Crop Acreage Measurement by using remote sensing in Chinese Agricultural Census ' 2016

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- The Third Chinese agricultural census has been conducted at the end of 2016, which is the year ended with 6 in every ten years. The reference time is December 31 24pm, and the reference period is year 2016.

- Chinese agricultural census ’2016 is included a module of crop acreage measurement by using remote sensing for major crops, covering 31 provinces (municipalities, autonomous regions) throughout the mainland China.

  It mainly includes 4 aspects of this work as follows.

Crop Acreage Measurement by Using Remote Sensing in Chinese Agricultural Census ’2016 (cont’d)

(1) Cropland interpretation. At provincial level, Land use was visually interpreted by using Chinese high resolution satellite images (GF-1/2 & ZY-3) to distinguish cropland and then delimitate them into each field with recognizable demarcation lines, in order to build (update) area frame and recognize the plots of cropland.

(2) Area frame construction and sample selection. Area frame was constructed by cropland extracted from either year 2015-2016 satellite images or updated results of Chinese Second Land Survey conducted by the Ministry of Land and Resources in year 2007-2009. A two stage sampling was adopted to select sample villages firstly and then sample grids.

Crop Acreage Measurement by Using Remote Sensing in Chinese Agricultural Census '2016 (cont'd)

(3) Collecting and interpreting sample information. For sample grids, a field survey for crop acreage was conducted. For sample villages, crop types were visually interpreted by each plot by using Chinese high resolution satellite images (GF-1&GF-2 etc.). Typically each province had around 300 sample villages, and each village had 3 sample grids.

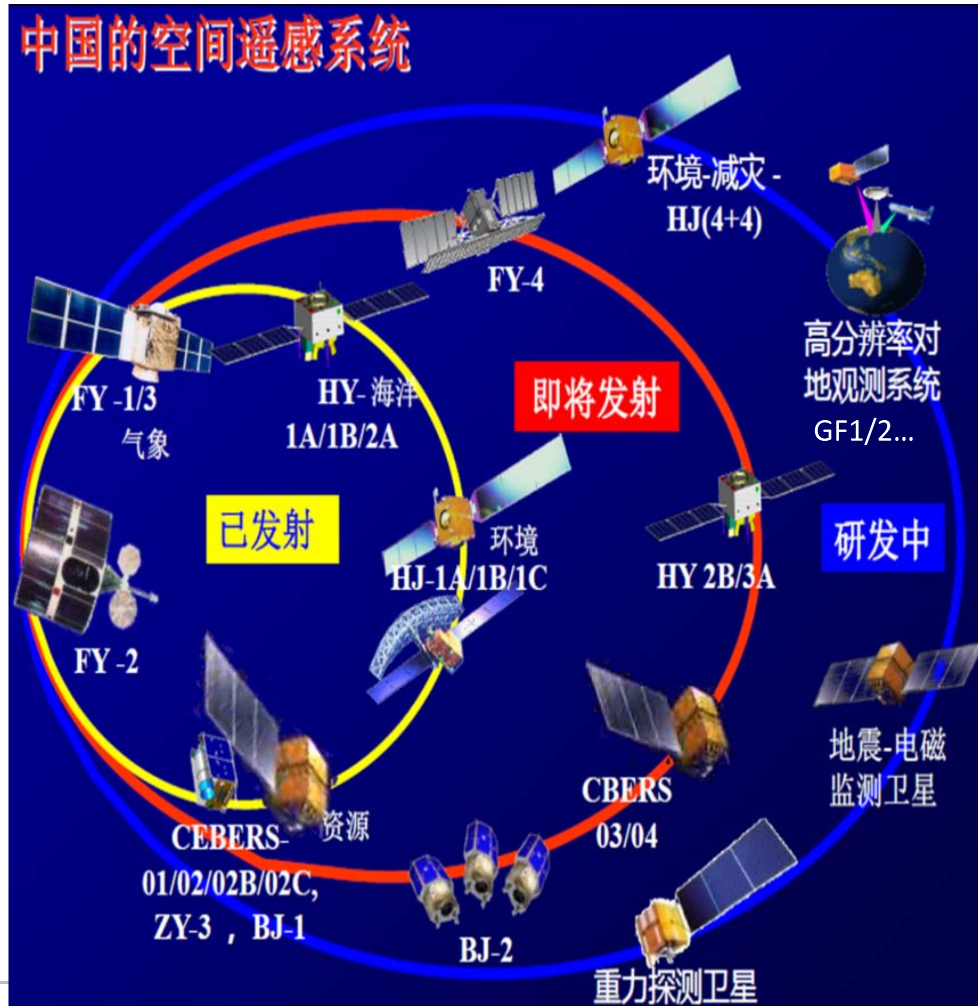
(4) Crop classification. At provincial level, crop classification was manipulated by using moderate resolution satellite (GF-1 16m CCD images, and sometimes Landsat 8 OLI) to obtain crop planted pattern.

Acquisition of Remote Sensing Satellite Images

Source of Satellite imagery

- For high resolution satellite images, mostly from Chinese domestic satellites available for government users, such as optical sensor satellites of GF-1, GF-2, ZY-3, CBERS-04 and complemented by commercial satellite BJ-2 etc.
- For moderate resolution satellite images, GF-1 is the main source, complemented by USA Landsat 8 (OLI) and EU Sentinel 2A.

