop region, [c] is the urban, [b] and [c] are located in Yunlin, all of them are used to check the Fusion imagery.

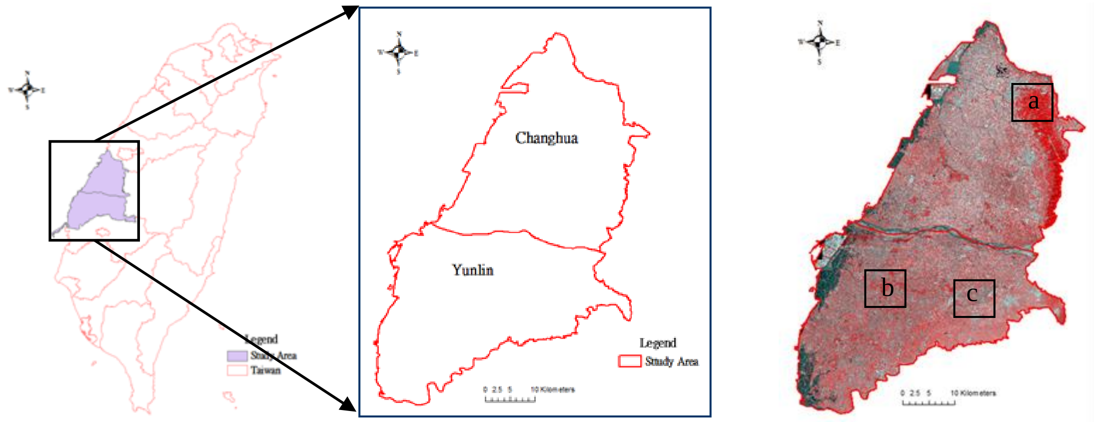

Figure 1: Study areas; [a]: forest area; [b]: crop area; and [c]: urban area (Landsat 8 imagery - 2013 false color; R, G, B =NIR, Red, Green)

2.2 Rice Calendar

Table1 shows the rice calendar in Taiwan. The first crop of rice was planted on January to March, harvested on June to July, second crop was planted on July to August, harvested on November to December.

Table 1: Rice calendar in Taiwan.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
First rice crop												
Second rice crop												

2.3 Satellite Data and Preprocessing

Based on rice phenology, the study added the high spatial resolution data in heading and harvested dates (Figure 2). Due to Landsat 8 started on May 2013 in Taiwan, the study used four satellites data (Landsat 8OLI, MODIS (09Q1), SPOT5 and Formosat2). Landsat8 has a higher spatial resolution (30m) but lower temporal resolution (16-day). MODIS 09Q1 resolution is 250m 8-day from the National Aeronautics and Space Administration (NASA). For the rice mapping, the collection 46 MODIS data in 2013 totally were used for the study, NIR band and Red band were be used to do the NDVI. Table2 shows the fine resolution data and correspond MODIS data of input STARFM algorithm.

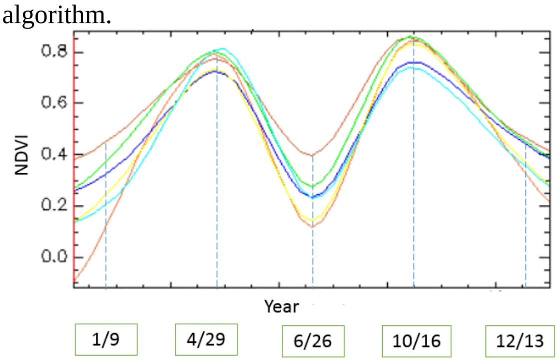

Figure 2: The input pairs based on phenology.

Table2: Each input pair of STARFM

Pair	Sensor	Date	Fine resolution(m)	Sensor2	Date	Coarse resolution(m)
1	Landsat8	2013/06/26	30	MOD 09Q1	2013/6/26	250
2	Landsat8	2013/10/16	30	MOD 09Q1	2013/10/16	250
3	Landsat8	2013/12/03	30	MOD 09Q1	2013/12/3	250
4	SPOT5	2013/01/19	10	MOD 09Q1	2013/01/17	250
5	Formosat2	2013/04/29	8	MOD 09Q1	2013/05/01	250

The satellite images were preprocessed before the calculation. In the study, the fine spatial resolution data were atmospherically corrected and converted to surface reflectance. The MODIS surface reflectance product data (MOD09Q1) were re-projected clipped and resampled (30m, bilinear approach) to the same extent at fine spatial resolution data.

