Crop Monitoring as an
E-agricultural tool in
Developing Countries

DATABASES ON USING DIFFERENT APPROACHES

DOCUMENT CONTROL

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LIST OF ACRONYMS

TM	Thematic Mapper
IRS	India Remote-sensing Satellite , P6 is the tenth satellite of ISRO in IRS series
Liss	Linear Imaging Self Scanner
HJ-1A/B	Environment and Disasters Monitoring Microsatellite
NIR	Near Infrared
RE	Red Edge
SWIR	Short-wavelength infrared
MWIR	Middle-wavelength Infrared
TIR	Thermal infrared
MODIS	Moderate Resolution Imaging Spectroradiometer
LAI	Leaf area index
NDVI	Normalized Difference Vegetation Index
CRESDA	China Centre for Resources Satellite Data and Application
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984
CC	Cubic Convolution
DN	Digital Number
MRT	Modis Reprojection Tool
S-G	Savitzky-Golay

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EXECUTIVE SUMMARY

In order to estimate the crop area of Mengcheng and Guoyang, satellite data from three types of sensors were collected: the low resolution form MODIS; the medium resolution from Liss3 and Landsat TM and SPOT5 and HJ-1A/B and RapidEye; the high resolution from QuickBird. The acquisition period was between 2009 and 2012, covered the phonological stages of different crops. For low resolution images, the time-series corresponding the crop growth seasons were selected. The pro-processing of low resolution imagery is consisted of S-G filtering (smoothing). For medium resolution images, the pre-processing consisted of the geometric and atmospheric corrections. For high resolution images such as QuickBird, the geometric correction was based on the data either from Google Earth, or collected during the dedicated field surveys.

1 INTRODUCTION

The study area, composed of Mengcheng and Guoyang counties, was located in the North of Anhui province (Fig.1.1). Winter wheat, maize and soybean were the main crops. Table 1.1 shows the location of the two counties. The growth period of winter wheat was from early October to the end of May the following year. The best phase to extract the winter wheat area using remote sensing images was in the tillering stage and turning green stage, usually from the end of November to the end of April. For maize and soybean, the growth period was almost the same, usually form early June to the end of September. The best phase of extraction was between late July to late August.
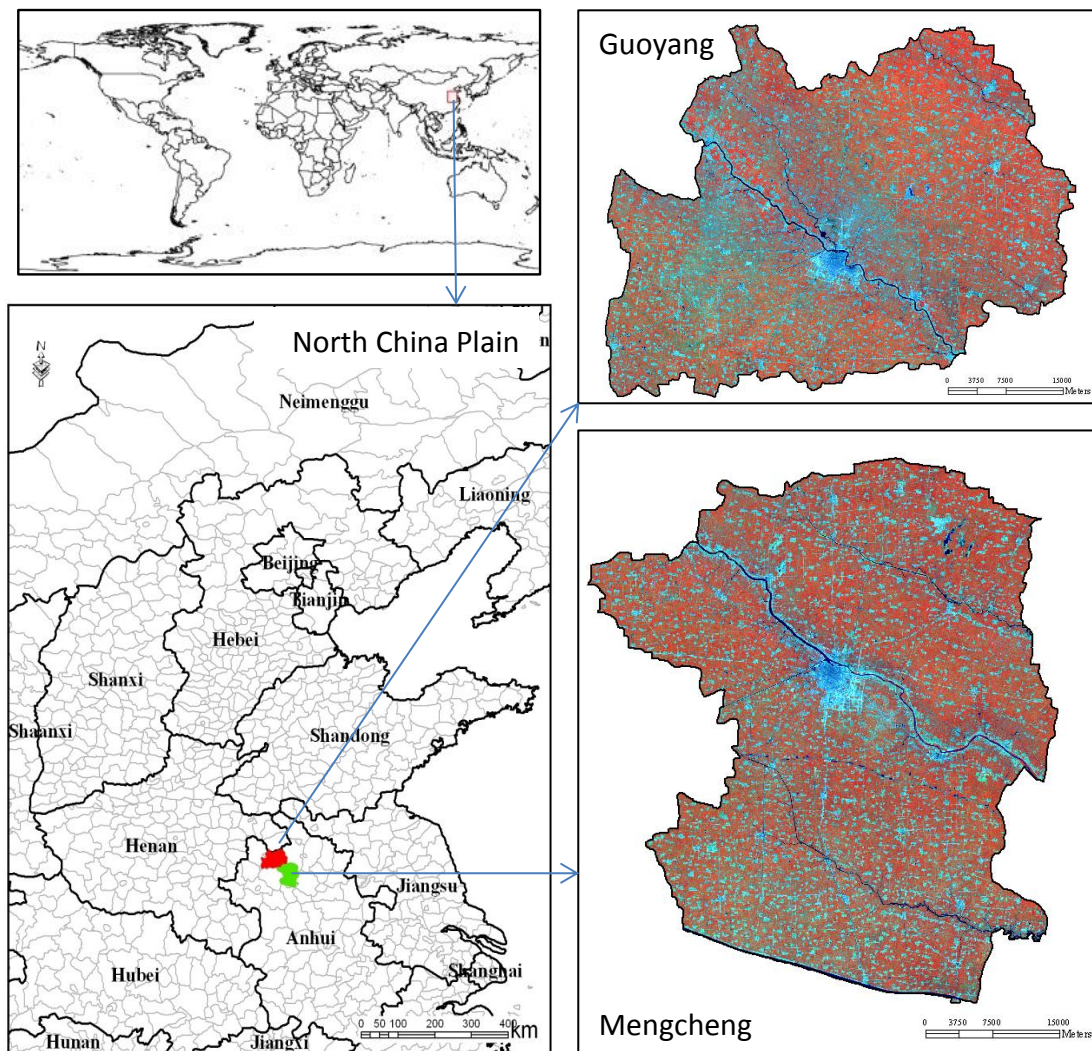
Figure 1.1 The Study Area