Chinese Remote Sensing Satellites for Earth Observation



Satellite GF-1 (Gaofen-1) Parameters

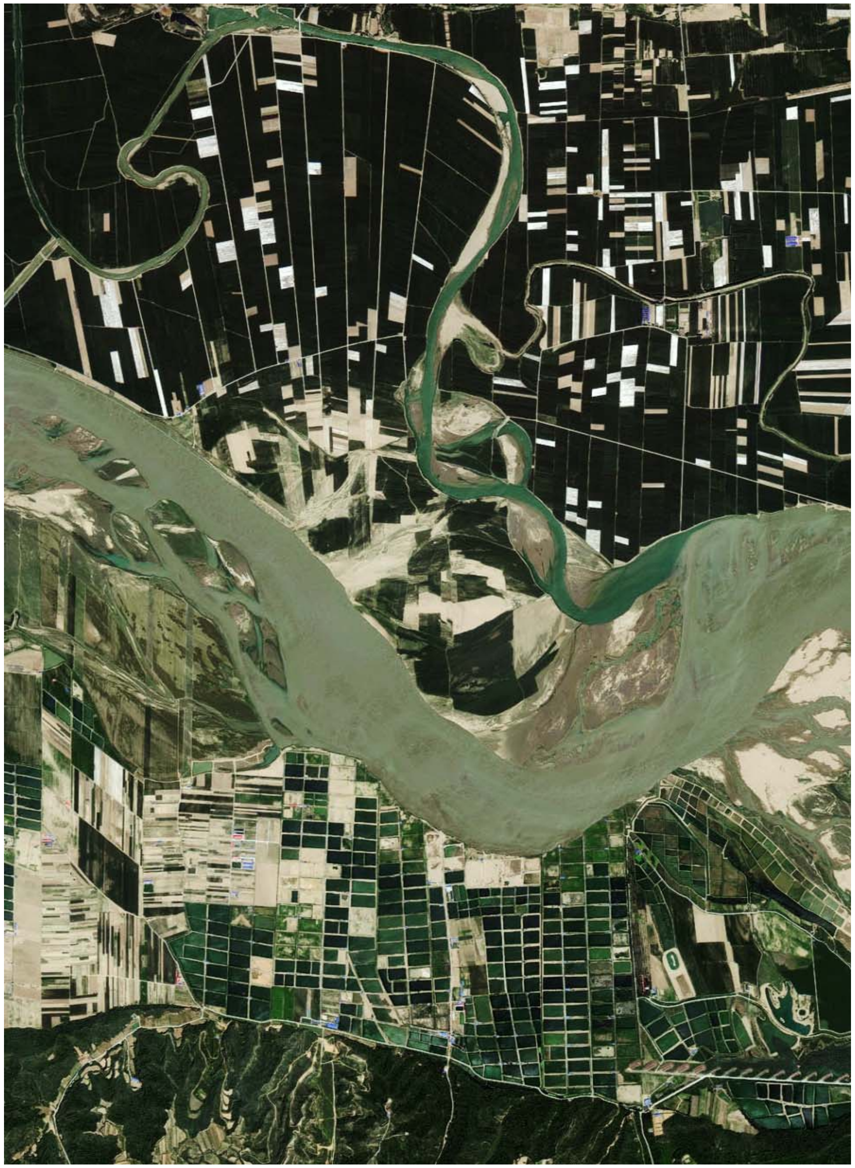
Main sensor	2×High Resolution Cameras	4×Wide Field of View Cameras
Spatial resolution	Pan 2 m; MS 8 m (nadir)	MS 16 m (nadir)
Swath width	70km with two cameras	800km with 4 cameras
Data Quantization	10 bit	10 bit
Revisit capability	4 days (roll near 35º)	4 days

GF-1 Ture Color of 2m/8m fusion, Northeastern Plain, China

GF-1 Ture Color of 2m/8m fusion, Paddy Land, China

Satellite GF-2 (Gaofen-2) Parameters

Main sensor	2×High Resolution Cameras
Spatial resolution	Pan 0.8 m; MS 3.2 m
Swath width	45 km with two cameras
Data Quantization	10 bit
Revisit capability	5 days (roll near 35º)



GF-2 Ture Color of 1m/4m fusion, River Impact landform in Henan, China

GF-2 Ture Color of 1m/4m fusion, Pond landform in Henan, China

Satellite ZY-3 (Resource-3) Parameters

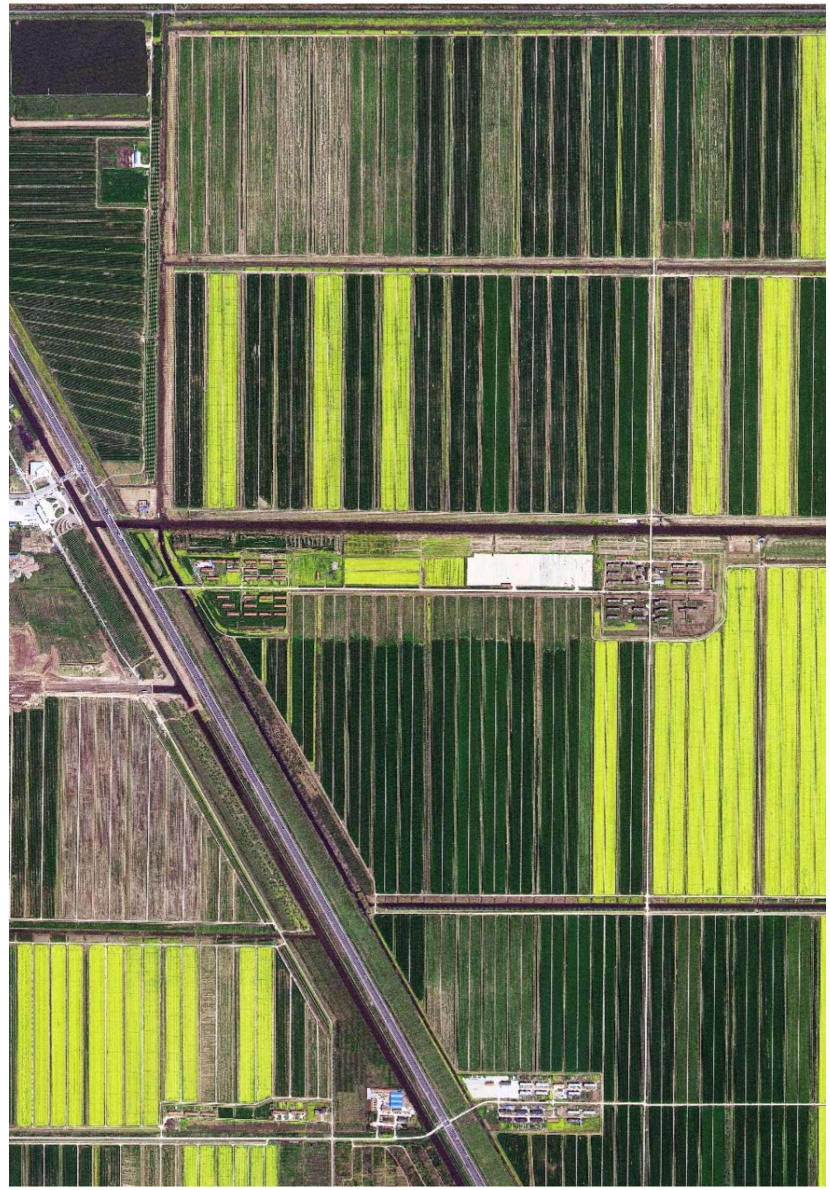
Main sensor	3 Panchromatic Cameras (Forward, Nadir, Backward)	1 Multi-spectrum Cameras
Spatial resolution	Pan 2.5/2.1/2.5 m	MS 5.8 m
Swath width	51 km	51 km
Data Quantization	10 bit	10 bit
Revisit capability	3-5 days (roll near 32º)	3 days (roll near 32º)

