CROP AREA ESTIMATION USING REMOTE SENSING ON TWO-STAGE STRATIFIED SAMPLING

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ABSTRACT:

In this paper, we analyses problems that remote sensing technique met in China. And provide a new methodology on stratified sampling technique. During the stratification procedure, physical factors, such as temperature, precipitation, soil type, sun eradiation was considered as well as proportions of main crop types. And then, we first estimate crop proportion using cluster sampling assisted by remotely sensed images. Secondly, we estimate crop type proportions of different crop types using transect sampling and GVG survey system. Here, transect sampling is a two-stage sampling in fact. In the first step, PSUs were selected randomly from a 4KM * 4KM area frame. And in the second stage, road segments were selected to survey crop type proportions. At last, crop area was calculated under the support of current 100,000-scaled land resource database. And a case study of early rice area estimation in 2003 showed this methodology was efficient and accuracy enough to meet the running of CCWS.

1. INTRODUCTION

Monitoring, estimating and forecasting agricultural production are very important for the management of world / regional or local food demand and supply balance for social security. China has made series of progresses from 1983 after tackling key problems with states plan and researches in some institutes and universities. Monitoring crop types has increased to including wheat, maize and rice with monitoring area increased to including 11 provinces. In 1998, China built a CCWS running system for crop early monitoring, predicting and estimating. Every year, CCWS publish the hot information on crop growing status, crop acreage, crop production, crop structure changing and multiple-plant index et al.

In China, crop acreage estimation using remote sensing always met the following problems. (1) Some methods that have great precise at small area become invalidate at country level. (2) Crop planting and harvesting time are all concentrated in the period from April to October every year, time is relatively shorter when carrying out crop acreage estimation. So crop acreage estimating-methods must be effective and time saving. As a result, some method with a large amount of processing successfully applied in small area cannot meet the request of large region. (3) Some method that successfully applied in small area cannot be applied because of their high-cost. Therefore, country level crop acreage estimation methodology must have the following properties:

-- Accuracy enough to support decision.

-- Speedy enough to meet the time that application section required.

-- Frugal enough not to go beyond the ability that application section could bear.

-- Having unified criterion and can be operated easily.

In this paper, we mainly introduced the crop acreage estimating methods used in China Crop Watch System, CCWS. Supported by the arable area data in Chinese Resource and Environment Database, we constructed a feasible methodology using a two-stage sampling to meet Chinese crop estimating request. And six years operating practice showed that, this crop acreage estimating technique is accuracy, reliable and practically.

2. METHDOLOGY

Estimating crop acreage at large region using remotely sensed data in operating always meet the following 3 obstacles when there is no other techniques assistant.

---- Remotely sensed data cannot cover the country completely in crop growing stage. Not only because the input reason, but also the excessive processing-time. For the running of CCWS, after image received, only there is 1 or 2 weeks left for image pre-processing and analyzing before results publishing, and we have no ability to process a large numbers of images required for crop acreage estimation in China such a large area.

---- It’s difficult to obtain enough images with proper date and spatial resolution for meteorological conditions and limited time slot. Sometimes, it is always cloud-covered or raining and we cannot receive cloud free or high quality images. Nevertheless, image-receiving date is extremely limited for crop acreage extraction. In China, the most appreciate image date for estimating rice acreage is the 2-5 week after moving. For winter wheat acreage estimation is in March and April. For maize acreage estimation in Northeast China is the last 10 days in August or the first 10-day in September. And for Northeast soybean acreage estimation is during the first 10-day in August. Because of this, the ratio of acquiring proper remotely sensed data is much lower.

---- Because of the special land-use system, rotation system and cadastral pattern in China, there exists the particular cross-planting and inter-planting phenomena everywhere. Early rice, single rice and late rice are planted crossly in south China. Spring wheat, maize and soybean are interlarded in Northeast China. Maize and cotton are also interlarded in North China. As a result, it’s very difficult to successfully identify crop patches by crop type from remotely sensed data directly. As a result, crop discrimination using remotely sensed data has maintained a very low accuracy in China. It’s very difficult to extract the crop area of every type using high spatial resolution images like Landsat TM or CBERS CCD data, even using very high spatial resolution data like IKONOS or Quickbird image at proper date. In some area, crop acreage could be estimated precisely using remotely sensed data on proper date. But this only limited to some special crop type in some special area. For example, winter wheat acreage estimation using NDVI from Landsat TM in North China could get a high accuracy above 90% in some area (Xu Xiru 1991). This is because winter wheat there has no other fusion crop types. This method could not be used in south China for low proportion of winter wheat and the fusion of seed rape. Meanwhile, the threshold of NDVI used to extract winter wheat area varies in different area and different year. At the same time, tests showed that, identification of different crop type have a very low accuracy for reason of the cross-planting and inter-planting phenomena. We have taken a test in Kaifeng area, Henan province. The accuracy of summer-harvest and fall-harvest crops is no more than 90% (Li Qiangzi, 2002). Therefore, crop acreage estimating techniques using optical data cannot meet the CCWS running request.

