THE APPLICATION OF SATELLITE IMAGERY TO ESTIMATE AGRICULTURAL LOSSES IN TAIWAN

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Abstract:

Natural disasters have caused severe damage to crop-planted areas during typhoon season from May to September in Central and Southern Taiwan. Because the authorities in townships do not have records of planted crop types, disputations regarding agricultural subsidies typically occur after disasters. Rapidly and accurately acquiring the planted crop types and areas in public river lands before and after natural disasters can help prevent disputations regarding agricultural subsidies. To achieve this tasks, remote sensing technology can be used for obtaining planted crop types and areas rapidly and on a large scale.

This study adopted watermelon as an example and employed several FORMOSAT-2 images (dated from February 2013 to April 2013) to interpret the watermelon planted areas on the 13 public river lands (including 48 townships) in Taiwan. Cadastral maps were used to overlap the satellite images. The texture characteristics of planted watermelon were then employed to help the township staffs interpret the planted areas from the overlaid maps. The results indicate that applying remote sensing technology can help acquire the watermelon planted areas on public river lands rapidly and reduce the cost and labor for the field investigation before and after the disasters. In addition, the resultant change detection maps can help the relevant authorities in the task of rescue and providing subsidies as well as conserve funds in the public treasury.

1. INTRODUCTION

Severe weather influenced by global climate changes has caused a drastic increase in natural disasters worldwide. Natural disasters have caused severe flooding in crop-planted areas during typhoon season from May to September in Central and Southern Taiwan. In particular, crops planted on the public river lands, next to the river channels, are easily damaged because of heavy rains. The Taiwan Agricultural Council has formulated "the subsidy policies of agricultural natural disasters" to provide considerable financial support to alleviate the plight of farmers' disaster losses. Because the authorities in townships do not have records of planted crop types, disputations regarding agricultural subsidies typically occur after disasters. For example, farmers lease public river lands for cultivation.

Farmers can apply subsidies from the local councils when crops are damaged by the natural disasters. However, farmers may request subsidies without actually planting crops or by falsifying statements regarding applying crop types with high amounts of subsidies. For instance, the amount for watermelons is US$2,000 per hectare, but that for vegetables is only US$800. To prevent such situations, local council officials often investigate the farmlands and capture photographs of planting conditions a few days before typhoons are to arrive. However, this investigation method is time consuming, and the inspected areas are limited. Thus, determining an effective method for mapping planted crop types and areas rapidly and on a large scale can provide information to authorities to execute agricultural subsidies of natural disasters efficiently.

Because satellite technology has been improved in recent years, cropland mapping by using satellite imagery has become an effective alternative to traditional methods. Unlike field surveys, satellite images can cover wide areas, making mapping work more efficient. Various satellite images have been broadly applied for numerous agricultural applications (Thornton et al., 1997; Turner & Congalton, 1998; Sui et al., 2001; Xiao et al., 2005, 2006; Doraiswamy et al., 2003, 2004, 2007; Cordero-Sancho & Sader, 2007; Ramarao et al., 2007; Wardlow et al., 2007; Simonneaux et al., 2008; Gwathmey et al., 2010; Wang et al., 2010; Vaiphasa1 et al., 2011). All of these previous studies have demonstrated that using appropriate remotely sensed imagery can acquire promising results and be used for mapping planted crop types and areas efficiently. Thus, arguments regarding the amounts of subsidies between farmers and government authorities can be reduced by comparing the pre- and post-disaster crop type maps. Because of the constraints of the acquisition cost and revisit frequency, the FORMOSAT-2 images, which have both high spatial resolution and increased revisit frequency, are used for creating maps of planted crop types. The FORMOSAT-2 images have been effective for crop mapping and yield estimates (Courault et al., 2008, 2010; Bsaibes et al., 2009; Hadria et al., 2009).

This study adopted watermelons as an example and employed several FORMOSAT-2 images (dated from February 2013 to April 2013) to interpret the watermelon planted areas on 13 public river lands (including 48 townships) in Taiwan. Cadastral maps were used to overlap the satellite images. The texture characteristics of planted watermelon were then employed to help the township staffs interpret the planted areas by using the overlaid maps.

