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Fallow land mapping for better crop monitoring in Huang-Huai-Hai Plain using HJ-1 CCD data

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Abstract: The prediction of grain production is essential for socio-economic development planning, guidance and control of macro cropping structure adjustment. Fallow areas should be identified each growing season which is critical for grain production prediction. This paper focuses on fallow arable land monitoring during summer grain season in the Huang-Huai-Hai Plain using China Environment Satellite HJ-1 CCD data. With the two satellites HJ-1A and HJ-1B, high temporal Normalized Difference Vegetation Index (NDVI) can be obtained. HJ-1 CCD data were acquired from early March to early June in 2010 over the Huang-Huai-Hai Plain. Multi-temporal HJ-1 CCD data were pre-processed and time series of NDVI were derived. An algorithm for separating cropped and fallow areas was developed based on three key periods of NDVI in early-March, mid-April and mid-May, 2010. The influence of fallow arable lands to yield estimation and crop condition monitoring over the Huang-Huai-Hai Plain were also investigated and analyzed. Preliminary results in this paper showed that HJ-1 CCD data are capable for fallow land monitoring. Information of fallow arable lands is an essential part of crop monitoring and it should be incorporated into crop monitoring systems. In the future, the fallow lands over autumn grain season should also be identified and information of fallow arable lands should be generated yearly in order to get more reliable production prediction.

Key words: fallow arable land, HJ-1 CCD, normalized difference vegetation index, crop monitoring

1. Introduction

China is the most populous nation in the world. Agriculture is the base of China and Food is first necessity [1]. China's food security is challenged by several factors, including population growth, land use changes, water shortage and so on [2]. The prediction of grain production is essential for socio-economic development planning, guidance and control of macro cropping structure adjustment in China. Since crop acreage estimation and crop yield prediction are the two components for crop production estimation, a large number of researches have been done in crop identification, acreage estimation and yield prediction [3][4][5][6][7]. Several countries and organizations, including the United States, the European Commission, the Food and Agriculture Organization of the United Nations (FAO), China, Brazil, Canada, and India currently employ crop monitoring systems to monitor their own countries' or regional and global crop production [8][9][10](CAPE, <http://dacnet.nic.in/eands/cape.htm>; CCAP, <http://www26.statcan.ca/ccap/overview-apercu-eng.jsp>;

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Geosafra, <http://www.conab.gov.br/conabweb/index.php?PAG=81>). While those systems can provide grain production information timely, much less is known about the impact of fallow arable land to crop monitoring and information of fallow land is rarely incorporated into crop monitoring systems.

Satellite imagery like MODIS can provide independent and consistent data to map fallow arable land. However, in China, the cultivation policy leads to extreme complexity in the agricultural landscape and diverse farming habits, especially in summer and autumn seasons [3]. Even in the Huang-Huai-Hai Plain, the small field size of cropland requires remote sensing data with high spatial resolution for accurate crop monitoring which is unaffordable. China Environment Satellite HJ-1 offers an opportunity to detect fallow land efficiently and objectively over large areas because it provides ground surface spectral information at 30 m spatial resolution with two-day revisit frequency.

This paper used multi-temporal HJ-1 charge-coupled device (CCD) images to generate fallow areas over Huang-Huai-Hai Plain of China, then analyzed the impact of fallow information to crop monitoring by incorporating time series of MODIS NDVI data. The objective of this paper is to provide preliminary research in fallow arable land mapping and crop monitoring with fallow information.

2. Material and methodology

2.1. Site description

This paper select Huang-Huai-Hai Plain as the study area which is one of China's major grain producing regions, extending from 32° 00' N to 40° 24' N and 112° 48' E to 122° 45' E. Seven provinces/mega-cities are situated on the Plain (Beijing, Tianjin, part of Hebei, Shandong, Henan, Anhui and Jiangsu province). This region belongs to the warm temperate climate zone with mean annual precipitation ranging between 480 and 1050mm [11], and it is concentrated between June and September during the summer monsoon. Within the study area, wheat, maize, cotton, groundnut, soybean and vegetables were inter-planted, and fields are divided into very small parcels and belonging to various families.

