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Aerial Photo and Landsat Image Use in Forest Inventory in China

Since 1953 the forest inventory of the People's Republic of China has been completed and a Continuous Forest Inventory System has been established.

Abstract: *The utilization of forest aerial photography began in China in 1953. A great many aerial photographic and photomapping projects in forestry were completed, and this promoted technological innovation in forest survey. Examples include an altered visual determination method, photo interpretation of forest type, photo stratified sampling, double sampling, triple sampling, office interpretation and field stands actually surveyed using regression analysis, as well as composition of aerial photo digitized volumetric tables, etc. All of these methods utilize aerial photography.*

At present the forest inventory of all of China has been completed for one or more times, and the data and charts of forest inventory have been completed for more than two thousand counties. In addition, a Continuous Forest Inventory System has been established.

As for the application of Landsat MSS images, a beginning has been made. What is the potential utilization, and what problems can it solve? In a large area of forest inventory, Landsat MSS imagery, has been utilized and some tests have been conducted, although they have not been completed. It has been shown that Landsat MSS can be applied to controlling of the entire measured region to the drawing of forest distribution sketches, and to revising obsolete maps.

Aerial Photos Used in Forest Surveys

A Good Beginning of Forest Aerial Photography

Before 1949 few forest inventory and management plans were carried out in China, and the new techniques of aerial photography had not been adopted. Since that time, enormous amounts of wood and forest products have been required for national economic construction. For this, a forest survey was urgently demanded, but ground survey techniques could not meet the needs.

In 1950, the Ministry of Forestry of the People's Republic of China began flying forest aerial photography. After two years of preparation a National Forest Aerial Photography Crew was set up and provided with the necessary equipment. The crew includes three units: (1) aerial photography, (2) ground survey control and mapping, and (3) forest survey. In 1953, the members of the crew satisfactorily flew aerial photography and completed a forest inventory of an area of 300,000 hectares.

Results of Forest Aerial Photography and Photomapping

From 1953 to 1958, aerial photography at a scale of 1:25,000 was completed over the Northeast, Southwest, and Northwest forest regions in China. The regions which were photographed occupied the one-third forested areas of the nation. These useful materials were successfully applied in forest inventory and forest management. At the same time, many 1:40,000-150,000 scale photos were enlarged to a scale of 1:25,000.

Some years later, about 30 million hectares in the Large Shing-An mountain area, the Small

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Shing-An mountain area, and the Chang-Bei mountain forest area were photographed at scales of 1:25,000 or 1:14,000. Aerial photography has also been completed over other forest regions.

Forest photomapping. In the early days of the foundation of our country, to meet the urgent needs of forest development, a simple and quick mapping method was applied, such i.e., radial triangulation, using a construction diagram control net point to make controlled mosaic image maps, and using perspective nets or radial line nets as a base for visually transferring details.

Precision of photomapping. In 1956, the National Forest Aerial Photography Crew introduced a specification for forest planimetry mapping and provided the tolerances for topographic mapping. The skill of the operator was improved more and more, so that the operator not only qualified for the forest map standard, but also for the national photogrammetric specification. In 1953, the forest inventory method was changed; after that a tremendous change took place in the ground survey, i.e., only a few control points were needed and it was not necessary to survey compartment lines. The forest map was compiled using aerial photos instead of the ground survey; therefore, the field work was reduced by 50 percent and, in the higher mountain area, it was reduced by 70 to 80 percent. If the new topographic maps were available for this area and the office control survey continued, it would not be necessary to carry out the ground control survey.

Since 1953 China's forest inventory technique has entered the modern era.

At present the forest inventory has been carried out one or more times nationwide, and stock maps have been compiled at a scale of 1:25,000. Therefore, every provincial (or autonomous region) municipality in China has already developed plans for forest-type maps at various scales.