2. MATERIALS

2.1 Study Areas

The study areas were located on 13 public river lands, flowing through 48 townships, in Taiwan (Fig. 1). The most cultivated crop on these public lands is watermelon. The growing seasons for the watermelon are approximately from February to early June and from July to October. The planting and harvesting times vary depending on the location of the rivers.

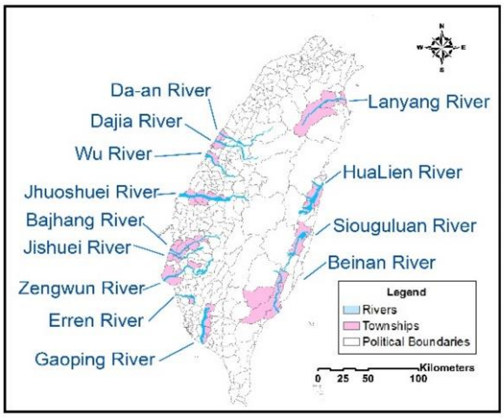

Fig. 1 Locations of 13 different public river lands in Taiwan

2.2 FORMOSAT-2 Satellite Imagery

The images used in this study were obtained from the remote sensing instrument on FORMOSAT-2, which collects multispectral images at an 8-m nadir spatial resolution in blue, green, red, and near-infrared bands and 2-m in the panchromatic band. Because the watermelon is a double-row crop, recognizing its texture directly from the FORMOSAT-2 fusion images is easy, particularly immediately after the plowing periods (Fig. 2). The texture characteristics and the growing phenology render the watermelon substantially different from other crops in the study areas. Thus, we acquired a total of 22 and 6 FORMOSAT-2 satellite scenes (including multispectral, panchromatic, and 2-m fusion images for each scene) during the planting periods (January–March and July–August) for the two growing seasons in 2013. To implement change detections after the natural disasters have occurred, several site specific images were purchased.

(a) (b)

Fig. 2 (a) shows the texture of the watermelon can be easily recognized from the FORMOSAT-2 2-m fusion image (natural color composite, date: 2013/02/18); (b) shows the field picture of the watermelon, which is the double-row crop.

3. METHODOLOGY

3.1 Creating the Watermelon Distribution Maps

To assist local authorities in executing field surveys, we created a series of 1 to 2500-scale watermelon distribution maps in digital and hardcopy formats for each township. We overlapped the cadastral maps with the FORMOSAT-2

2-m fusion images and created a site index for each township. The site index indicated the location of each map in that township. Figure 3 shows an example of the resultant maps. In addition, these maps were used as evidence for verifying each watermelon-planted parcel while offering agricultural subsidies to the farmers.

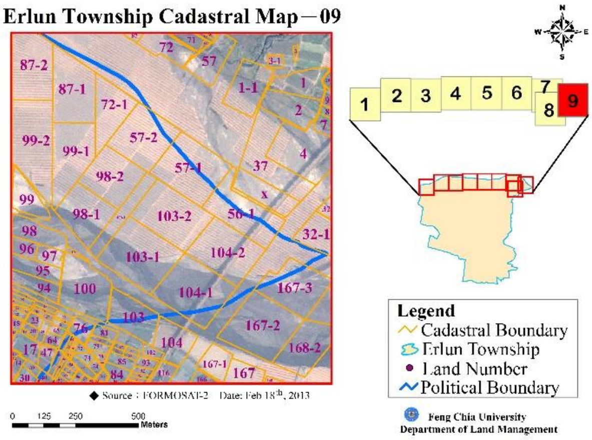

Fig. 3 The example of the overlaid cadastral image maps.

3.2 Change Detection Analysis

After the natural disasters occurred, a post-classification comparison approach was performed to locate the watermelon-planted lands damaged by the floods. We first employed the supervised classification and texture analysis to record the watermelon-planted areas by using the FORMOSAT-2 multispectral images. Visual interpretation was then employed to modify a few omission errors of the classified images. Because the textures of the watermelon-planted areas were extremely obvious in the images, nearly all of the cultivated areas were mapped easily. The accuracy of the modified classified maps was higher than 95%. Finally, the two pre- and post-natural disaster classified maps were overlaid to produce the change maps. An example of the classified maps is shown in Fig. 4. The changed areas of each parcel were calculated. The township authorities can use these change maps as ancillary evidence when managing the agricultural subsidies after natural disasters.