2.2. Remote sensing data

Multi-temporal China Environment Satellite (HJ-1) CCD images acquired during March 10th to May 25th in 2010 were used to map fallow and cropped areas in Huang-Huai-Hai Plain. All those data were collected from China Centre for Resource Satellite Data and Applications (CRESDA) (<http://www.cresda.com/n16/n92006/n92066/n98627/index.html>). The HJ-1 CCD image processing, which included geo-correction, radiance calibration and atmospheric correction, was carried out using ENVI 4.8 software.

Time series of 16-day composite MODIS 250 m NDVI data (MOD/MYD13Q1 V005) spanning one growing season (January to June in 2009 and 2010) were acquired from the next generation metadata and service discovery tools Reverb (<http://reverb.echo.nasa.gov>). Time series of NDVI data were extracted by tile, mosaiced, reprojected and subset to generate NDVI for Huang-Huai-Hai Plain. This data were used for crop condition monitoring and crop yield prediction.

2.3. Fallow and cropped arable land monitoring

The Land-use map of year 2010 [12] at 1:100,000 scale derived from HJ-1 CCD images was used to extract fallow and cropped area. NDVI was calculated for each HJ-1 CCD images and temporal NDVI was obtained. Three key periods for fallow and cropped area mapping are in early-March, mid-April and mid-May. NDVI at these three periods was used after cloud was masked out. Two NDVI difference images between NDVI images on mid-April and early-March and between mid-May and early-March are derived. A threshold of 0.3 is set to separate fallow fields from cropped fields. The pixels value less than 0.2 in two NDVI difference images were classified as fallow land. Fallow and cropped distribution map was then resampled to generate fallow land ratio (R_f) map with 250m

resolution. The value for each pixels were obtained by counting number of fallow pixels (N_f) and number of cropped pixels (N_c) with 30m resolution located in each 250m pixels.

2.4. Crop monitoring with fallow information

A time series of NDVI images derived from 16-day composite MODIS 250 m NDVI data was used to develop crop-growth profiles based on the statistical average of the NDVI (weighted for the percentage of farmland) in the study area [13]. The NDVI data of 2010 were also modified according to fallow land ratio map. We assumed that the true NDVI of crops in the mixed pixel can be calculated from original NDVI value as follows:

$$NDVI_{\text{true}} = \frac{NDVI - NDVI_f * R_f}{1 - R_f}$$

Where NDVI means value of MODIS NDVI data, $NDVI_f$ means NDVI of fallow lands, R_f is fallow land ratio for each pixel, $NDVI_{\text{true}}$ is the modified NDVI value.

We compares average and maximum crop growing profiles of year 2005 to 2009, crop growing profile of 2009, NDVI profiles of 2010 and modified NDVI profiles of 2010 to evaluate crop conditions in 2010. The difference between crop condition result with NDVI profiles and modified NDVI profiles was analyzed. By comparison crop growing profile, the contrast between year and year can reflect crop growing condition continuance during the growing season.

Crop biomass and harvest index method [14], which estimates crop biomass based on the crop's photosynthetic accumulation and water stress during the growing season, and then estimates the harvest index of crops from their growth parameters [15] was employed to estimate crop yield. Time series modified NDVI data were used to estimate summer grain yield in 2010 in Huang-Huai-Hai Plain. Yield was then statistical averaged for different provinces. Beijing and Tianjin was excluded because only few crops were planted. Yield with modified NDVI data was compared to 2009 and multi-year average yield.

3. Results and discussion

Fallow and cropped map of the study area in 2010 was generated using the method described in section 2.3 (Figure 1). Fallow lands were found distributed throughout the study area. A total of 14.7% of the croplands over the study area were left as fallow, but were very unevenly distributed. Most of fallow lands located in the north of the study region, specifically in Hebei and Shandong province. The fallow land ratio was larger than 15% for Hebei and Shandong provinces because some of fields in the two provinces were kept for cotton planting during autumn season. A distributed fallow land ratio map with 250m resolution was also generated.