TECHNOLOGICAL DEVELOPMENT OF FOREST SURVEY PROMOTED BY AERIAL PHOTOGRAPHY

Visual determination method altered. In the fifties and early sixties, the "visual determination method" was used on the aerial photograph to outline stands and land types for the forest survey. Stand maps were then made with a simple and quick mapping method. Experience has shown that to carry out a large area forest inventory with aerial photography is the correct way. Advantages of this method are to hasten and reduce field work and to improve quality. Therefore, after 1950, because the needs of forestry quickly developed, the work of aerial photo applications also developed rapidly. Since the early sixties, aerial photography in the work of forest survey has become a primary tool. The nationwide forest survey crews strived to apply aerial photography, and recently all logging survey crews have utilized aerial photos.

Stratified sampling on aerial photos promotes technical innovation. In 1963, the forest sampling survey was tested by using a stratified sampling survey for the forest resource at an aerial photo scale of 1:25,000. Some test results have proved the sampling precision to be very good. The sample theoretical precision attained is 91.7 percent. Then, the computation precision was compared with the field survey, which showed that an actual precision of 95.6 percent was attained. Practical precision is higher than theoretical precision by about 4 percent. In addition, in checking the precision of the stratified sampling to the measurement of every stem from a total area of 17,479 ha by the 15 crews in our country, all results showed relative errors of about ±2-5 percent. For example, the check of precision of stratified sampling was carried out in the county of Hua-Ping in the province of Yun-Nan. Three populations were checked against the method of measure of every stem in an area of 5,389 ha. To compare with the precision of stratified sampling by aerial photography, the actual precisions of three populations were: I = 92.5 percent, II = 95.0 percent, and III = 99.0 percent. This precision greatly exceeded the theoretical precision. The survey crews of every province were interested in stratified sampling on aerial photos since they all requested that the forest inventory be conducted by aerial photo stratified sampling.

Photo interpretation and field survey using regression analysis. The regression analysis method of aerial photo stand interpretation and field actual stand volume are based on the photo interpretation factors determined from the photo interpreted stand volume, and then on measurements of a certain number of plots in the field. From the measured data and relevant interpreted data, a regression equation is developed to modify photo interpreted stand volume. Tests proved the precision of every block regressed volume and regressed total volume to be 90-92 percent, the already attained precision of stratified sampling. The work efficiency has improved greatly and the cost has been reduced.

Composition of aerial photo digitized volumetric table. In order to develop the technique of forest aerial photography and photo interpretation, to sum up our own experience in the application of aerial photography, and to learn from foreign advanced techniques, we worked out aerial photo digitized volumetric tables and some stereograms on a photo scale of 1:10,000 or 1:25,000. We then compared the stereogram estimated volume with the "stand digitized volumetric table." Therefore, composition of the photo digitized volumetric table made for further advances on the already very good utilization using medium and small scale photos for forest inventory.

Accordingly, we used the digitized theory and applied multifactor regression analysis to make up aerial photo digitized volumetric tables.

Test proved, according to aerial photo digitized volumetric tables, that precision for estimation volume is for the state forestry centre, 95 percent; and for the compartment, 80 percent. Through the field exercise and comparison with a stereogram, precision interpreted by the members of forest surveys is over 80 percent. But this method only determines stand volume; it cannot obtain volume for every species and every diameter-class. It cannot meet the requirements of the logging areas survey. Therefore, further research is being performed in this area.

Application of aerial photo, Landsat imagery, and sampling technical theory of mathematical statistics are the most effective methods of forest inventory in our country.

AERIAL FOREST SURVEYS

Apart from the application of aerial photos to visual air surveys and actual ground sample surveys, we used visual surveys from a light airplane at low altitude. It proved to be a highly efficient method of forest survey since a large area can be surveyed in a short time.

Procedure and methods: First, we made sketch interpretations by aerial photos as to forest type and drew the boundary of the composite stands. Then, we determined the main factor by visual methods from an airplane.

According to the forest growth or decline of the forest economy, the investigation was finished in the field in combination with the forest management classification. We may then determine forest management plans, forest utilization, and forest fire protection.