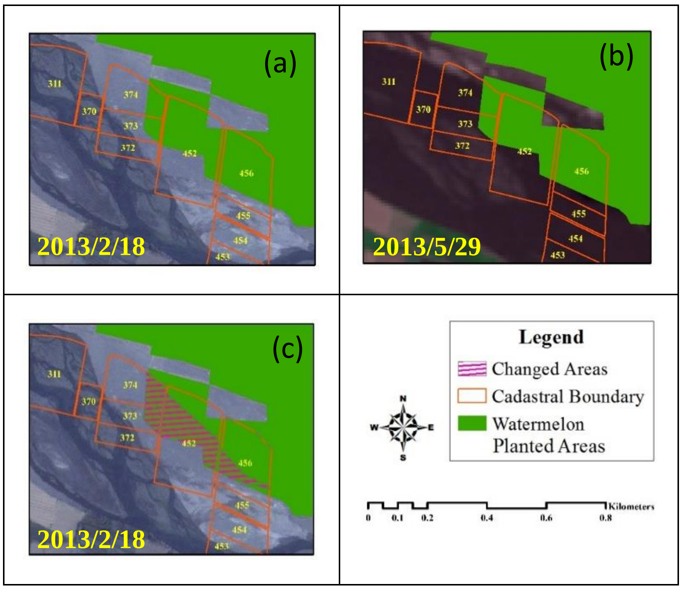

Fig. 4 (a) the pre-disaster classified map overlying on the original image, the green areas stand for the watermelon planted areas; (b) the post-disaster classified map; (c) the pink-shaded areas are the change fields.

4. RESULTS AND CONCLUSIONS

Since the execution of this project in 2010, the 1 to 2500-scale watermelon distribution maps and resultant change maps have been widely used by local authorities to determine each watermelon-planted parcel while offering agricultural subsidies to the farmers. Millions of dollars have been saved in the recent years. Table 1 presents the examples of applied subsidy areas and amounts for the watermelon planted in five townships after severe rainfall in May 2013. After the pre- and post-disaster watermelon classified maps were compared, nearly 200 hectares between the applied and approved watermelon-planted areas existed. The amount of subsidies has been reduced by nearly US$106,000.

Table 1 The examples of applied subsidy areas and amounts for the watermelon after the sever rainfall in May, 2013.

Township	Applied Areas (ha.)	Applied US$	Approved Areas (ha.)	Approved US$
Dacheng	137.25	194,454	95.75	153,200
Chutang	78.18	18,524	0	0
Hsilo	37.89	60,624	33.13	53,008
Erlun	42.87	47,885	13.16	21,060
Lunbei	279.07	438,867	232.01	371,217
Total	575.26	760,354	374.05	598,485

*Source: data provided by the Agriculture and Food Agency, Council of Agriculture

The results of this project indicate that applying remote sensing technology can help acquire the watermelon planted areas in the public river lands rapidly and reduce the cost and labor for the field investigation before and after natural disasters. In addition, the resultant change detection maps can help the relevant authorities in the task of rescue and providing subsidies as well as conserve funds in the public treasury.

5. REFERENCES

Bsaibes, A., D. Courault, F. Baret, M. Weiss, A. Olioso, O. Marloie, N.Bertrand, V. Desfond, F. Kzemipour, F. Jacob, O. Hagolle, 2009. Albedo and LAI estimates from FORMOSAT-2 data for crop monitoring. Remote Sens. Environ. 113(4), 716–729.

Cordero-sancho S., S. A. Sader, 2007. Spectral analysis and classification accuracy of coffee crops using Landsat and a topographic-environmental model. International Journal of Remote Sensing, 28(7):1577–1593.

Courault, D., A. Bsaibes, E. Kpemlie, R. Hadria, O. Marloie, J.-F. Hanocq, A. Olioso, N. Bertrand, V. Desfonds, O. Hagolle, 2008. Assessing the potentialities of FORMOSAT-2 data for water and crop monitoring at small regional scale in South-Eastern France. Sensors 8(5), 3460–3481.

