

AIR-SPACE METHODS APPLICATION FOR
 FOREST STUDY AND CARTOGRAPHY
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Abstract

In the USSR the forest foundation is situated in different Nature zones, it has a heterogeneous structure and degree of exploitation. That is the main reason for application of various techniques for forest study and cartography. However, the common feature of all the techniques is the use of air-space data as technical base. Besides if in the regions of intensive forestry with fragmental structure and complex species composition, the techniques are based on the traditional application of air-survey data, in the taiga regions space-survey data are widely and effectively used for one forest inventory and cartography, current disturbances account in the forest foundation and data refreshment about it.

1. General theses

At Symposium (Beenf, Canada) in 1974, Commission VII and at the XIIIth Congress of International Society for Photogrammetry in 1976 (Helsinki, Finland) in our reports 1.2 problems were considered in respect of airmethods application in the USSR forestry, and their prospects for forest study and evaluation, new types of remote sensing, especially space-survey data. In the USSR for the passed period the whole circle of researchful, production-experimental and production works, which are assigned for developing and implementing into practice of more perfect and economical methods of forest study. These works have once more confirmed, that the successful solution of the task of comprehensive forest study and forest state control as well as data supply for directing bodies and other forestry organizations, that use forest resources and operate on the forest foundation territories is possible only on the base of complex usage of both, air and space surveys. The task can't be practically solved without space data.

For the last years the list of problems, solved with the help of air and space methods and the range of applied survey documents is considerably widened. Moreover, space survey application does not exclude the traditional methods of forest study. With the use of airphotographs. Forest study methods, based on both air and space surveys, will be further developed and used for forestry practice. But their application range is defined and limited by the specific tasks and the level of their solution; regions of operations and technical potentialities of the survey documents. It can be explained by the fact, that the USSR territory

is situated in seven Nature zones: Arctic desert, tundra, forest tundra, forests, forest steppe, desert, subtropics. Forest zone, in its turn is subdivided into three parts: conifer forests (taiga), mixed forests (conifer and broadleaved) and broadleaved forests. Along with great varieties of Nature condi-

tions the country is characterized by different degree of territory exploitation, including the forest foundation.

Forest vegetation and its structure are formed under the influence of Nature-economical conditions of every region of the country. They are characterized by great variety of species composition afforestation degree, quality and quantity characteristics of forests. The differences in the forest foundation structure, its fragmentation, knowledge of its forestry activity level determine the necessity of differential approach application for forest study methods of various regions, as well as for choice of remote sensing data and determination of their place for applied technologies. At present all the methods and technologies, applied for forest study and mapping, are based on the air-space data, which are in all cases used for basic map compilation and field and laboratory photointerpretation with the purpose of space distribution of quality and quantity characteristics of landuse categories, included into forest foundation, and its forest stands, growing on every separate evaluation plot. However, depending on the structure and the degree of forestry exploitation, application of various methods of forest study turned out to be possible. They are based on air-space data with such observance and detail, which correspond to the forest foundation structure and economical conditions of every partialar region.

2. Forest Study for Forest Management

Taking into account different structure and the degree of forest foundation exploitation forestry and forest industry intensity the differential approach to forest study and mapping methods is adopted. Two zones are pointed out: a) a zone of forest management; b) a zone of photostatistical forest inventory.

The zone of forest management includes upto 60% of the forest foundation territory. That is practically all the forests of the European part of the country, Caucasus, oasis, riparian and mountain forests of Central Asia and considerably large territories of Siberia and Far East, exploited or projected for forestry and forest industry exploitation.

The principle part of them (about 90%) has been managed with territory organization in nature (thinning of boderlines and quarter cuttings) and total valuation of every compartment.

Valuation operations in management zone at present and up till 2000 year are oriented for application of highly informative aerial photographs, providing registration of compartments (0.1 - 1 hectar area) and obtaining of main valuation characteristics of stands in every compartment with high accuracy in the field in complex with field and laboratory photo interpretation. As the experience shows, color multi-spectral data (1:10000 - 1:20000 scale) meet the requirement in the best way. Aerial photographs of larger scales (1:10000) are applied in zones of intensive forestry where forest foundation has fragmental structure. The specific weight of field and laboratory interpretation in forests with different species composition, structure, intensive forestry differs greatly. In ordinary taiga forests, having relatively low intensity of forestry, the specific weight of laboratory interpretation increases. In mixed broad-leaved and subtropic forests only preliminary delineation of compartments on air-photos is performed in laboratory, but their evaluation characteristics

are defined partly in nature survey of every compartment in complex with field photo interpretation.

The operating techniques in forest valuation and interpretation for forest management are considered in detail in our report in Symposium proceedings, Commission VII of International photographic society in 1974 I, and in subsequent papers 3,4,5.

In managed forests every 10-12 years repeated forest management operations are performed with the purpose to renew plan-cartographic, inventory and projected documents. Since every particular compartment requires precise renewed valuation indications, characterizing forest stands, soil-typological and topographic conditions, the repeated total valuation for every compartment is adopted in practice. It is performed in complex with field and laboratory interpretation of color multi-spectral air-photographs, using the same technology, like for primary forest management.