ZY-3 Ture Color of 2m/6m fusion,
Landscape of cropland

Satellite BJ-2 (Beijing-2) Parameters

Main sensor	1×High Resolution Cameras
Spatial resolution	Pan 0.8 m; MS 3.2 m
Swath width	24 km with two cameras
Data Quantization	10 bit
Revisit capability	1-2 days (roll near 45º)

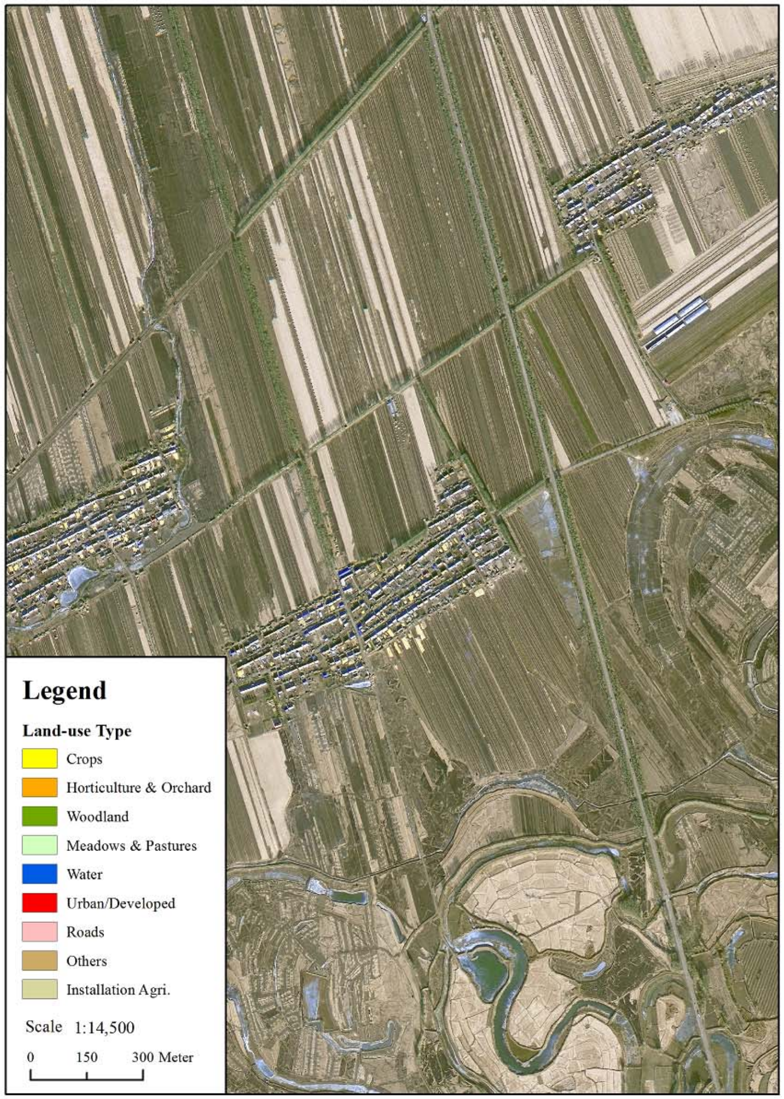
BJ-2 Ture Color of 0.8m/3.2m fusion,
Terrace landform in Shanxi, China

