Satellite and Computer Aid Forest Resources Survey

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Remote sensing data by satellite are extremely useful for monitoring present situation or pattern of changes of forests, and effects of forest works, and for compiling numerical data to evaluate various functions of forests. This advantage can develop more efficient forest survey methods, when combined with the use of computer.

Characteristics of remote sensing by satellite

Many progresses in survey techniques brought about by remote sensing by satellite are attributed to two innovative technological advancements: the use of space platform instead of aircraft, and opt-electro-spectoral senser in place of optical camera. These basic mechanical changes have caused the striking progress in the survey of earth surface. The characteristics of the progress are as follows:

1) Simultaneous coverage for wide area with repetition: This characteristic has made it possible to develop remote sensing to a practically effective survey technique.

2) Mechanical interpretation of data and collection of numerical data: Skill needed for visual interpretation of imagery, and time and labor required for processings are dramatically reduced. In addition, it was made possible to provide numerical data.

3) Expression of processed data by clear imagery: Results of data interpretation and sequential steps of processing can be expressed by easily understandable figures, and rapidly made up into maps, etc.

4) Construction of frame-work to compile earth surface data: By constructing a frame-work by which various information such as on natural conditions and artificial conditions can be accumulated on the earth surface conditions, production of information-analysis document is made possible.

5) Possibility to explore unknown techniques: The remote sensing by satellite, still in the course of development, has a possibility to bring about presently unknown indicators to discriminating technique by utilizing wavelength range beyond the human perception and by employing operational capacity of computer system.

Effectiveness of the remote sensing can be expected by utilizing these five items of charteristics listed above[2,5]

Procedure of processing satellite data by computer

Satellite data which we use most effectively at present are the data obtained by LANDSAT. Imagery on earth covers synthesized from these data give a remarkable effectiveness in producing land utilization maps, vegetation maps, land condition maps or photographic figures in developing countries, where information of land have not yet fully made clear. In developed countries too, these data are utilized for correcting or revising the existing maps[1,2]. Application of these data for knowing what is land surface is, so to say, to increase efficiency of existing methods.

On the other hand, the above mentioned five items of characteristics of remote sensing by satellite can not be utilized as the procedure for overcoming obstacles and barriers of the existing survey methods unless they are processed by the aid of computer.

At present, the use of CCT (computer comparative tape) of satellite data is progressing rapidly, but it is not yet well understood and standardized so as terminal users can handle it easily. Procedures of necessary processing and their contents are summarized as follows:

Step 1: Input data handling

CCT data format transformation for each user's computer system. Then, input data handling is done for whole or partial area data operation by one observation scenery record. Also, inputs of reference data such as map, air-photo and other numerical data are made, if possible.

Step 2: Pre-processing

Geometric correction, electric correction, GCP (Ground control point) subtraction, data normalization, projection transformation, etc. are made. At this process, normalized recognition of data, and overlaying of data obtained at different survey dates or of different kinds of data are made possible.

Step 3: Spacial (graphical) processing

Extractions (emphasized expression) of edge, texture and pattern, formation of mesh data, extraction of division area by masking, incorporation of polygon data, etc.

Step 4: Spectro-processing

In the process of making distinction by the recognition of spectral vector of data, there are two different methods: supervised method in which prescribed criteria for distinction are given by training data, and non-supervised method in which the distinction is made by the resolvability of data. The former requires computing system with particulary high efficiency of operation. The latter is used in developing countries or for seas where existing data are lacking or confirmation on the spot is difficult. In this case, density slice method similar to photographic processing and operations such as addition and subtraction, ratio computation, cluster classification, etc. are employed.

Data recognition can be made effectively when this spectral distinction is combined with human visual ability for graphical distinction by the use of an interactive display.

Step 5: Utility processing

Depending on the purpose of utilization, such as overlaying of survey data obtained at various times and at different altitudes, tracing of forest changes by analysis of various related data, analysis of processed information, compilation of data for data bank, etc., various methods of calculation, such as multi-variable analysis or simulation, are employed. Connection to universal computer is often needed.

Step 6: Output

Depending upon the purposes, processed results are output to hard copy, MT, printer, etc.