The purpose of the study was to compare the accuracy of different methods to extract crop areas using remote sensing images at county level. According to the best phases of extraction, three types of images were collected. One was the high resolution images from QuickBird or equivalent resolution images provided for example by GoogleEarth. The second category was the medium resolution images from TM, SPOT5, RapidEye and HJ-1A/B. The last one was the low resolution images from MODIS vegetation index (NDVI) and lead area index (LAI) time series. The acquisition date of images was between 2011 to 2012, covered the different phenological periods of crops.

### Table 1.1 The Crop Groeth Stages of Mengcheng and Guoyang

Crop	Growth Stage	Start Data	General Growing Date	End Date
Winter wheat	Sowing time	Early October	Mid-October	Late October
	Emergence	Mid-October	Late October	Early November
	Tillering time	Early November	Mid-November	Late November
	Stop growing	Late December	January	Early February
	Turning green	Eraly February	Mid-February	Late February
	Jointing	Early March	Mid-March	Early April
	Heading	Mid-April	Mid-April	Late April
	Milky stage	Early May	Mid-May	Late May
	Maturation	Late May	Early June	Early June
Summer Maize	Sowing time	Early June	Mid-June	Late June
	Emergence	Mid-June	Mid-June	Late June
	3rd leaf stage	Mid-June	Late June	Late June
	7th leaf stage	Early July	Early July	Early July
	Jointing	Mid-July	Mid-July	Mid-July
	Heading	Late July	Late July	Early August
	Milky stage	Mid-August	Mid-August	Mid-September
	Maturation	Late September	Late September	Early October
Summer Soybean	Sowing time	Early June	Mid-June	Mid-June
	Emergence	Mid_june	Late June	Late June

Crop	Growth Stage	Start Data	General Growing Date	End Date
	3rd trifoliolate	Late June	Early July	Early July
	Bloom	Early July	Mid-July	Mid-July
	Flowering	Late July	Late July	Early August
	Pod-seed	Early August	Early August	Mid-August
	Maturation	Mid-September	Mid-September	Late September

2 HIGH RESOLUTION IMAGES

The high resolution images of the study area are derived most often from Google Earth. with spatial resolution higher than 1m. They were used for stratification of the ground sampling and field surveys.