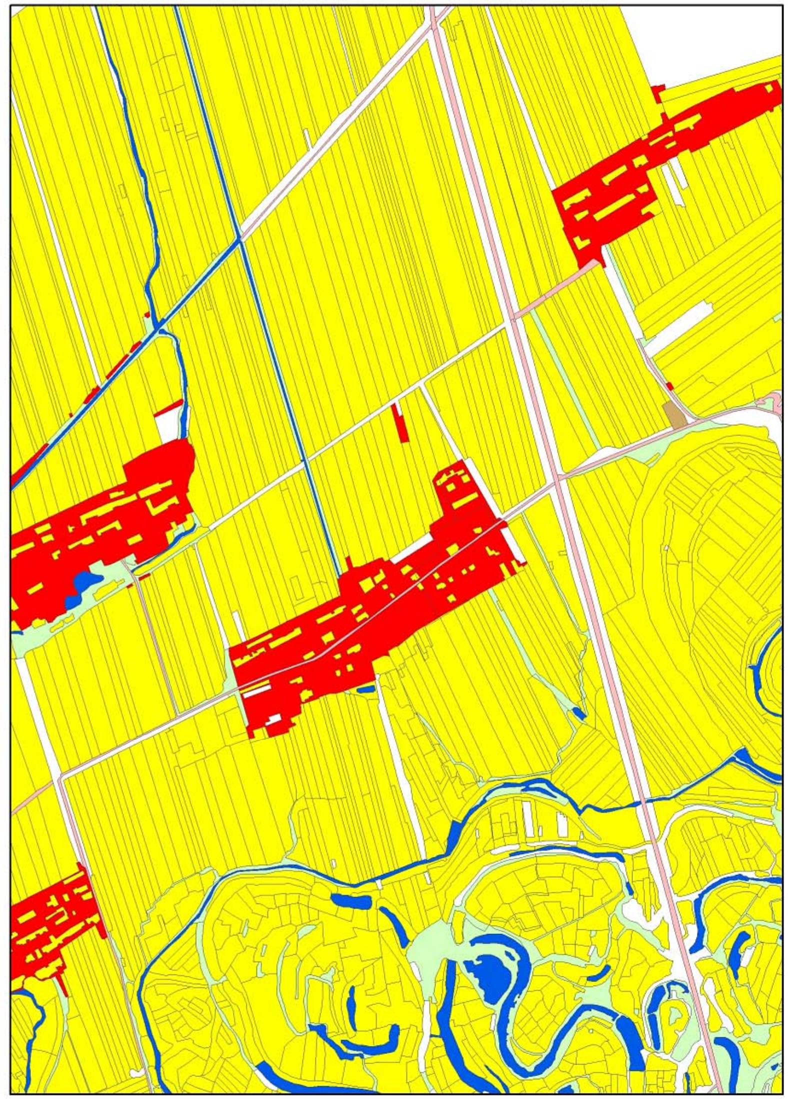


BJ-2 Ture Color of 0.8m/3.2m fusion,
Cropland landscape in Jiangsu, China

Cropland Extraction and Area Frame Construction

Land Use Visually Interpretation





Area Frame Construction and Sampling

- Cropland extracted from the visual interpretation of high resolution satellite images, was used to construct or update area frame.
- A two stage sampling is adopted, sample villages were selected by PPS method, and sample grids were selected by SRS method.

Field Survey for Sample Grids

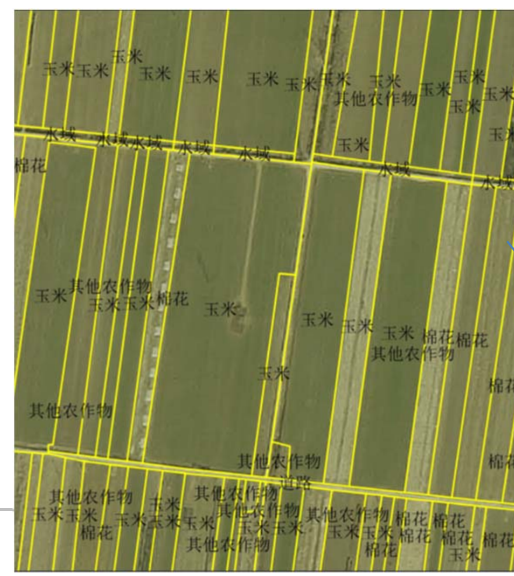
PDA used to navigate and collect info.