2.4 STARFM

Spatial and temporal adaptive reflectance fusion model (STARFM) was developed by NASA, it was applied to blend MODIS and Landsat images. This method predicts pixel values based on spatial weights determined by regional statistics. It can be used to track quantitative changes in surface reflectance due to phenology (Feng *et al.*, 2006). For a homogenous coarse resolution (MODIS) pixel, the corresponding Landsat reflectance can be expressed as:

$$L(X_i, Y_j, t_0) = M(X_i, Y_j, t_0) + \varepsilon_0$$

X_i and Y_j are the pixel locations of Landsat data and MODIS data; $M(X_i, Y_j, t_0)$ means the MODIS surface reflectance;$L(X_i, Y_j, t_0)$ means the Landsat surface reflectance; t_0 is the acquisition date for both MODIS and Landsat data;ε_0 represents the difference between observed MODIS and Landsat surface reflectance.
Suppose that the ground coverage type and system errors at pixel (X_i, Y_j) remains consistent across time, it will have $\varepsilon_k = \varepsilon_0$. On a date t_k for which MODIS data are available, but Landsat data are not, the synthetic Landsat data can be predicted by using:

$$L(X_i, Y_j, t_0) = M(X_i, Y_j, t_0) + L(X_i, Y_j, t_j) - M(X_i, Y_j, t_j)$$

Considering neighboring same class pixels with similar reflectance changes, a moving window method is used to take full advantage of the information from neighboring pixels. The Landsat image reflectance is calculated with a weight function:

$$L\left({}^{X_w}/_2, {}^{Y_w}/_2, t_0\right) = \sum_{i=1}^{w}\sum_{j=1}^{w}\sum_{k=1}^{w} W_{ijk} \times (M(X_i, Y_j, t_0) + L(X_i, Y_j, t_k) - M(X_i, Y_j, t_k))$$

Where w is the searching window size and $(X_w/2, Y_w/2)$ central pixel of this moving window. The combined spectral, temporal and spatial distance can be compared with using a normalized reverse distance as:

$$W_{ijk} = (1/C_{ijk}) / \sum_{i=1}^{w}\sum_{j=1}^{w}\sum_{k=1}^{w} (1/C_{ijk})$$

$$C_{ijk} = S_{ijk} \cdot T_{ijk} \cdot D_{ijk}$$

3. RESULT

The study used five pairs to blend fine resolution image on 2013/11/17 and compared with real Landsat 8 image (Figure 3). The root mean square error of NDVI is 0.078, Figure 4 shows the scatter plots of real image and the predicted NDVI on the three regions. The data fall closer to the one by one line, it's similar between real and predicted image.

(a) (b)