In the stage of field survey design, we used the high-resolution remote sensing images to determine land use type of each sampling unit. After choosing the field sampling units, the image of each unit had been saved as JPG format with a scale 1:2500. All JPG file had been saved to the database. The file name was such as 'Guoyang_nnnn.jpg'. ' nnnn' was the number of sampling units. Value range was from 0001 to 2074.
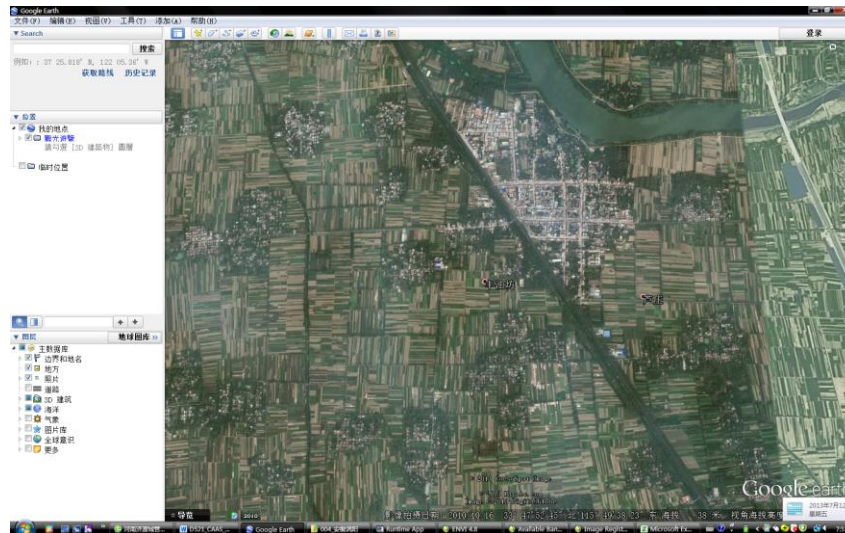
Figure 2.1 High-resolution images in Google Erath
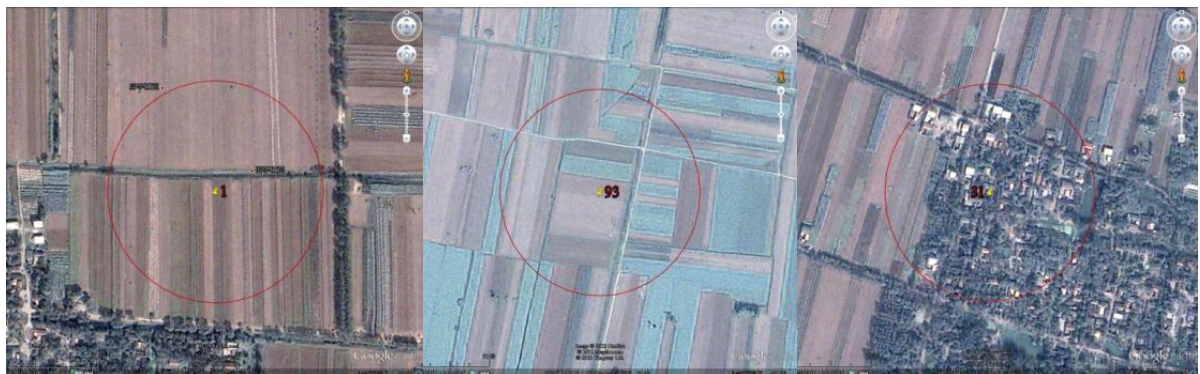
Figure 2.2 High-resolution images for each sampling unit in JPG format