Task Assignment

Navigation

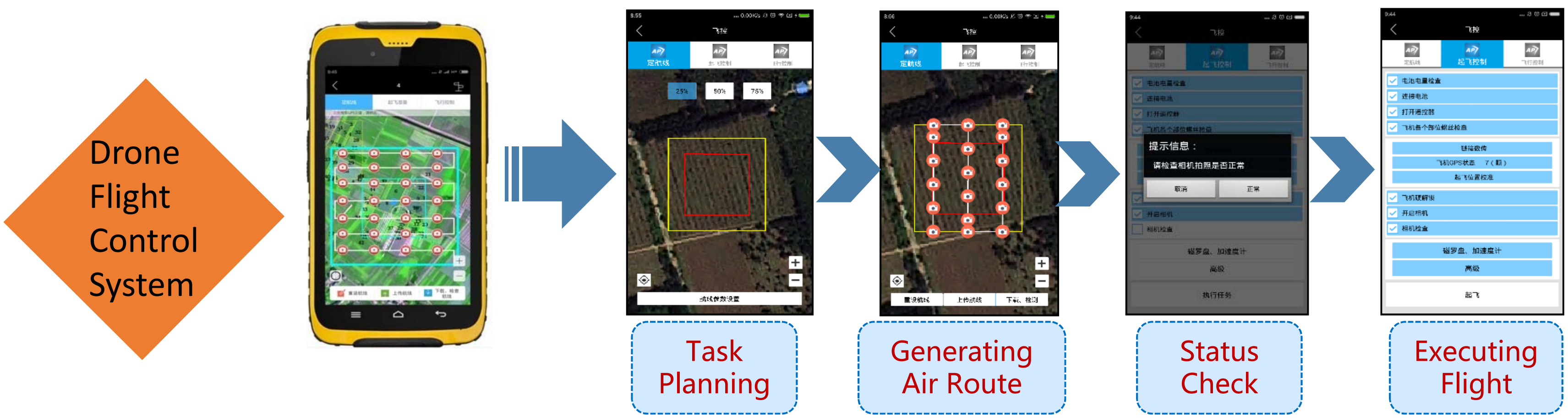
Base Map

Feature Capture

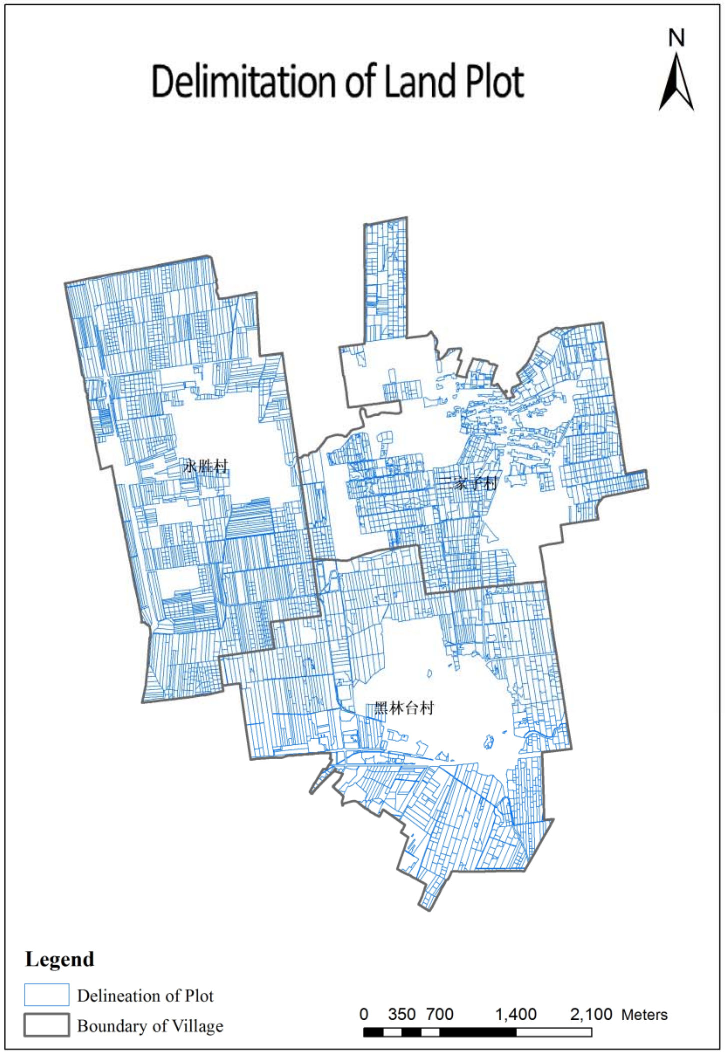


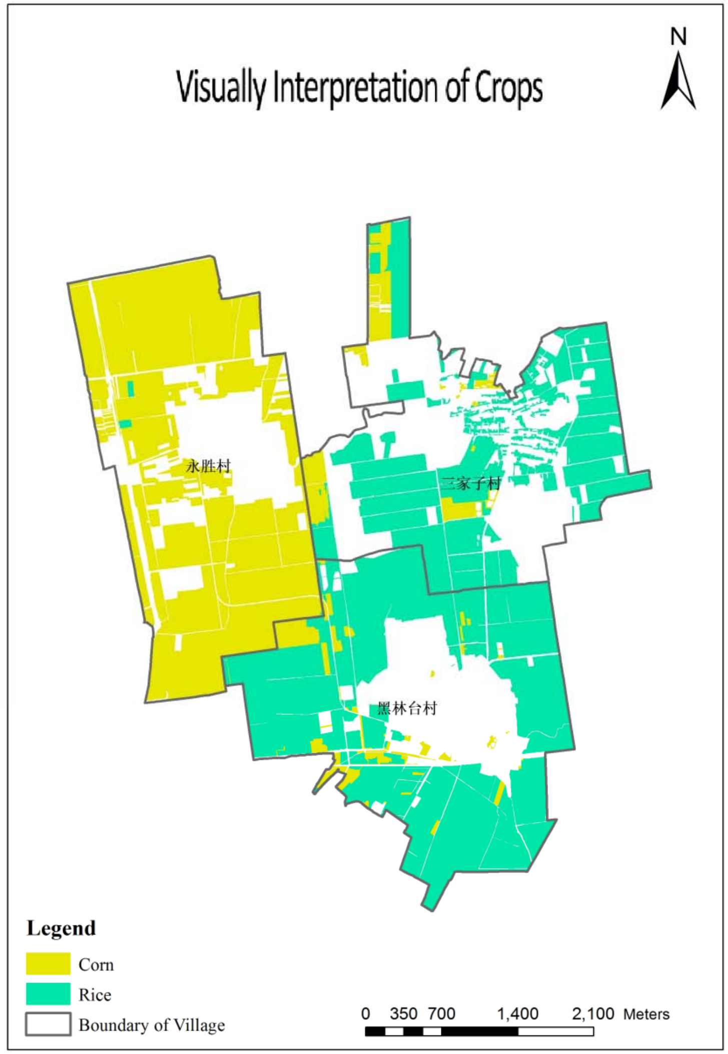
Identity Crop Types

Visually Interpreting Crops from UAV Images for (Part of) Sample Villages



Crop Interpretation from Satellite Images for Sample Villages



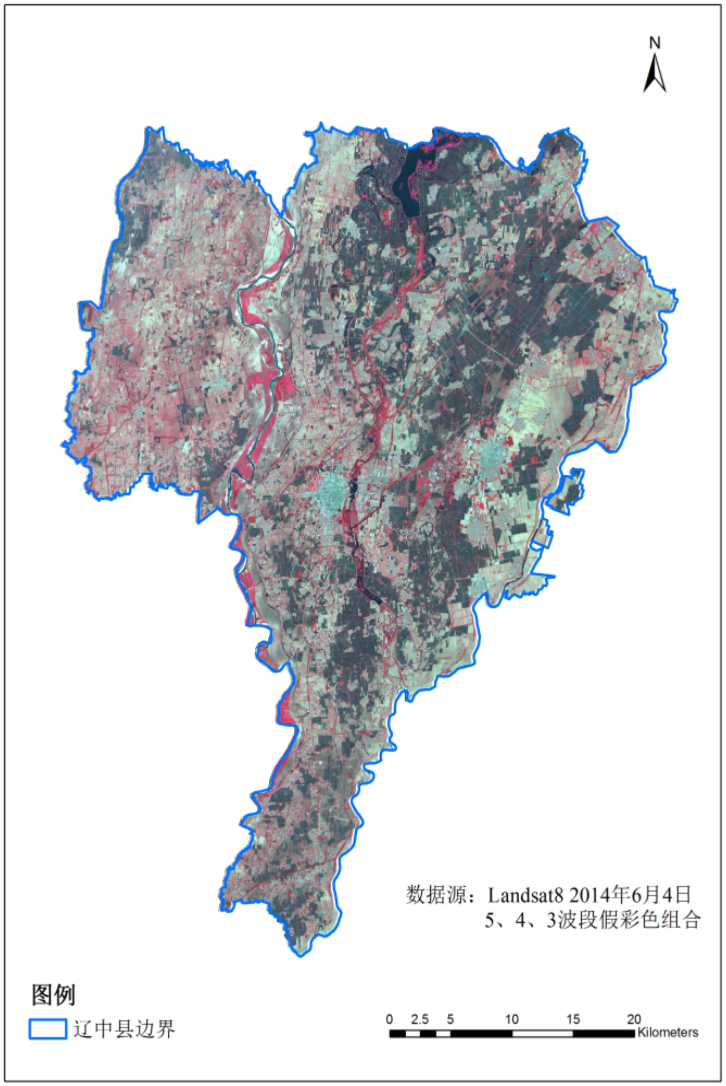


Crop Classification from Moderate Resolution Images

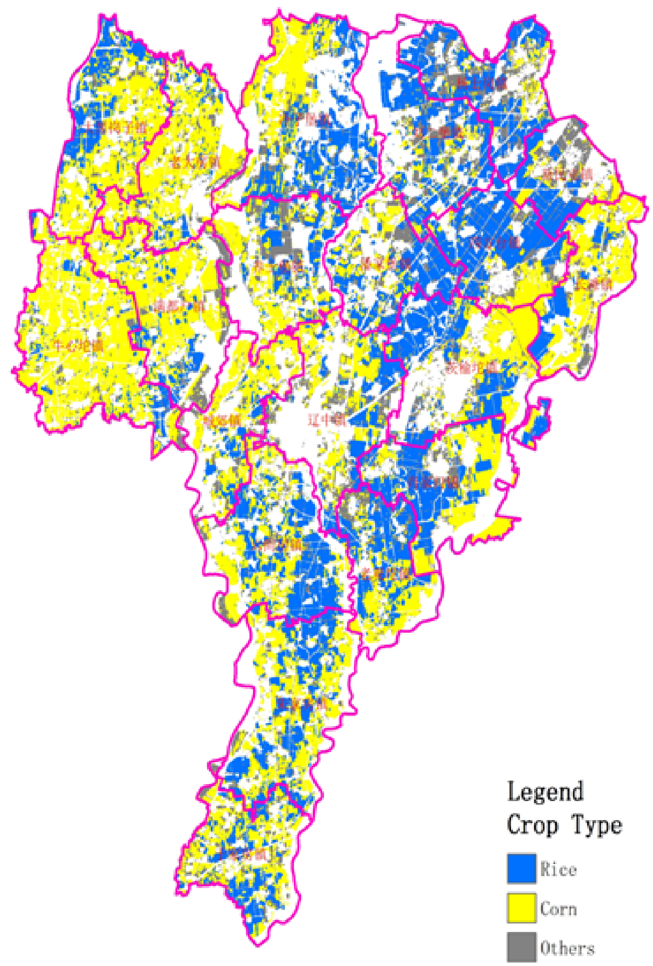
Source of Moderate Resolution Images

- GF-1 16m CCD images, and sometimes Landsat 8 OLI and Sentinel 2A.
- For crop classification in Agricultural Census’2016, multi-temporal especially in key phenological calendar of crop growth’s Digital Orthophoto Map (DOM) images which covered the entire province was expected.

Landsat 8 OLI



Classified Distribution of Rice and Corn
from Moderate Resolution Satellite Images



Improvement of Crop Acreage Estimation by Using Small Area Estimation Model

Methods of Crop Acreage Estimation

- According to Stephen V. Stehman (2009), for crop acreage estimation we have (1) director estimator from sample expansion,(2) mapping-based confusion matrix area estimator,(3) model assisted estimator, (4) others, like survey sampling calibration estimators, small-area estimator (SAE).
- In agricultural census, we had survey data from field observation and full-coverage classified crops as auxiliary information for entire population (e.g province), small area estimation (SAE) provides an improved approach of crop acreage estimation both at population and sub-population (e.g county) levels by combining the crop classification data with the data of sample survey.

SAE Model with Random Effects

- For a unit level model, model specification is as follows:

$$y_{ij} = \mu + X_{ij}^{T}\beta + v_i + e_{ij}, \quad j = 1,2,...,n_i \;, \; i = 1,2,\ldots,m$$

Where， y_{ij} is a specified crop (e.g rice or corn) acreage for the j**th** sample grid in the i**th** county (small area), m is the total number of counties. n_i is the sample size of the i**th** county, μ is the intercept in the model. Random effects v_i and error term e_i are subject to independent and identical distribution of normality with mean 0 and identical variance σ_v^2 and σ_e^2 respectively .