It is a good quick method for surveying borders for large areas of forest. For example, in the Large and Small Shing-An Mountains, Mudan (peony) River, Yan-Bian, Qin Mountain, Nen River, Da-Pa Mountain, as well as the province of Yan-Nan, Si-Chuan forest areas. Therefore, in 1953-1959 we accomplished a survey of about 380 thousand km.^{2} This method is not suitable for higher mountain forest areas.

In addition to inventory, aerial photography can be applied to survey and design of afforestation and desert improvement. It is also applied to road reconnaissance. Since the 1950's aerial photography and photo interpretation have played an important role in the forest survey. They have solved many difficult problems and have been widely used either in products application or research tests. Now we have established the Continuous Forest Inventory (CFI) System in our country. Our forest resources have been inventoried in more than two thousand counties of the entire country.

Application of Landsat MSS Imagery to Forest Inventory in China

The application of satellite imagery to forestry survey in China has just begun; therefore, in recent years, we have gained experience in the production and scientific experiments as follows.

In large areas such as the Tibet Autonomus region, Jiang-Xi, Liaoning province, etc, we have made and are performing some tests utilizing Landsat MSS imagery.

- Forest inventory in high mountain regions.
- Forest area movement trends of the CFI system.
- Forestry base planning for a province survey
- For the surveying and planning of the "Protective Forest System in the north, northwest, and northeast of China."

Now, we are going to simply describe some experiences as follows.

MEASUREMENT OF TOTAL AREAS AND FOREST AREAS

First, we carried out a field survey based on the laws of the horizontal and vertical distribution of type of forest; then we accurately drew the boundary of land type and forest type. Total area in every county was measured by planimeter for control on every land type areas. Areas of forest type are determined separately by dot-grid.

For the check of precision of the boundary area of forest types on the Landsat MSS image, we selected 24 watersheds, drew their boundaries on topographic maps and on Landsat MSS images at a scale of 1:100,000, and measured areas as indicated in Table 1.

According to the specifications of the technique, the errors of total and forest area can not be over 5 percent and 10 percent, respectively. The above errors do not exceed that.

COMPILATION OF 1:500,000 SCALE FOREST MAP

We classified every land and forest type on the Landsat image. The forest type is divided into (1)

Table 1. Watershed and Forest Areas, as Determined on Landsat Imagery, Aerial Photos, and Topographic Maps

Item	Landsat-MSS Image	Aerial Photo	Topographic Map	Relative Error
Watershed area	501,702 ha		502,815 ha	0.21%
Forest area	127,800 ha	134,023 ha		−4.65%

dark coniferous forest; (2) light coniferous forest; (3) broad-leaved forest; (4) coppice forest; and (5) brush.

The satellite image interpreter must have practical experience in field work and understand the laws of forest distribution. First, the class of forest type depends on the laws of forest vertical distribution, then on the information feature of response in the Landsat image.

The classification of forest type must be compared on bands 5 and 7. Band 5 responds to the forest boundary and density and band 7 shows coniferous trees in contrast to other vegetation.

The forest and land type boundary are drafted onto the Landsat image and then the drafted boundary is transferred to a manuscript scale of 1:500,000, which is the forest map.

In order to check the accuracy of Earth surface features on the Landsat image, we reduced the 1:100,000 scale topographic map in part of the region to the rivers network map at a scale of 1:500,000 and later compared it with the Landsat image at a scale of 1:500,000. The results show that every river mainly overlays itself, and that the geometric positioning of the Landsat MSS image is good.

On the Landsat MSS image are marked longitude and latitude. In comparing latitude with the topographic map, the line error is about 0.5 km less, but the line error of longitude is about 3 km.

The practical application of Landsat imagery to forest inventory practice shows that we may control the entire area, measure the regional area, and sketch the forest distribution or modify old maps by use of the Landsat image.

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2. Ordinarily *two* copies of the manuscript and two sets of illustrations should be submitted where the second set of illustrations need not be prime quality; EXCEPT that *five* copies of papers on Remote Sensing and Photointerpretation are needed, all with prime quality illustrations to facilitate the review process.
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