The images in Google Earth were good enough to design the field sampling units. Based on these images, the land use map of each sampling unit with 1:2500 scale had papered in the office. But due to some geographical deviation in Google Earth (Fig.2.3), some sampling units had to be adjusted in the field.
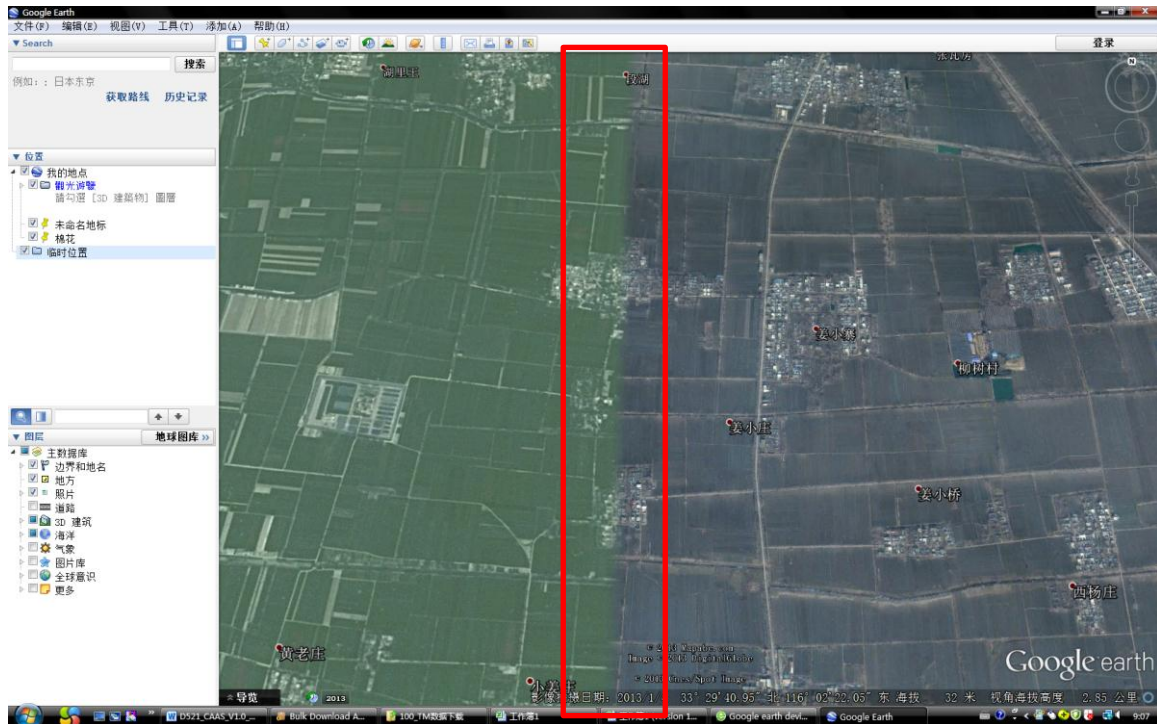
Figure 2.3 Deviation in Google Earth

3 MIDDLE RESOLUTION IMAGES

3.1 Data list

In order to accurately extract crop acreage on county level, middle resolution images were used. The images were from ALOS, Landsat TM, SPOT5, RapidEye, IRS P6-Liss3 and HJ-1 A/B covering the study area. There were 84-scene images from 2009 to 2012. HJ-1A/B CCD images were free downloaded from the website of CRESDA, with the spatial resolution of 30m. Two-scene images of Landsat TM were free downloaded from the website of USGS. Other images were purchased from image data providers. Data list was shown in Table 3.1.

Table 3.1 Middle Resolution Remote Sensing Data List

Satellite	Sensor	Data	Range	Data sources
ALOS	AVNIR-2	2009-2-12	116.13^{o}E,32.86^{o}N-117.08^{o}E,33.72^{o}N	Purchase on market
SPOT5	HRG2J	2010-11-18	Path285/Row283, engcheng 116.08^{o}E,33.07^{o}N -116.99^{o}E,33.76^{o}N	Purchase on market
SPOT5	HRG2J	2010-11-18	Path285/Row284 Mengcheng 115.92^{o}E,32.58^{o}N -116.82^{o}E,33.27^{o}N	Purchase on market
Landsat5	TM	2010-9-18	Path122/Row37 Guoyang &Mengcheng 114.86^{o}E,32.26^{o}N-117.36^{o}E,34.10^{o}N	Free download
Landsat5	TM	2011-3-29	Path122/Row37 Guoyang & Mengcheng 114.90^{o}E,32.25^{o}N-117.40^{o}E,34.10^{o}N	Free download
Landsat5	TM	2011-9-21	Path122/Row37 Guoyang &Mengcheng 114.89^{o}E,32.25^{o}N-117.39^{o}E,34.10^{o}N	Purchase on market
RapidEye		2012/4/26	Guoyang	Purchase on market

Satellite	Sensor	Data	Range	Data sources
RapidEye		2012/5/16	Guoyang &Mengcheng	Purchase on market
IRS P6	Liss3	2012/9/15	Path131/Row47, North of Anhui 114.80^{o}E,32.56^{o}N-116.66^{o}E,34.12^{o}N	Purchase on market
HJ-1A/B	CCD	2011.04 - 2012.12	Anhui (75 Scenes)	Free download

3.2 Data features

Data features are shown in Table 3.2. All images include green, red and near IR bands. In addition to SPOT5 and Liss3, other data also includes blue band. For each band, the wavelengths are approximate, exact values depend on the particular satellite's payloads.