SAE Model with Random Effects

- For parameter estimation, using the generalized ordinary least square method, we have:

$$\hat{\beta} = \left(\sum_{i=1}^{m} X_i' V_i^{-1} X_i\right)\left(\sum_{i=1}^{m} X_i' V_i^{-1} Y_i\right)$$

$$\hat{v}_i = \frac{\sigma_v^2}{\sigma_v^2 + \sigma_e^2 / n_i}(\bar{y}_i - \bar{x}_i \hat{\beta})$$

- The total estimate $\hat{Y}_i$ for the i*th* town and township by BLUP estimation：

$$\hat{Y}_i = N_i[\bar{X}_i \hat{\beta} + \frac{\sigma_v^2}{\sigma_v^2 + \sigma_e^2 / n_i}(\bar{y}_i - \bar{x}_i \hat{\beta})]$$

SAE Model with Random Effects

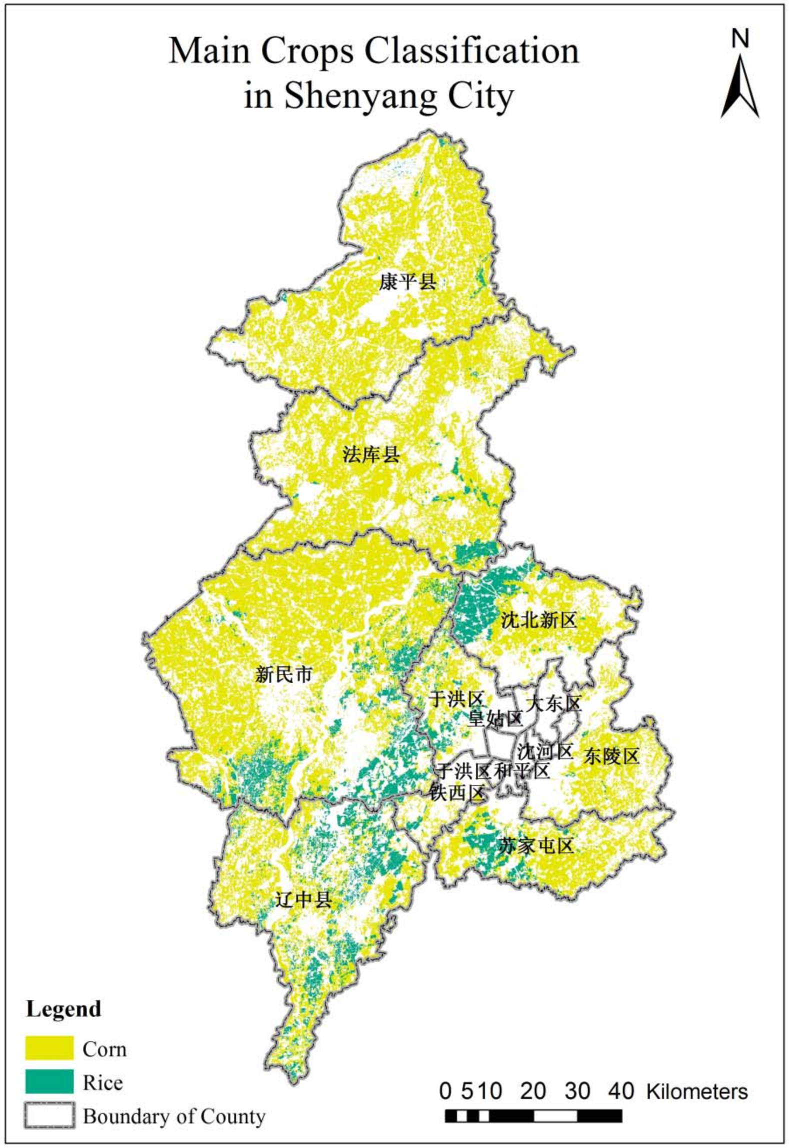
- MSE of $\hat{Y}_i$ at town level

$$MSE(\hat{Y}_i) = g_{1i}(\hat{\sigma}_v^2, \hat{\sigma}_e^2) + g_{2i}(\hat{\sigma}_v^2, \hat{\sigma}_e^2) + 2g_{3i}(\hat{\sigma}_v^2, \hat{\sigma}_e^2)$$