So, we need a new methodology integrating remote sensing and other techniques to estimate with in precise. In this paper, supported by remote sensing, we provided a stratified two-stage sampling methodology to meet the running of CCWS, integrated remote sensing and sampling techniques together. Using sampling technique in CCWS, not only solved the difficulties of full-coverage image receiving, but also provided an efficiency way to control the estimating accuracy.

In the methodology, we used a two-stage sampling procedure to estimate crop acreage supported by the 100,000-scaled China Land Resource Database (Liu Jiyuan, 1996). In the first sampling procedure, we built the cluster-sampling frame by using 1:100000 scaled map-sheet and selected remotely sensed data under cluster-sampling technique. Although it is difficult to extract crop area from remotely sensed data like Landsat TM, but it is easy to estimate crop proportion accurately (Li Qiangzi, 2004). Using the ability of estimating total area of all crops, complete estimating the total proportion of crop on the farm in every second-stratum. In the second sampling procedure, we use transect sampling to survey crop type proportion. At last, crop acreage is the product of crop proportion on the arable area and crop type proportion of every crop type on the planted area and the arable area.

For the need of sampling, we brought into the stratification. We divided China cultivated region from three different levels. After the stratification, we get 11 first-level strata 44 second-level strata and 102 third-level strata and we estimating crop proportion at the second-level strata and surveying crop type proportion at the third-level strata.

But when estimating rice acreage, we always use SAR data and optical data together. SAR could extract rice proportion directly with high accuracy (Liew S C, Kam S, Tuong T et al 1998), so there is no need of ground survey for crop type proportion, and rice acreage can be calculated using arable area multiple rice proportion directly.

3. STRATIFICATION

For crop acreage estimation, stratification is an effective way to increase the estimation accuracy and efficiency. After stratification, the planting structure, crop rotation system and crop calendar development is similar within every stratum. That will be benefit to cluster sampling for crop proportion monitoring and transect sampling for crop type proportion survey.

During the first level stratification, the main stratification tools used including atmosphere temperature, precipitation, solar eradiation, soil types and physiognomy properties and crop rotation. After clustering the stratification tools and removing small polygons, we get 11 first-level strata.

During the second level stratification, the main stratification tools are the proportions of different crop type at county level, here we considered the main 4 crop types, including rice, wheat, maize and soybean. During the procedure, we extract strata boundary from county boundary for the reason of statistics data collected on county level. At last, we get 44 second-level strata.

During the third-level stratification, the main stratification tools used mainly is the farm consistency. Firstly we extract cultivate area from 100,000 scaled China Land Resource Database and calculate cultivating consistency in every 1 KM * 1 KM grid, then, reclassified the cultivating consistency into 4 levels (> 80%, 50-80%, 15-50%, 0-15%) and used in stratification. After the procedure, we get 102 third-level strata (See figure 1).

Level	Stratification tools
First	Atmosphere temperature, precipitation, solar eradiation, soil types and physiognomy properties and crop rotation.
Second	rice, wheat, maize and soybean proportion at county level,

Table 1. Factors used in stratification

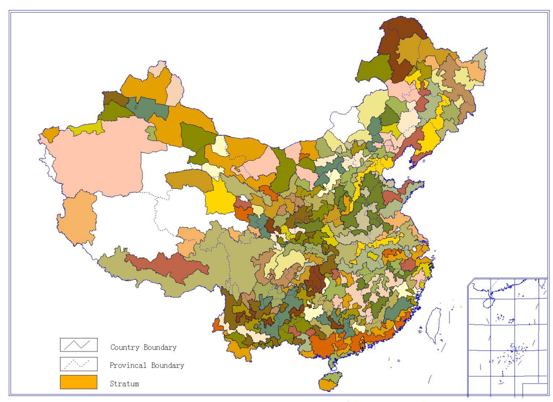

Figure 1. Stratification used for crop acreage estimation

4. CROP PROPORTION MONITORING

4.1 Cluster Sample Design

China Crop Watch System re-divided strata into clusters and selected clusters enough to meet the requirement of given accuracy at second-level strata.