Table 3.2 Middle Resolution Remote Sensing Data Features

Satellite		ALOS		SPOT5		Landsat5		RapidEye		IRS P6		HJ-1A/B	
Sensor		AVNIR-2		HRG		TM				Liss3		CCD	
	Blue	0.42-0.50	10			0.45-0.52	30	0.44-0.51	5			0.43-0.52	30
	Green	0.52-0.60	10	0.50-0.59	10	0.52-0.60	30	0.52-0.59	5	0.52-0.59	23.5	0.52-0.60	30
	Red	0.61-0.69	10	0.61-0.68	10	0.63-0.69	30	0.63-0.685	5	0.62-0.68	23.5	0.63-0.69	30
	RE							0.69-0.73	5				
Bands (μm) Resolutin (m)	NIR	0.76-0.89	10	0.78-0.89	10	0.76-0.90	30	0.76-0.85	5	0.77-0.86	23.5	0.76-0.90	30
	SWIR			1.58-1.75	20	1.55-1.75	30			1.55-1.70	23.5		
	TIR					10.4-12.5	120						
	MWIR					2.08-2.35	30						
Digitization		8bit		8bit		8bit		12bit		7bit		8bit	
Swath Width		70km		60km		185km		77km		141km		360(700km)	

Besides conventional visible and near infrared bands, Liss3 and TM and SPOT5 data include SWIR band. The wavelength of SWIR usually is 1.55-1.75μm. This band is very useful to identify the crop types. It is sensitive to water contents in crop. It can provides surface wetness information. Lower values of reflected energy in SWIR band signify more surface wetness. With SWIR band we can improve the recognition accuracy of crops. In Anhui province, this band can help us to identify the maize and soybean and rice.

For RapidEye, it is the first commercial satellite-image to include the Red-Edge band,

which is sensitive to variation in chlorophyll content of vegetation. The wavelength is 0.69-0.73 μm . Studies show that this band can assist in monitoring vegetation health, improve crop-types separation and help in measuring protein and nitrogen content in biomass. There are five identical Earth Observation satellites to consist of RapidEye's constellation. The constellation offers the largest collection capacities and the quickest return time. The data spatial resolution is 5m, higher than other data listed in Table3.1. Considering the bands and the spatial resolution, RapidEye data are the best choice for crop area monitoring on county level.

Figure 3.2 shows the RapidEye and Liss3 images.

Figure 3.1 The RapidEye and Liss-3 images

3.3 Data pre-processing

Apart from the TM data downloaded from the USGS website, the other data was on system level (1B). These data were radiometric corrected and sensor corrected without any further corrections. The system error had been eliminated. The value of each pixel

was dimensionless Digital Number (DN). DN value range was 0-255 or 0-1023. In order to crop acreage monitoring, geometric correction and atmospheric correction had been performed for these data.

3.3.1 Geometric correction

Crop area monitoring required the remote sensing images with accurate geolocation and cartographic projection. Geometric correction is to avoid geometric errors or distortions. The geometric correction was done in ENVI software with Orthorectification module. DEM file was downloaded from ASTER with 90 meters resolution (SRTM 90m DEM). For RapidEye data and SPOT5 data, Ground GCPS was collected in the field using differential GPS. For other data, GCPS was collected in the TM images which were downloaded from USGS.

The map projection was Universal Transverse Mercator (UTM), datum was WGS84, zone was 50N. Resampling kernel was Cubic Convolution (CC).

3.3.2 Radiometric correction

Radiometric correction is to avoid radiometric errors or distortions. For the data which were on system level, radiometric correction was divided into two steps.

First step was radiometric calibration. DN value was converted to apparent reflectance. The formula to convert the Digital Number (DN) of a pixel to radiance was as follow:

$$L = DN \times Gain + Bias \qquad (1)$$

L: radiance, W/m^2 sr µm.
DN: digital number of the pixels, dimensionless.
Gain: gain, radiometric scale factor , W/m^2 sr µm.
Bias: bias factor, W/m^2 sr µm.

Second step was atmospheric correction. Various atmospheric effects cause absorption and scattering of the solar radiation. According to radiation transfer model, the apparent reflectance converted to surface reflectance, eliminating errors caused by the atmosphere. Atmospheric correction was processed by using ENVI FLASSH module.