Figure. 1 The distribution of cropped and fallow lands for summer season in Huang-Huai-Hai Plain in 2010. Green regions are the croplands that are planted while gray regions are the fallow lands during the summer grain season in 2010. Blue regions are croplands covered with cloud in early March or mid-April or mid-May.

Crop growing profiles of the study area from year 2005 to 2010 was derived from MODIS NDVI data. Average and maximum crop growing profiles of year 2005 to 2009 was calculated. The crop growing profile of modified time series of NDVI data was also generated. Figure 2 showed the crop growing process monitoring result.

According to Figure 2, the phenology of summer crops in 2010 was about eight days delay compared with 2009. The peak of MODIS NDVI profile in 2010 was similar as that of 2009 and was smaller than peak of maximum NDVI profile of year 2005 to 2009. The accumulated NDVI from March to early June in 2010 was less than that of 2009. Regarding modified crop growing profile, the peak was larger than that of maximum NDVI profile of year 2005 to 2009. So, inaccurate crop condition results may be obtained without considering fallow information.

Summer grain yield was estimated using time series of NDVI and modified NDVI data based on crop biomass and harvest index model [14]. The average yield of Huang-Huai-Hai Plain and five provinces situated on the Plain was listed in Table 1. As is shown in Table 1, great differences were observed in summer grain yield for all five regions and the whole study area. Yield of 2009 should also be estimated using fallow information of year 2009 in order to capture reliable yield variation from year to year.

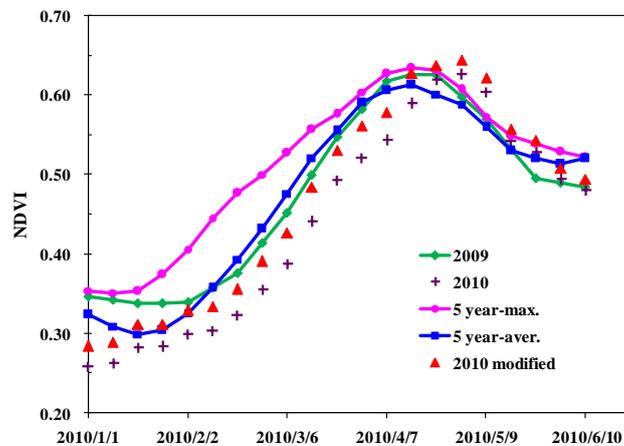


Figure. 2 Crop growing profiles chart of Huang-Huai-Hai Plain. Profile of 2009 represents time series of smoothed NDVI value. Profile of '5 year-max.' and '5 year-aver.' mean maximum and average crop growing profiles of year 2005 to 2009. Cross marks and triangle marks are NDVI profiles and modified NDVI profiles of 2010, respectively.

Table 1 Summer grain yield predicted with and without fallow information compared with yield of 2009 and average yield from 2005 to 2009. (Units: Kg/ha)

Region	Summer grain yield			
	Average ¹	2009	2010	2010 modified ²
Hebei	3,659	3,655	3,513	4516
Jiangsu	4,110	4,177	4,151	4422
Anhui	4,035	4,171	4,147	4312
Shandong	3,953	4,049	4,002	4509
Henan	4,179	4,362	4,392	4692
Whole study area	4,027	4,116	4,081	4503

¹Yield was averaged from year 2005 to 2009.

²Modified yield was the average yield of planted farmland, yield from 2005 to 2010 was the average yield of all farmland in the study area.

4. Conclusion

Based on multi-temporal of HJ-1 CCD images, a total of 14.7% croplands were observed to be fallow during the summer grain season in 2010 in Huang-Huai-Hai Plain. Most of fallow lands were kept fallow for cotton planting during autumn season. Information about fallow lands played significant role in both crop growing process monitoring and crop yield prediction. Fallow land mapping should be carried out and incorporated into crop monitoring systems in order to provide reliable production information.

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