Firstly, we built sampling frames on 1:100000 scaled standard topographic map sheet. A cluster is a standard 1:1000000 scaled map sheet with area from 1270 to 1950 KM2 correspond to a 1/16 Landsat TM view which area is about 1977 KM2. Because the area equality, we use the sampled cluster to select remotely sensed images to monitor crop proportion (see figure 2).

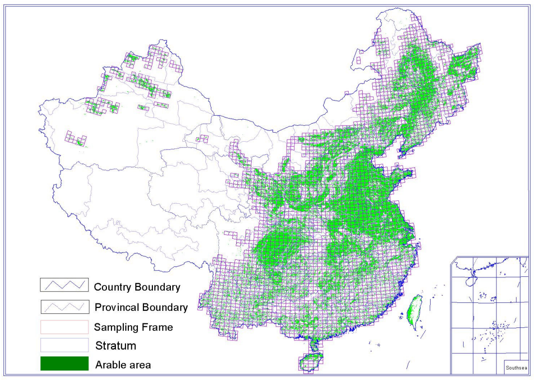

Figure 2. Sampling frame used for the estimation of the proportion of all crop

At last, we selected sample clusters randomly. And sample size is calculated using the following equation.

$$n = \frac{n_0}{1 + \frac{n_0 - 1}{N}} \quad (1)$$

$$n_0 = \frac{t_\alpha^2 p(1-p)}{d^2} \quad (2)$$

Where: n is sample size, n0 is sample size of simple random sampling, N is population, d is predefined sampling error, t and d are obtained from the assumption of normal-distribution. Here given sampling accuracy is 95%, and d = 0.05, t_a = 1.96 at 95% estimation level. At the same time, give p assurance 0.75 by pre-sampling. Then n = 264. In order to ensure the sampling accuracy, we give the calculated sample size a 5% above. And the last sample size equal 278, total sampling ratio is about 9% all over China. Here, we did not calculate sample size based on variance between clusters and within cluster because sample size of simple random sampling is larger than that of cluster sampling and could result in a more accuracy sampling.

During the sample selection, map sheets bestriding on more than one stratum is partition into the strata with larger area. When sample size of a stratum is less than 1, let the sample size to 1. At last, sample size all over china is 282.

4.2 Image processing

For crop proportion monitoring, Landsat TM or CBERS CCD images were processed under the following 7 steps:

−− Atmospheric Correction. Use meteorological observation data to remove the effects of atmosphere components, such as O3, CO2, water and aerosol et al. the algorithm used here is Modtran.

−−Geometric Correction. Use topographic maps to determine the coordinates and to correct the distortions in satellite images arise from sensor, changing altitude, height and speed of the satellite, the angle of the orbit path in relation to earth, and the rotation of the earth under the satellite. In the correction procedure, UTM system and polynomial model were applied.

−−SAVI layer Calculation. SAVI is a good derived index to reflect ground features in the imagery and will be used in the classification process later. Here, SAVI is calculated using the following equation,

SAVI = ((TM4 – TM3) / (TM4 + TM3 + 0.5) + 1) × 100 (5)

−−Image Composition. Combine SAVI layer with the 6 TM bands.

−−Non-arable Area Removal. Remove non-arable area assisted by land-use map assisted by land-use maps. This is done to reduce calculation time for the classification process, and to make sure that the calculate area relates only to the arable area.

−−Unsupervised Classification. Use an automatic clustering of ISODATA algorithm to create classes. This classification procedure can be repeatable, and can be accepted by the running of CCWS.

−−Labeling. After the classification, every cluster is identified to specify crop area or not. Here veteran personnel especially ground survey person take part in the labeling procedure.