The effects of atmospheric correction for RapidEye data was illustrated in the Figure 3.1. The Figure shows, after atmospheric correction, reflectivity of Blue, Green and Red bands obviously went down, while the reflectivity of Red Edge and Near-infrared bands notably went up, with relatively clearer image texture. For Liss3 and HJ-1 images, same pre-processing approach was used.
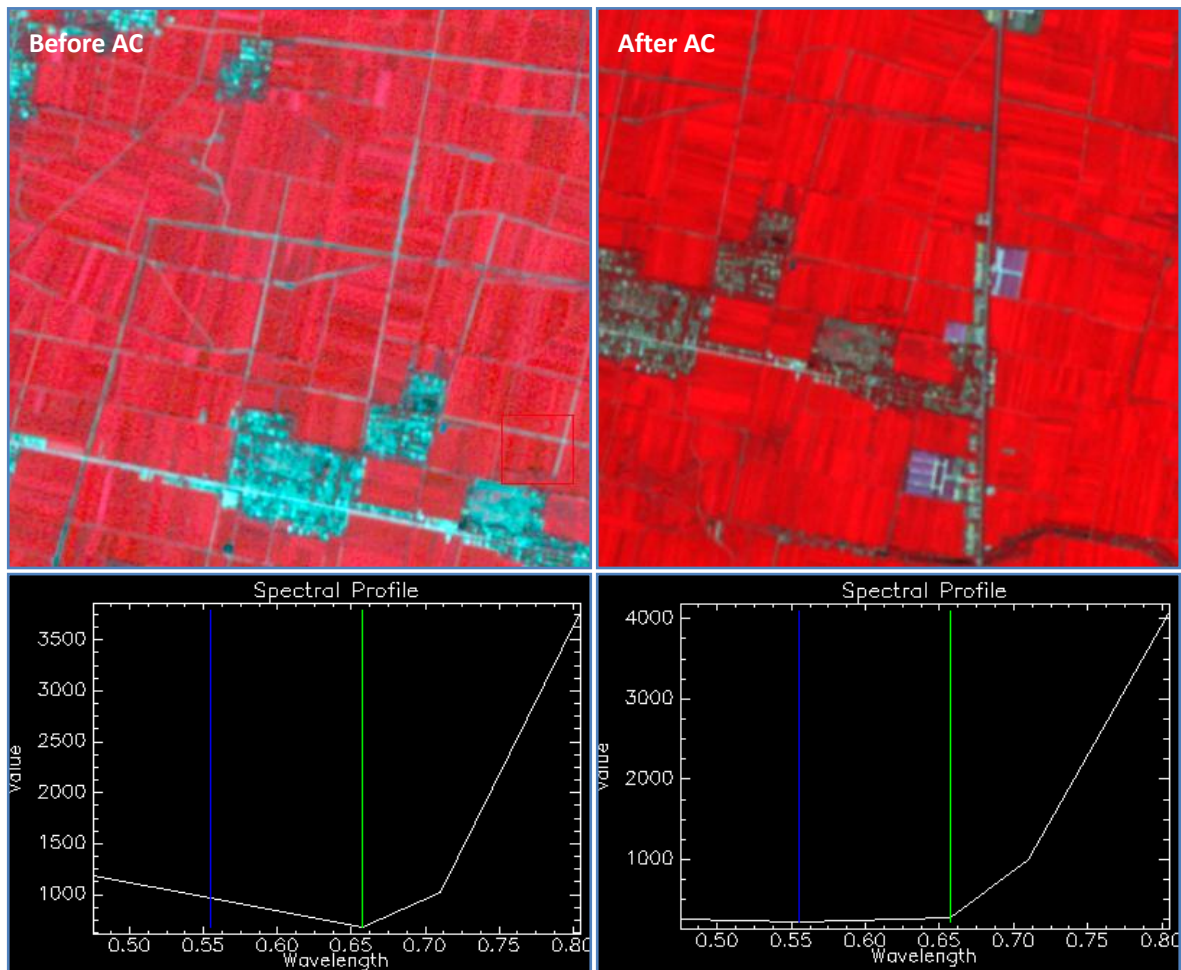
Figure 3.2 The Comparison Before and After Atmospheric Correction

4 LOW RESOLUTION IMAGES

4.1 Data list

Low resolution images applied MODIS LAI and NDVI data downloaded from the partner website of NASA (ftp://e4ftl01.cr.usgs.gov/MOLT/). LAI was from January 1st 2012 to June 30th 2012, covered Anhui province. Product ID was MOD15A2. The products were composited every 8 days at 1km resolution. NDVI was from January 1st 2011 to December 30th 2012. Product ID was MOD13Q1. The products were composited every 16 days at 250m resolution. The time series of LAI were used to extract the area and the phenological period of winter wheat . The time series of NDVI were used to extract the area of soybean and corn.