Works which require human labor in the course of these processings are selection and incorporation of GCP and training data, except selection of survey areas and machine handling. Trial and error of processings to induce desirable results of distinction is important.

If the necessary processings are made in a centralized organization and the processed data are supplied to researchers, in stead of the processing by individual researchers, the terminal facilities will be very much simplified and number of users will be increased.

The summarized flow of data processing and functional facilities order of each stage, including required soft wares are shown in Table 1.

Practical utilization and future problems

Based on the experiences so far obtained, the present LANDSAT's data can be practically utilized as follows:

1) Information on present situation of forests

Analysis of overlaid multi-seasons data, in particular, increases markedly the accuracy of recognition of forest types and vegetation communities. Expression of forest types by usual 10–15 items can be made quickly with 80–100% of accuracy. Its numerical data at 50-m mesh unit can also be obtained[1].

Table 1. Summarized flow of data processing and functional order of processing procedure with required soft wares

	Facility function order		
	1st order facility		
	2nd order facility		
	3rd order facility		
Step 1. Input Standard data format transformation →	Low cost graphic display Partial scenery data input	Standard data processing system (256 kw.) Whole or partial scenery data input	Optional standard processing system (4 mega w.) Multi-data input
Step 2. Pre-processing Geometric & electronic correction G.C.P. subtraction Normalization Projection transformation etc. →		Afin transfer Biband processing Normalization Partial smoothing	Projection & coordinate transfer Radiometric intensity correction Projection character subtruction Histogram correlation
Step 3. Graphical processing Edge extraction Texture extraction Pattern extraction Mesh formation Registration etc. →	Contrast transfer Scale transfer	Edge extraction Nearest neigbour computation Space differential computation	Registration Texture subtruction Pattern subtruction Mesh formation
Step 4. Spectro processing Training data input and correction Multi-data overlay Supervised, non-supervised classification Change pattern subtruction etc. →		Maximum likelihood computation Multi-density slice method	Tree-identification method Table look up method Clustering method
Step 5. Utility processing Data analysis Versified information →		Multi-equation computation	Statistic calculation
Step 6. Out put →	Serial printer MT.	Line printer MT.	Protter Film recorder Color paper MT.

2) Monitoring information of forest changes

As to logging, clear cutting on 3 ha or more and on 1–3 ha can be recognized with 100% and about 80% exactness, respectively (Plate 1). Growth of forest at planted areas can be graded into 3–5 levels by comparing 3–5 years data. Land slip of 1 ha or more can clearly be detected, and its expansion or recovery can be monitored. As to diseases and insect pests, the damage by pine-nematoda was recognized exactly by overlaid yearly data.[4].

In an experiment to estimate standing volume, it was found by comparing the satellite

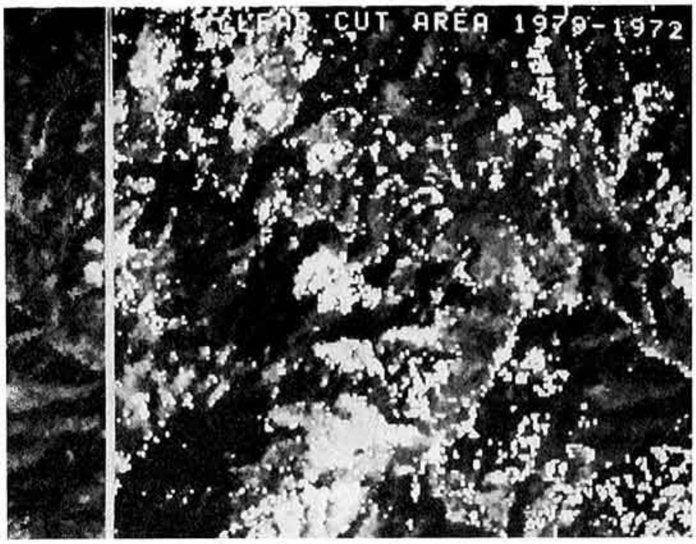

Plate 1. Extraction of areas where logging was made during a 7-year period from 1972 to 1979 in southern part of Mt. Kiso-ontake
(one dot: 50×50 m)