4.3 Crop proportion calculation

CCWS estimates crop proportion using unequal cluster-sampling estimation methods. That is, Crop proportion p is estimated by equation (3)

$$p = \frac{\sum_{i=1}^{n} a_i}{\sum_{i=1}^{n} m_i} \quad (3)$$

Where: p is crop proportion, and n is cluster number, also means the number of image frames, a_i is all the crop pixels in the images and m is all the pixels in the images. And the variance of estimation is estimated by equation (4)

$$v(p) = \frac{1-f}{n\bar{m}^2} \cdot \frac{\sum_{i=1}^{n}(a_i - pm_i)^2}{n-1} \quad (4)$$

Where: $\bar{m} = \frac{1}{n}\sum_{i=1}^{n} m_i$,means average crop pixel numbers in every image□ $f = n / N$ means sampling ratio. At last, estimation accuracy is estimated by equation (5)

$$A(p) = 1 - t_\alpha \cdot \sqrt{v(p)} / p \quad (5)$$

Where: t_α is obtained from the assumption of normal-distribution.

Here, crop proportion calculation include 3 levels, firstly it is accounted on image level using equation above, and then account to strata level by weighted average, the weight here is the arable land area of every image in the stratum. At last, crop proportion on province level is accounted also by weighted average methods, the weight here is the arable land area of every stratum in the province.

4.4 Image selected and date request for crop proportion monitoring

CCWS mainly estimate acreage of 7 crops, including winter wheat, spring wheat, maize, early rice, middle rice or single rice, later rice and soybean.

CCWS mainly selected Landsat TM as image resource to monitor crop proportion. Sometimes, CBERS CCD had also been used to assistant Landsat TM. At the same time, it is difficult to get optional data in the limited time slot for meteorological reason in some regions, especially when rice acreage monitoring in summer in south China. For the running of CCWS, radar data is also used for rice acreage monitoring in low optical data acquisition area, especially in south China.

For crop proportion monitoring, data phase request mainly depend on the spatial distribution of crops, phonological calendar, crop rotation custom and growing stage. In China, crop plant phenomena had been very complex except summer-harvest crops in North China, Such as early rice, middle rice, later rice in south China, spring wheat, soybean, single rice and maize in North East China. But now this had change very much. In south China, growing stage has change to 2 growing stage for economic reason, this provide many convenience for data acquisition.

4.5 Crop proportion monitoring precise assessment

In order to assess the precise of crop proportion monitoring using remote sensing, two test-regions, Kaifeng and Taigu were selected.

In Kaifeng region, one Landsat TM image was accepted on Apr. 1 in 2001 for summer-harvested crop proportion monitoring. In Taigu region, Landsat TM image was accepted on Oct. 14 in 2003 for fall-harvested crop proportion monitoring.

At the same time, an IKONOS image was accepted in Kaifeng region on Mar. 21 in 2001. After classification, we get another crop proportion to compare to that from Landsat TM. In Taigu region, we accepted a Quickbird imagery to draw a plant patch map. By filling crop type or land-use type in every patch, we get another crop proportion by summing up the total crop area and divided with arable area extracted from the very high spatial resolution images.

After the comparisons between crop proportion from Landsat TM and from very high spatial resolution images, we can draw conclusion that Landsat TM can be sure to monitor crop proportion very well. Monitoring accuracy in Kaifeng region was up to 99% and 97% in Taigu region. And this is acceptable for the running of China Crop Watch System (Li Qiangzi, Wu Bingfang 2004).

5. CROP TYPE PROPORTION SURVEY

China has a complicated topography and results in the small patch of land in much area. This has given much difficult when carrying out agricultural survey because of the low proportion of arable land. At the same time, actual land use system in China had pricked up the difficulty of agricultural survey, because arable area are divided into small patches and every patch is owned by personnel and is used at discretion. Occasionally, a farm is dived into many thin patches and used to plant several crops severally. In order to carry out agricultural survey to estimate crop type proportion, sampling methods must solve the following problems.

---- Sampling efficiency enough to complete the survey during the limited time slot.

---- Sampling accuracy enough to complete unbiased estimate crop type proportion

CCWS selected transect sampling frame to solve the problems. Transect sampling frame is actually a two-step sampling technique. During the first sampling step, CCWS use tessellated plane sampling to build area frame and selected PSU randomly. During the second sampling step, CCWS uses transect sampling technique to select transect belt based on roads in PSU.

5.1 Transect Sampling Frame Design

For first step sampling, CCWS built its area sampling frame randomly on the third level crop proportion stratification, and the frame size set to 4 KM by 4 KM. And sample size calculation use the sample size equation of simple random sampling.