Table4.1 was the list of low resolution remote sensing data.

Table 4.1 Low Resolution Remote Sensing Data List

Sensor	Resolution	Data	Range	Data sources
EOS-MODIS	1000m	MOD15A2 2012.01 to 2012.06	Anhui	Free download
EOS-MODIS	250m	MOD13Q1 2011.01 to 2012.12	Anhui	Free download

4.2 Data pre-processing

Time series of NDVI (MOD13Q1) and LAI (MOD15A2) were used to extract crop phenology and crop area. The main pre-processing was carried out to smooth and reconstruct the datasets. The noise caused by cloud were mostly removed, and the missing values were replaced.

There are many filtering approaches to rebuild the datasets, such as MVC, HANTS, BISE, or MVI. In this study S-G filter was selected. S-G filter performs well on vegetation monitoring, and the procedure is simple and requires less priori knowledge. The pre-processing procedure is detailed below.

After downloaded, all products were projected and converted under support of MRT (Modis Reprojection Tool). In order to overlay with other map easily, they were converted to Albers Equal Area Conic projected tiff files. The projection parameters were

as follows:

Projection: Albers Equal Area Conic

Spheroid: Krasovsky

Central Meridian: 105°E

Standard parallel 1: 25°N

Standard parallel 2: 47°N

In order to eliminate the effect of non-cultivated land, Cropland Map was taken as mask. For LAI products, each pixel has 24 values after mask. 0 means non-cultivated land, 1-23 stand for MODIS-LAI). Based on the envelope filtering algorithm of S-G, the data were operated point-by-point, so as to remove the impact of cloud and noise (Figure4.1). It can be seen from the Figure, LAI data are very smooth after up envelope filtering, which is consistent with the universal law of crop growth. Time series of LAI was applied to extract the crop phonology.

For NDVI products, the same filtering algorithm was used to remove the impact of cloud and noise. Time series of NDVI was applied for soft classification..
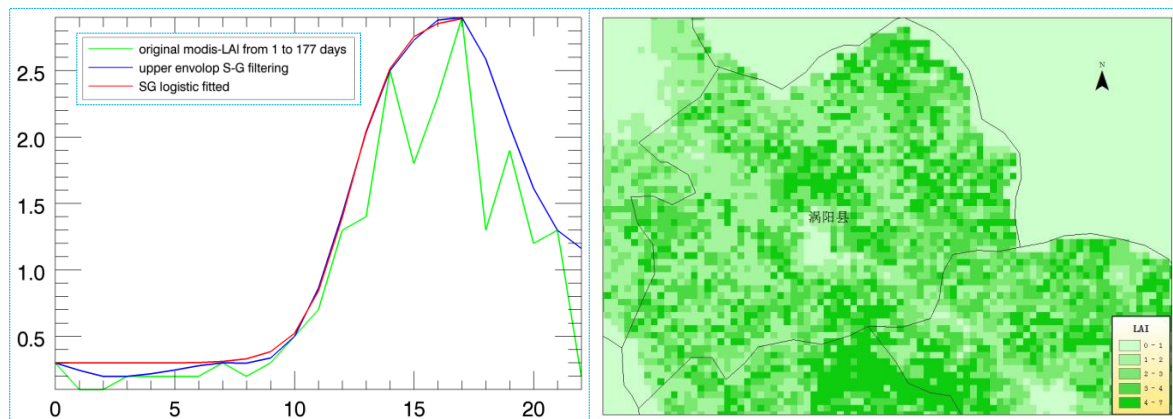
*Figure 4.1 LAI Distribution by the Different Smoothing Methods*

4.3 Crop phenological period extraction

From January 1st 2012 to June 30 2012, winter wheat experienced growth periods of striking root, jointing, flagging, head sprouting, blossom, maturity, and harvest. According to the features of rapid rise of LAI during striking root and due to the fact that the LAI reaches its maximum value of growth period during head sprouting, the 8-day synthesized EOS/MODIS/LAI could approximately depict this growth process. Based on

above principles, the extraction of winter wheat during striking root and head sprouting periods was made in Guoyang county.

Major steps of phenological period extraction based on up envelope filtering LAI, LAI (1-177 day) maximum value of each pixel point by point was extracted, and it was taken as the maturity date. And then, logistic curve fitting of LAI from 1 to maturity date was conducted, and then the curvature of the fitted curve was calculated. Output of maximum value of curvature was taken as the striking root date.