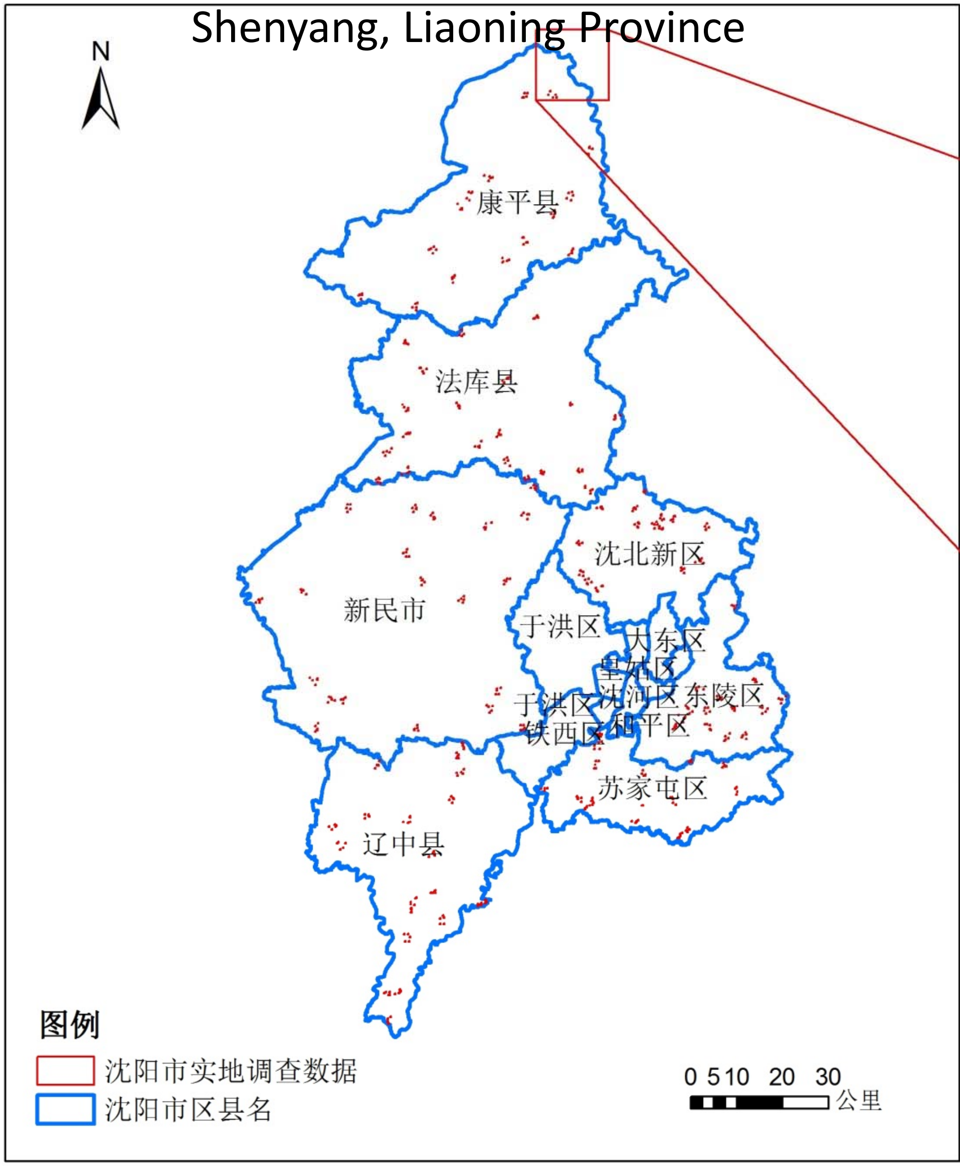
- Population total at county level

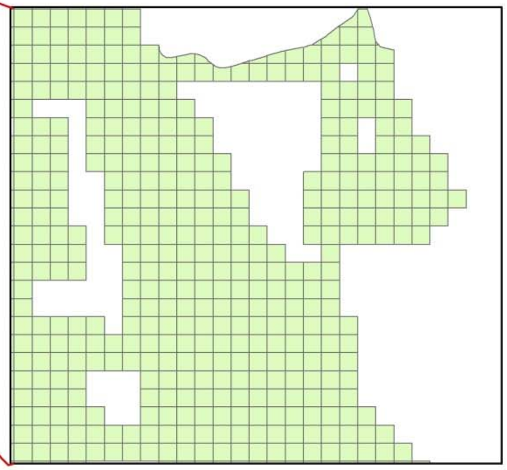
$$E(\hat{Y}) = E(\hat{Y}_1) + E(\hat{Y}_2) + ... + E(\hat{Y}_m)$$

Estimating Crop Acreage by SAE in Shenyang City



Estimating Crop Acreage by SAE in Shenyang City (cont'd)





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Grids within the scope of cropland

Estimating Crop Acreage by SAE in Shenyang City (cont'd)

- Data description used for SAE model in Shenyang city

County Name	County Code	Total No. of Grids	No. of Sample Grids	Corn Area Surveyed m^2/Grid	Rice Area Surveyed m^2/Grid	Corn Area Classified m^2/Grid	Rice Area Classified m^2/Grid
浑南区	210112	14385	66	27135.77	902.63	26160.65	780.04
沈北新区	210113	17918	67	20467.88	12170.74	20186.72	9063.32
于洪区	210114	9499				14172.83	5765.67
辽中县	210122	37447	100	16772.38	11849.48	15857.21	7903.62
康平县	210123	47455	75	28986.18	251.72	29066.78	224.80
法库县	210124	54405	99	26493.65	2016.88	25152.68	1191.79
新民县	210181	74857	101	22880.79	8216.61	21452.30	6085.45

Estimating Crop Acreage by SAE in Shenyang City (cont'd)

- C.Vs of Corn and Rice Acreages by county from SAE, compared with C.Vs from direct estimator from sample expansion (in bracket).

County Name	County code	C. Vs of Corn Acreage	C. Vs of Rice Acreage	Remark
浑南区	210112	6. 41% (15. 9%)	48. 6% (64. 6%)	Rice rarely planted
沈北新区	210113	6. 93% (24. 6%)	7. 3% (36. 7%)	
于洪区	210114	21. 59%	33. 10%	No samples selected
辽中县	210122	5. 01% (19. 0%)	4. 8% (19. 4%)	
康平县	210123	2. 95% (11. 5%)	63. 5% (69. 7%)	Rice rarely planted
法库县	210124	2. 89% (13. 3%)	22. 5% (44. 6%)	
新民县	210181	2. 52% (15. 0%)	5. 8% (26. 7%)	

Summary

- A unit level small area model in the form of one-response multiple regression with random effects could produce the estimates at province and county levels simultaneously.
- Taking the advantages of combining crop classification from satellite images with field survey data, SAE model could improve the estimate precision of crop acreage.
- Therefore, remote sensing application in agricultural statistics could (1) facilitating construction and update of area frame, (2) improving the sample design for crop surveys, (3) improving the crop acreage estimation and etc.
- For National Bureau of Statistics (NBS) of China, although NBS facing some challenges in applying remote sensing techniques, we are moving forward to further apply remote sensing in agricultural statistics and attempt to extend to relevant areas of the System of Environmental-Economic Accounting.

Thanks for your attention!