During sample calculation, crop type proportion p is important for sample size. Here we use simple random sampling equation to calculate sample size, and p is set to 0.5 to ensure enough samples. For some strata, sample size calculated is larger than 5% sampling ratio, then used 5% sampling ratio to select samples. For all China, 3579 PSUs are selected for all 102 strata with an average sampling ratio 1.82%.

For the second sampling step, we selected transect belt from road segments in every PSU by experience. Given D is the width of transect belt, sampling ratio n is,

$$n = \frac{LD}{K^2} \times 100\% \qquad (6)$$

Where: L is the transect belt length, K is the size of PSU. When sample selecting, K and D is known, then L changes with sampling ratio,

$$L = \frac{K^2}{D} n_s \qquad (7)$$

When selecting transect sampling belt, CCWS used 2% sampling ratio to carry out crop type proportion survey. Here, PSU size K = 4 km, belt width D = 0.1 km, sampling ratio n = 2%, then belt length L = 3.2 km, the total transect belt length is 11.5 thousands kilometre all China.

5.2 Ground survey and GVG survey system

Every year, ground survey is carried out based on transect sampling design results. In order to ensure completing ground survey in limited time, CCWS, divided the agricultural region into 9 sampling regions and built special sampling team for every one. At the same time, CCWS built a quality-control mechanism by regulating sampling schedule and frequency for every sampling region.

In order to improve survey efficiency, CCWS designed a patent product, GVG surveying system to equip every survey team to assist ground survey. GVG survey system is the integration of GPS receiver, Video camera and GIS analysis system (Wu Bingfang, 2000). Using video camera to snap pictures along the transect lines and locate the geo-location of every picture by GPS, then interpreting crop type proportion of every picture inside and summing up for every stratum using GIS system.

5.3 Crop type proportion calculation

After ground survey, crop type proportion is interpreted for every picture, and then accounted using equation (8).

$$P_j = \frac{\sum_{i=1}^{N} a_{ij}}{\sum_{i=1}^{N} A_i} \qquad j = 1,2,3 \ldots M \qquad (8)$$

Where: P_j is the proportion of crop j, a_{ij} is the proportion of crop j in photo i. A_i is the total proportion of all crops in photo i. N is the total number of validate photos, M is the total crop types in survey area.

Crop type proportion calculation include 3 levels, firstly it is accounted on PSU level, and then account to strata level by average. At last, crop type proportion on province level is accounted using weighted average method, the weight here is the area of every strata within the province.

5.4 Feasibility analysis of transect sampling based on road segments

The main argumentation for the feasibility of transect sampling frame is whether the road density is high enough to support the sampling required. According to the data in 2002 from China

State Statistic Bureau, road density of almost all the provincial administrative units in China is above the required level. In Shandong province, the average road density is 47%, and all cities except Dezhou have a density more than 4%, required for the 2% sampling ratio. It is a truth that the road density may be less than 2% in some area in some province, but we could get a fact by experience that the convenient road or pathway between villages can also be used as transect belt. We had taken a ground survey in Taigu region in Shanxi province. Within a 5 KM by 5 KM test area, there are about 255 KM roads that can be used as transect belt, the density is 10.2 high (Li Qiangzi, 2004).

Another argumentation we must answer is that the crop plant structure may have difference with that in other and whether transect along roads may draw a bias for crop proportion survey. This phenomenon exists in some area. We can seen that there are more vegetable areas and fruits farms along the road, but we have not carried out a farther research about this, but we mapped out a remedial schema for transect selection. That is, keeping away from highways when building transect-sampling frames and roads should clipped into segments no longer than 2 kilometres.

5.5 Crop type proportion sampling precise assessment

In order to assess the precise of crop type proportion survey, we began to set test areas from 2000. Jiangning test area in Jiangsu province and Dehui test area in Jilin province set in 2000, and Shuangyang test area also in Jilin province, Luancheng test area in Hebei province and Xinzhou test area in Hubei province set in 2002. Every test area is 5 KM * 5 KM size.

In every test area, firstly we build transect frames and select randomly the transect belt and carry out the ground survey with help of GVG survey system. After inside interpretation and statistics, we get the crop type proportion surveyed from transect sampling. At the same time, our survey team went to every field and wrote down the crop type assisted by high spatial resolution images or big scale land-use maps, after area calculation and area account, we got the exactly crop type proportion. At last, by comparing the two crop type proportion value from different ways, we assessed the precise of transect sampling technique and GVG survey system (see table 2).