Distribution of winter wheat striking root period and head sprouting period. Extraction result of winter wheat striking root period and head sprouting period of Guoyang county is illustrated in the Figure 7.4. The Figure shows that, striking root process approximately starts from 50th day, and ends at 70th day, corresponding to the dates of February 20th – March 10th, which is consistent with the ground development period. Maturity period approximately starts at 100th day, and ends at 120th day, corresponding to the dates of October 4th – April 30th, which is also consistent with the ground development period. For crop rotation system of winter wheat – corn, and winter wheat – beans, Guoyang county possesses of sufficient heating condition. Rush-harvesting and rush planting is not common in this area, and the winter wheat planting and harvesting periods are not concentrated, which is the major factor for the long striking root and maturity periods.
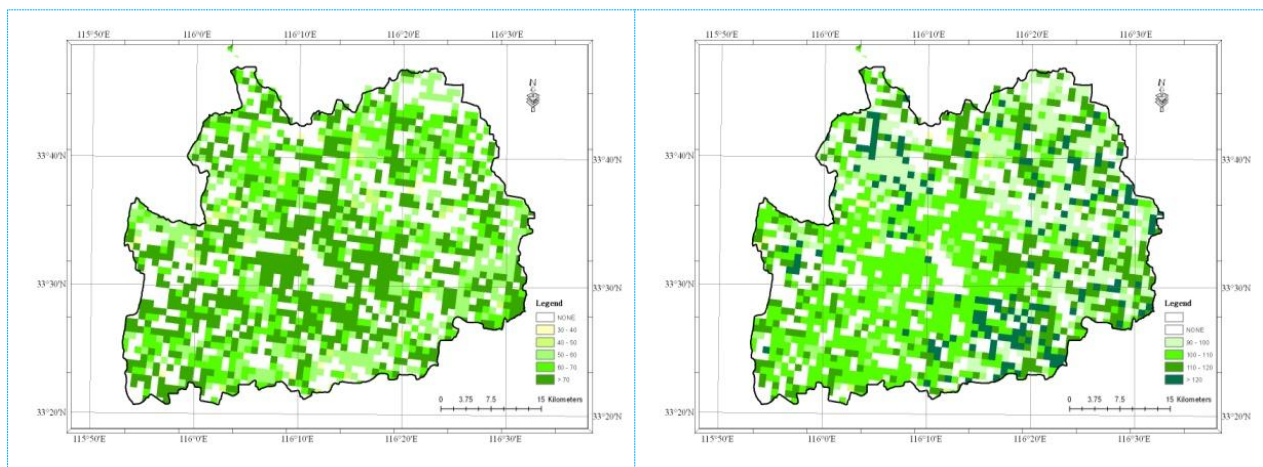
Figure 4.2 Returning Green and Maturity of Winter Wheat at Guoyang

5 CONCLUSION

In order to estimate the crop area of Mengcheng and Guoyang, satellite data from three types of sensors were collected: the low resolution imagery from MODIS; the medium resolution from Liss3, Landsat TM, SPOT5, HJ-1A/B and RapidEye; the high resolution from QucikBird or other similar images..

(1). The high resolution images were provided by QuickBird and/or Google Earth. They were used for field surveys and stratification purposes. The images were detailed enough to design the field sampling. Based on these images, the land use map of each sampling unit with 1:2500 scale had papered in the office. In some cases sampling units had to registered again in fields.

(2). The medium resolution images were used to extract the crop area with hard classification. There were 83-scene / images. The acquisition period was form 2011 to 2012, covered different phenological periods of crops. Geometric correction and atmospheric correction had been performed for these data. Considering the bands and the spatial resolution, RapidEye data is the best choice for crop area monitoring on county level. The SPOT5 data were also well suitable.

(3). The low resolution images were mainly used to extract the crop area with soft classification. The time-series of MODIS LAI and NDVI corresponding the crop growth seasons were selected. The products were downloaded from USGS website. LAI products were from September 1st 2011 to June 30th 2012, composited every 8 days at 1km resolution. NDVI was from January 1st 2011 to December 30th 2012, composited every 16 days at 250m resolution. The time series of LAI were used to extract the phonological period of winter wheat. The time series of NDVI were used to extract the area of winter wheat, soybean and maize. The pre-processing was performed using of S-G filtering.