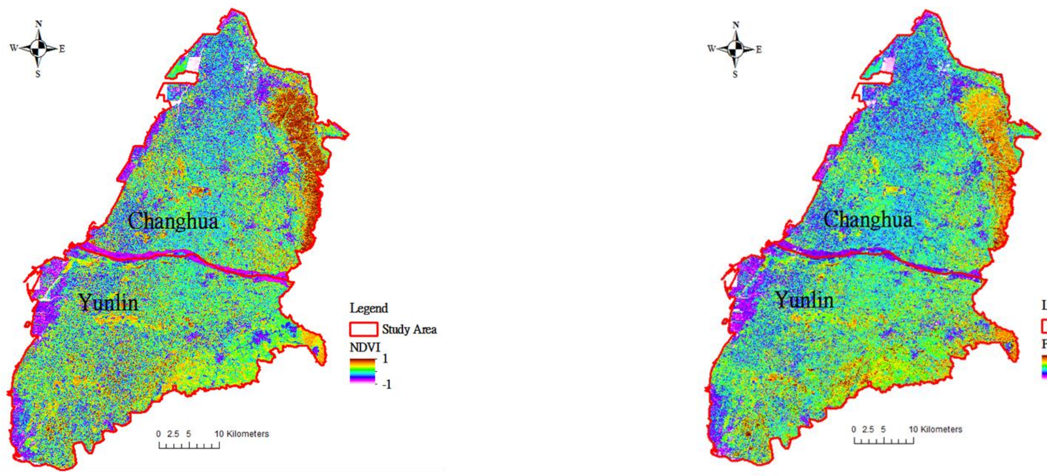

Figure 3: (a) The NDVI of the real Landsat8 image (2013/11/17); (b) The NDVI of the predicted image.

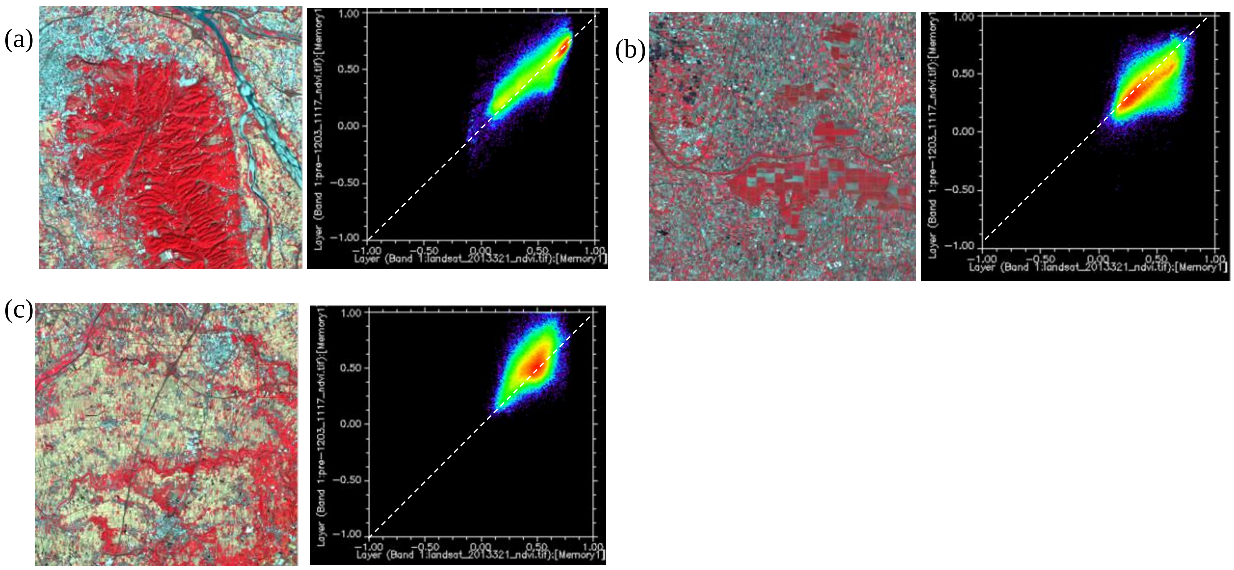

Figure 4: (a) The region of forest; (b) The region of crop; (c) The region of urban.

Both two pairs predicted data and five pairs predicted data were mapped the first rice in Erlun Township of Yunlin County for checking the STARFM feasibility in Taiwan. The two pairs predicted images were based on the date of heading. The research computed accuracy assessment with ground reference data by randomly selected the checked points, 1000 points for rice crop and 1000 points for others (Figure 5).