Test area	2000	2001	2002		
	Rice	Rice	Rice	Maize	Winter wheat
Dehui	94.3	94.4	-	-	-
Shuangyang	-	-	95.9	92.5	-
Luancheng	-	-	-	100.0	98.9
Xinzhou	-	-	89.1		-
Jiangning	96.0	99.9	92.4		-

Table 2: Transect sampling precise validated from 2000 to 2002

We found that rice proportion survey precise changes between 89.1% and 99.9%, most survey precise are higher than 94%. Winter wheat proportion survey precise is also very high and can be 98.9%. Maize proportion survey precise is 92%. All the test results showed us that crop type proportion survey through transect sampling and GVG survey system is precise enough to meet the running request of CCWS.

Another precise test result from Taigu test area in Shanxi province told us that, Although maize and soybean proportion precise are more than 95% high for their not low proportion, but using transect sampling and GVG survey system to survey crop type proportion may survey off some very low proportion crops, and this lead to a system error. That is, crop type proportion surveyed may be a very small higher than the “true value”. This system error should be calibrated by experience and be eliminated later (Li Qiangzi, 2004).

6. CROP AREA ESTIMATION PROCEDURE USED BY CCWS

Under the total crop area estimation methodology, CCWS estimate crop area at strata level in first, then deduced to county level or city level. At last, crop areas were summed up at province level.

Because the methodology has a little difference between using optical images and using radar images, we must discuss it here respectively.

When using Radar images to monitoring rice area, the estimation is very simple, that is,

Rice area = arable area * rice proportion

Here rice proportion is also monitored using cluster sampling and radar images.

When using optical images, crop area estimation includes two steps. First, CCWS estimate crop total area by multiple arable area and crop proportion monitored using cluster sampling and remote sensing,

Crop total area = arable area * crop proportion

Then, CCWS estimate the area of every main monitoring crop type by multiple crop total area and crop type proportion estimated using transect sampling and surveyed by GVG survey system.

Crop area = Crop total area * crop type proportion

After the estimation at strata level, CCWS deduced crop area estimation to county level or city level. Here, CCWS first deduced crop proportion and crop type proportion to county level or city level, that is, all counties in the strata has the same crop proportion or crop type proportion with the strata, and the city level crop proportion and crop type proportion is the arable area weighted average of all counties in the city. Then, county level of city level estimation is based on the corresponding arable area, crop proportion and crop type proportion.

At last, province level crop area are accounted using weighted average method, here the weight is the arable area or crop area within the province. For the crop area is more feasible than arable area, if crop areas in the last can be used, we use crop area as weight. For the crop area is always not available, we have not accounted province level crop area from strata level.

7. A CASE STUDY OF EARLY RICE AREA ESTIMATION IN 2003

CCWS began estimate the early rice area in April. Ground survey teams began to execute sampling groundwork in Fujian, Jiangxi, Guangdong, Guangxi, Hainan, Yunan province during the second 10 days in April, survey teams to Zhejiang, Anhui, Hubei, Hunan, began their fieldwork in the second 10 days in May. All ground survey works finished in the first 10 day. After inside interpretation and accounting, crop type proportion data were transferred to CCWS during the second 10 days in June.

Images orders were sent out during the first 10 days in June, including 14 Landsat TM images and 2 Radarsat Scan SAR images (see Figure 3). After 10 days processing, crop proportion monitoring results accounted out nearly the same time getting of the crop type proportion data.

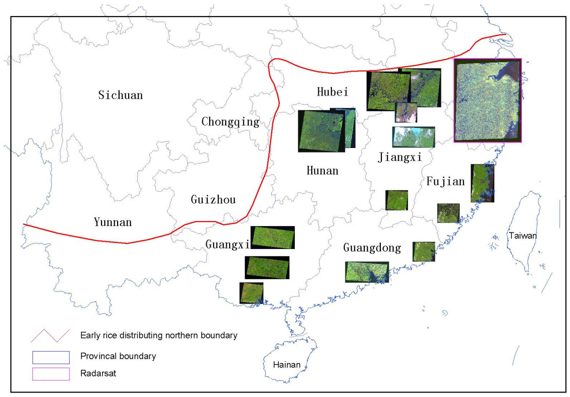

Figure 3 Images used for early rice area estimation in 2003

Rice area estimation was first on strata level and then deduced to city level. At last, rice areas of every province were summed up based on the data of every city. And the results showed that, rice area in 2003 was 5,941,000 hectares in China (See table 3).