However, space survey data obtained from "Kosmos" series, allow in a great deal to rationalize the technology of data renewal when repeated forest management is carried out in taiga zone with dominant mature or overmature stands in cases, when disturbances in forest foundation of the managed object or its part as a result of economical activity and elemental factors effects are relatively small.

In this case during the space photos interpretation process with the use of forest plantation plans, working maps, valuation surveys and other documents, understory of the 1st age class, unclosed forest cultures, sparse stands, burns, cuts (on last inventory year) are located on photographs. Then cuts, burns, winter falls and other categories of areas are interpreted, which have appeared during the revision period as a result of forestry activity and natural calamities. Forest cultures of revision period, areas after clean cutting and sanitation cutting. Final borderlines and valuation characteristics of compartments of the enumerated categories are established in nature valuation.

Valuation characteristics of the rest compartments are established on the base of the previous inventory. The valuation characteristics of overmature stands are not changed, but for understory (II age class), average age, ripening and mature stands corrections are made which are defined on patterns, made on the base of mass data of previous inventory.

To reveal the disturbances which were not accounted by forestry enterprise and occasional errors in valuation characteristics, which can occur in forestry data, the stereoscopic analysis of all the compartments on all the rest forest foundation area is carried out every quarter of the year. During interpretation land-use category is defined and for forested area the dominant species or group of species as well as age group, type, ecological group and relative density are also defined. Then the correspondence of compartment characteristics defined during the previous inventory and interpretation is evaluated. All the doubtful compartments are marked before the nature observance.

After enumerated operations are executed the project of nature evaluation operations is designed. The subjects of nature valuation are:

- a) understory of the 1st age class, unclosed artificial stands non-forested areas, accounted by the previous inventory;
- b) all the plots, in which economical activity was performed during the revision period as well as exposed to calamities (fires, windfalls, etc.);

c) compartments, the interpretation results of which were doubtful;

d) no less than 10% of compartments which were corrected on the subject of valuation indications. All the enumerated compartment categories are delineated on the space photographs, which are further for nature evaluation are used as contours.

Additionally plotless sampling for defining of accuracy correction of valuation indication is performed. Accuracy evaluation is performed on 4 strata: coniferous ripening, deciduous ripening; coniferous mean aged, deciduous mean aged stands. The accuracy of average timber volume for 1 hectare for strata is $\pm 10\%$ with the tolerance of 0.68.

3. Forest Study in Forest Inventory Zone

Forest inventory zone includes all the rest forest foundation territory. There are taiga and near tundra forests of northern and West-northern regions of the country as well as timber-shrub vegetation of the Central Asia deserts. Forest foundation, included into forest inventory zone is not to be included into active forestry or forest logging activity, and its main aim till 2000 year is execution of environment-protective function; timber volume reservation for providing the perspective economical organizations, which are to be created in the given regions as well as game-preserves, reindeer farms and grazing. The forest foundation is characterized by dominating of mature and overmature stands, relatively simple and homogeneous on composition and structure.

The photostatistical method has been developed and passed through the wide production approbation [3,4,5] for taiga and tundra forests inventory in northern and east-northern regions of the country. The method is based on the total manual and man/machine interpretation of color spectrozonal and multispectral highly informative space photographs (or ultra-small-scale airphotographs) with 20 m and better resolution and interpretation of photosampling from air-photographs with 0.5-1 m resolution. The method is based on the landscape typological base. In the limits of every landscape the inventory is performed on the base of four-staged sampling:

- Territory stratification on the base of contour and valuation interpretation of space photographs with the determination of land-use categories for every contour (compartment) of land-use category, the dominant species, forest type group, density group, age group. On the base of stratification, starting from volume dispersion in strata and the given accuracy for volume defining on the whole for the object (2-5% for the assumption level 0.95), a sample air-survey (1:10000) is planned.

- Photo samples are distributed systematically along the landscape territory and their air-survey is performed by strip total or discrete courses by triplets with 18x18 cm frame. Photo sample interpretation is performed by analytical-measuring methods with the purpose to define the whole complex of valuation indications on strata. Photosample size is 1 hectare. If it falls into two valuation compartments, every part of it is interpreted and accounted proportionally to the area. Sample air-survey covers upto 5%

of inventoried territory.

Because of generalization stands of various species composition and age are included in strata. Due to the great variety of these indications, photo samples do not provide sufficient accuracy of their determination. So to obtain area distribution in the limits of strata on dominant species and age classes, analytical interpretation is executed on the whole area of selective course air-survey.

- Nature enumeration valuation of the part of selective photo samples and compartments is made with the purpose of accuracy evaluation of interpretation and defining of the systematic error value.