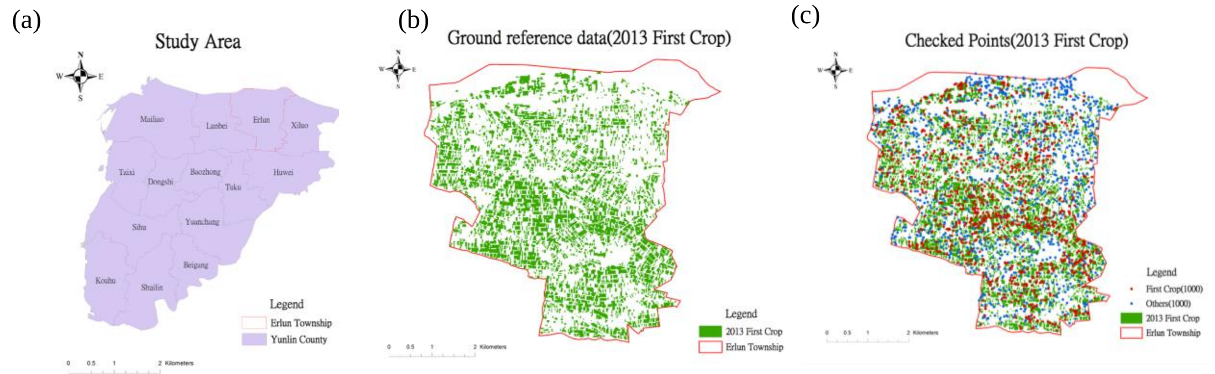

Figure 5: (a) The location of Erlun Township; (b) Ground reference data; (b) Random points for accuracy assessment.

Figure 6 shows the classification results. For calculated accuracy assessment, the random points from ground reference data were used. Comparison between five pairs predicted images and two pairs predicted images, the result of five pairs predicted images shown that overall accuracy is 83.00% and kappa coefficient is 0.66; the result of two pairs predicted images shown that overall accuracy is 63.40% and kappa coefficient is 0.26. Table 3 and table 4 are the confusion matrices of two pairs predicted images and five pairs predicted images.

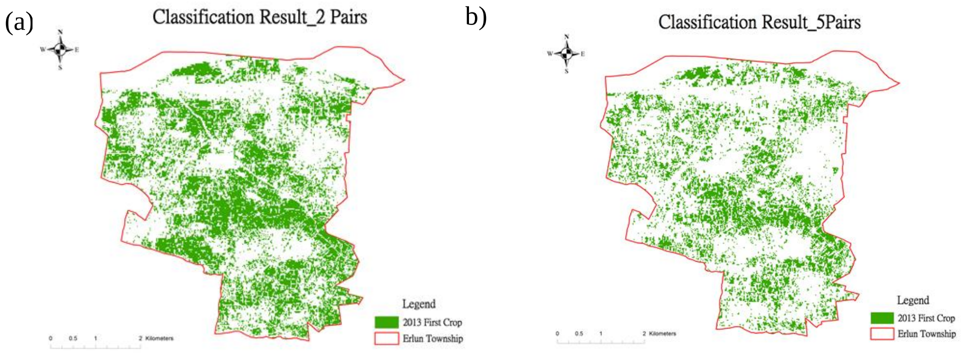

Figure 6: (a) Classification of using two pairs; (b) Classification of using five pairs.

Table 3: Accuracy assessment from the classification by two pairs.

Reference data	**Classification result(2 pairs)**		
	First Rice	Non-First Rice	Total
First Rice	663	337	1000
Non- First Rice	395	605	1000
Producer Accuracy	66.30%	60.50%	
User accuracy	62.67%	64.23%	
Overall Accuracy	63.40%		
Kappa Coefficient	0.26		

Table 4: Accuracy assessment from the classification by five pairs.

Reference data	**Classification result(5 pairs)**		
	First Rice	Non-First Rice	Total
First Rice	883	117	1000
Non- First Rice	223	777	1000
Producer Accuracy	88.30%	77.70%	
User accuracy	79.84%	86.91%	
Overall Accuracy	83.00%		
Kappa Coefficient	0.66		

4. DISCUSSION& CONCLUSION

In the study, the mapping result shows the five pairs predicted images are better than two pairs predicted images. In two pairs predicted images, the result of comparison between classification and ground reference data shows the overall accuracy is 63.40% and the Kappa is 0.26. In five pairs predicted confusion matrix, the result shows the overall accuracy is 83.00% and the Kappa is 0.66. The predicted images based on phenology using five pairs are higher than based on date of heading using two pairs. It means that predicted images by using STARFM method in Taiwan based on phenology is feasible. But it is still smoother than ground reference data. In the future work, it's necessary to add other index value, like Normalized Difference Water Index (NDWI) for improving the accuracy.

5. REFERENCES

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