Courault, D., R. Hadria, F. Ruget, A. Olioso, B. Duchemin, O. Hagolle, G. Dedieu, 2010. Combined use of FORMOSAT-2 images with a crop model for biomass and water monitoring of permanent grassland in Mediterranean region. Hydrol. Earth Syst. Sci. 14(9), 1731–1744.

Doraiswamy, P. C., Sophie Moulin, P.W. Cook, Alan Stern, 2003. Crop yield assessment from remote sensing, Photogram. Eng. Remote Sens. 69(6), 665–674.

Doraiswamy, P. C., J.L. Hatfield, T.J. Jackson B. Akhmedov, J. Prueger, A. Stern, 2004. Crop condition and yield simulations using Landsat and MODIS," Remote Sens. Environ. 92(4).

Doraiswamy, P.C. , A.J. Stern, B. Akhmedov, 2007. Crop Classification in the U.S. Corn Belt Using MODIS Imagery. Presentation at the International Geoscience and Remote Sensing Symposium July 19 – 27, 2007, Barcelona, Spain.

Gwathmey, C., D.D. Tyler, X. Yin, 2010. Prospects for monitoring cotton crop maturity with normalized difference vegetation index. Agronomy Journal, 102(5):1352–1360.

Hadria, R., B. Duchemin, F. Baup, T. Le Toan, A. Bouvet, G. Dedieu, M. Le Page, 2009. Combined use of optical and radar satellite data for the detection of tillage and irrigation operations: case study in Central Morocco. Agric. Water Manage. 96(7), 1120–1127.

Ramarao, N., M. Kapoor, N. Sharma, K. Venkateswarlu, 2007. Yield prediction and waterlogging assessment for tea plantation land using satellite image-based techniques. International Journal of Remote Sensing, 28(7):1561–1576.

Simonneaux V., B. Duchemin, D. Helson, S. Er-raki, A. Olioso, A. G. Chehbouni, 2008. The use of high-resolution image time series for crop classification and evapotranspiration estimate over an irrigated area in central Morocco International Journal of Remote Sensing, 29(1): 95–116

Sui, X, S. Zhou, C. Lin, 2011. The Dynamical Monitoring on Quality of Agricultural Land Resources Based on Vegetation Index by MODIS Data. 2011 Seventh International Conference on Natural Computation, 284-287.

Thornton, P. K., W.T. Bowen, A.C. Ravelo, P.W. Wilkens, G. Farmer, J. Brock, J.E. Brink, 1997. Estimating millet production for famine early warning: an application of crop simulation modelling using satellite and ground-based data in Burkina Faso. Agric. For. Meteorol. 83(1–2), 95–112.

Turner, M. D. and R. G. Congalton, 1998. Classification of multi-temporal SPOT-XS satellite data for mapping rice fields on a West African floodplain. Int. J. Remote Sens. 19(1), 21–41.

Vaiphasa1, K., S. Piamduaytham, T. Vaiphasa, A.K. Skidmore, 2011. A normalized difference vegetation index (NDVI) time-series of idle agriculture lands: a preliminary study. Engineering Journal, 15(1): 9-16.

Wang, Y.-P., Y. Shen, K.-W. Chang, R.-K. Chen, J.-C. Lo, 2010. Large-area rice yield forecasting using satellite imageries. Int. J.Appl.Earth Observ. Geoinform. 12(1), 27–35.

Wardlow, B.D., S. L. Egbert, J.H. Kastens, 2007. Analysis of time-series MODIS 250 m vegetation index data for crop classification in the U.S. Central Great Plains. Remote Sensing of Environment, 108:290–310.

Xiao, X. M., S. Boles, J.Y. Liu, D.F. Zhuang, S. Frolking, C.S. Li, et al., 2005. Mapping paddy rice agriculture in southern China using multi-temporal MODIS images. Remote Sensing of Environment, 95(4):480– 492.

Xiao, X., S. Boles, S. Frolking, C. Li, J.Y. Babu, W. Salas, B. Moore III, 2006. Mapping paddy rice agriculture in South and Southeast Asia using multi-temporal MODIS images. Remote Sensing of Environment 100:95 – 113.