Province	Rice Field (Hectares)	Crop Proportion	Crop type Proportion	Rice area (Hectares)
Anhui	1,679,473	0.2256	--	378,889
Fujian	1,035,038	0.7322	0.5315	402,800
Guangdong	2,103,162	0.6929	0.5691	829,339
Guangxi	2,305,494	0.7878	0.5404	981,511
Hainan	304,861	0.6394	0.5508	107,366
Hubei	1,411,893	0.6861	0.4145	401,526
Hunan	3,111,682	0.8197	0.545	1,390,102
Jiangxi	2,336,755	0.8527	0.5354	1,066,812
Yunnan	669,415	0.2487	0.1941	32,314
Zhejiang	1,958,220	0.1758	--	344,255
Subtotal	16,915,992	--	--	5,934,914
China	296,937,519	--	--	5,941,568

Table 3 Acreage estimated of early rice in 2003

8. CONCLUSION

Considered the properties of China crop planting system, CCWS suggested a special methodology to estimate crop area. After 6 years running of CCWS, we could draw such conclusions that,

Supported by the crop stratification and 1:10,0000 scaled land resource database, CCWS use cluster sampling and remote sensing to estimate crop proportion, use transect sampling and GVG survey system to estimate crop proportion, then use arable area, crop proportion and crop type proportion to calculate crop area at strata level, at last account the crop area at city level and province level. This is a feasible way to estimate crop area in China with such a complex crop planting system.

Crop proportion stratification is a valid method to increase crop area estimation accuracy. Through stratification, China planting area is divided into 102 strata, in every stratum, there has the same planting system, crop calendar and nearly the similar crop proportion. Stratification not only has reduced the sampling size of crop proportion and crop type proportion sampling, but also maintained a high accuracy of the sampling.

Monitor crop proportion using cluster sampling technique and remote sensing, this avoided the full coverage images receiving, saved a large mount of input charges, meanwhile, sampling technique provided an effective utility to maintain the monitoring accuracy. Test results showed the monitoring precise are more that 97% high.

Monitor crop type proportion using transect sampling and GVG survey system, this provided an effective sampling method to solve the ground survey works for China with such a far-flung crop area. Test results showed the monitoring precise is no less that 96% for high proportion crops.

References from Journals:

Li Qiangzi, Wu Bingfang, Crop proportion monitoring precise assessment (In Chinese), Journal of Remote Sensing, 2004

Li Qiangzi, Wu Bingfang, Crop type proportion survey precise by transect sampling assessment (In Chinese), Journal of Remote Sensing, 2004

Liew S C, Kam S, Tuong T et al. Application of Multitemporal ERS-2 Synthetic Aperture Radar in Delineating Rice Cropping Systems in the Mekong River Delta[J]. Vietnam, IEEE Transactions on Geosciences and Remote Sensing, 1998, 36(5): 1412-1240.

Wu Bing-fang. Operational Remote Sensing Methods for Agricultural Statistics [J]. (In Chinese) Acta Geographica Sinica□2000□55□1□□23~35

References from Books:

Liu Jiyuan, China Land Resource Survey and Monitoring (In Chinese), Beijing□China Science and Technology Press□1996

Multiple frame agricultural surveys, Vol. I, Published by Food and Agriculture Organization of the United Nations, 1998

Ripely,B.D.,1981,Spatial Statistics. Wiley, New York.

Sun Jiu-lin □ Pandect on dynamic monitoring and yield estimation for crop in China[M] (In Chinese), Beijing□China Science and Technology Press□1996

Winter Wheat Remote Sensing Production Estimation Cooperation Team, Winter Wheat Dynamic Monitoring Using meteorological Satellite[M]□(In Chinese) Published by Beijing Press, 1993.

Xu Xiru(ed.), Bulletin on environment monitoringand crop yield estimation with remote sensing[C], (In Chinese) Beijing: Beijing University Press,1991.

References from Other Literature:

Li Qiangzi, Wu Bingfang, Discrimination of Seed Rape and Winter Wheat using two-date ETM Data □ Proceedings of 'International Conference on Computer Graphics and Spatial Information System', China Meteorological Press, 2002