The study of interpretation indications, interconnections between valuation and interpretation indications, morphological landscape structure, compiling of interpretation tables on the landscape base precede space and air-photographs interpretation with the use of photometric and textural indications and training of operators. Reliability of dominant species interpretation age groups, density groups, forest type groups is 75-85%. Mean-square errors in volume determination for valuation compartments are $\pm 25-30\%$ (assumption 0.68) when the mean size of the compartment is 200 hectares; systematical errors in volume determination for various age groups range from 2-5%.

As a result of operations, executed during photostatistical inventory, forest plantation plans (1:100000) are made as well as valuation surveys, forestry enterprises maps (1:200000-1:500000) per quarter results register of areas and volumes, forest foundation inventory. The commodity structure of stands and possible size of forest exploitation is defined and measures are developed for forest protection.

For scrub vegetation inventory of the Central Asia deserts black-and-white space photographs are used in complex with the selective largescale black-and-white air-survey (1:1500-1:2000). Vegetation on these territories is represented by saxaul formations (1.5-5.5 m height) and shrubs psammophytes in complex with herbaceous vegetation.

Space survey data are used for determination of planned forestry enterprises boderlines and other economical units strata contour interpretation and designing of the project of selective large-scale air-survey.

The approximate scheme of photo sample distribution is 5x2 km. On the base of large scale air photographs species composition average height and diameter density of stocking, number of trees and timber volume per 1 hectare. Mean-square errors of their determination are in the range from 7-15%. Interpretation data of photo sample also allow to divide geomorphological strata into homogeneous plots in accord with the certain valuation indications.

4. Small-scale Thematic Mapping

On the base of forestry and photostatistical inventory data the series of thematic forest maps with different scales by way of generalization of a cartographic and forest inventory data. But the more is the difference between scales of available cartographic documents and compiled thematic small-scale maps, the more complex generalization process forest management or forest inventory is. Besides forest management and forest inventory documents are not often correlated in time, and reliable data about

forest foundation are absent for the part of it. In accord with the fact, the technique of small-scale thematic forest maps on the base of space photographs interpretation [3,4] is developed and approved.

When mapping forests, the three-stage method of data obtaining is recommended. The first, primary stage is a space one: compiling of topographic map base, total interpretation of the territory with the purpose to determine the generalized borderlines of cartographic objects and principle load, implied by the map legend. The second stage is aerial - for air sampling with the purpose to specify the interpretation results and to obtain missing data. The third stage is ground - for studying laws in the forest foundation structure and interpretation particularities of space photographs as well as mapping accuracy control. For adequate thematic forest cartography, space photographs would meet the following requirements: a) they must be multi-spectral or spectrozonal, obtained, if possible, during the season, characterizing the most by the greatest contrasts of the elements mapped; b) the resolution must be no worse than for maps with the scales 1:2.500.000
1-1.000.000 1:200.000 To compile topographic map base, landscape regioning, simplified object classification of the territory mapped. And providing the volume of air-visual and ground operations is increased, it is possible to apply less detailed space photographs.

Since for compiling thematic forest maps with principle scales (1:200.000 - 1:1.000.000), space photographs with close quality characteristics are necessary, their legends can be identical and only the generalization degree of mapping situation will be changed from scale to scale.

5. Current Disturbances Account in the Forest Foundation

Considerable changes in forest foundation occur due to cuts, territory exploitation, nature factors impact. Operative account of these changes and their estimation from ecological and economical point of view, especially in sparsely populated regions and taiga regions with difficult access was rather troublesome with the help of conventional ground methods. So at present methods of detection and account of current disturbances in forest foundation in regions with great number of forests on the base of space-survey data is widely used.

Space surveys with the aim to detect type, size and character of disturbances depend on knowledge data of the territory studied and are performed on one of three variants:

- a) on the base of joint analysis of space photographs and knowledge data about the territory studied;
- b) during joint processing of multi-date space photographs for the same forest foundation territory, obtained beforehand and after disturbances in the forest foundation;
- c) on the base of combined interpretation of space photographs with plots images, converted by economical activity and calamities with further air-valuation of these areas.

The second and the third variants are applied in regions, where territory knowledge data are absent or older.

During the survey process cutting areas, mines, oil and gas industries, highways, electrotransmission lines, oil and gas-mains, hydrotechnical constructions, construction grounds, windfall areas and forests suffered from great forest fires are detected. For every detected plot the type of influence is determined as well as

borderlines, character and change size. Space distribution and forest areas contours, in which disturbances have occurred are graphically shown by conventional marks on cartographic data. In reports made on the base of survey results, corrections of forest inventory and statistical data are made; allowable final cut is specified; change character is estimated from the economical and ecological point of view; recommendations are made on forest protection.

In cases when the detailed information of forest foundation disturbances is needed as well as economical activity consequences on the particular areas, additionally to the space survey, selective large-scale air-survey is performed.

Space photographs data application for forest inventories, their cartography, change accounts in the forest foundation, the data refreshments of its knowledge provide considerable ecological and economical effect at the expense of operativeness increase in data obtaining and lowering of labour expenses upto 2-4 times.

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