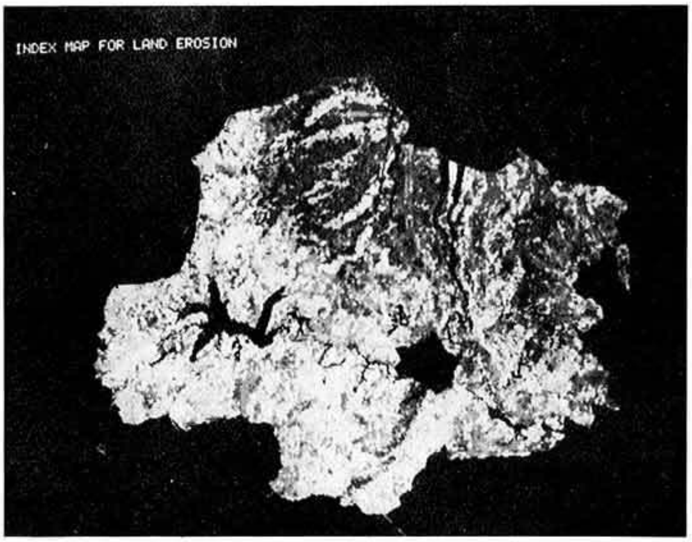

Plate 2. Map showing danger of land slip
White portion → Black portion
highly dangerous less dangerous

Table 2. Farm land and forestry observation items and examples of processed information

	Item	Type	Survey frequency/year	Processed information
Management, land use environment	Main species & mixture of species	20	2	Resources classification
	Tree height class & density class	10	1	Productivity evaluation
	Tree crown diameter construction	10	1	Forest faculty evaluation
	Stand density & coverage	5	1	Resources balance sheet
	Tree growth & mortality	5	1	Insect, disease forecast
	Vegetation & plant community	10	2	Grazing capacity
	Vegetation vitality	5	4	Wild life potential
	Glass leaves quantity	5	4	Exploitation potential
	Farm field type	5	4	Latent residential area
	Fallow & waste land	5	1	Environmental negative list
	Orchard	5	1	Naturality
	Disease & insect damage	5	4	Nature conservation evaluation
Land environmental conservation				Latent waste area
	Land slide. Erosion	5	Timely	Climatic disaster zoning
	Snow avalanche & flood	3	〃	Flooding area zoning
	Fire. Eruption	3	〃	Snow avalanche zone
	Construction distribution	5	1	Tidal wave critical zone
	Land reclamation	5	4	Disaster safety zoning
	Road and other engineering works	5	4	Forest fire. Eruption forecast
	Bare soil type	10	1	Exploitation impact
	Solar intensity & cloud quantity	5	8	Revival potential
	Heat stock & discharge	5	8	Scenery conservation & change forecast
				Residential amenity
Water resources hydro environment	Water quality. Muddy water discharge	5	8	
	Surface water distribution	5	8	Water resources capacity
	Water stock & discharge	5	8	Heat balance
	Snow coverage & quantity	5	8	Ground stability
	Snow flood	3	8	Basin population capacity
	Air contents. Aerozol	5	8	Basin exploitation capacity
	Soil moisture	5	8	Social life use capacity
	Surface temperature	10	8	
	Underground water	3	4	

data with the results of aerial photograph and sampling survey on the spot that the standing volume was graded into three classes with the accuracy of 88.6%.

These examples indicate the high effectiveness of the remote sensing by satellite as the method of forest survey aiming at practical forest works.

Soft wares to evaluate water-holding capacity by regions or river basins, or to predict quantity of soil erosion, etc. are now being developed (Plate 2).

Observation items by the remote sensing and anticipated examples of processed information required for management of farmlands and forest lands are shown in Table 2.

Main future problems are information analysis based on accumulated data to induce these processed information, and set-up of complemental system such as the use of aircraft to improve accuracy and efficiency of satellite data processing. Flow chart of resources survey for undeveloped natural forests, presently adopted in South America, is shown in Fig. 1[1].

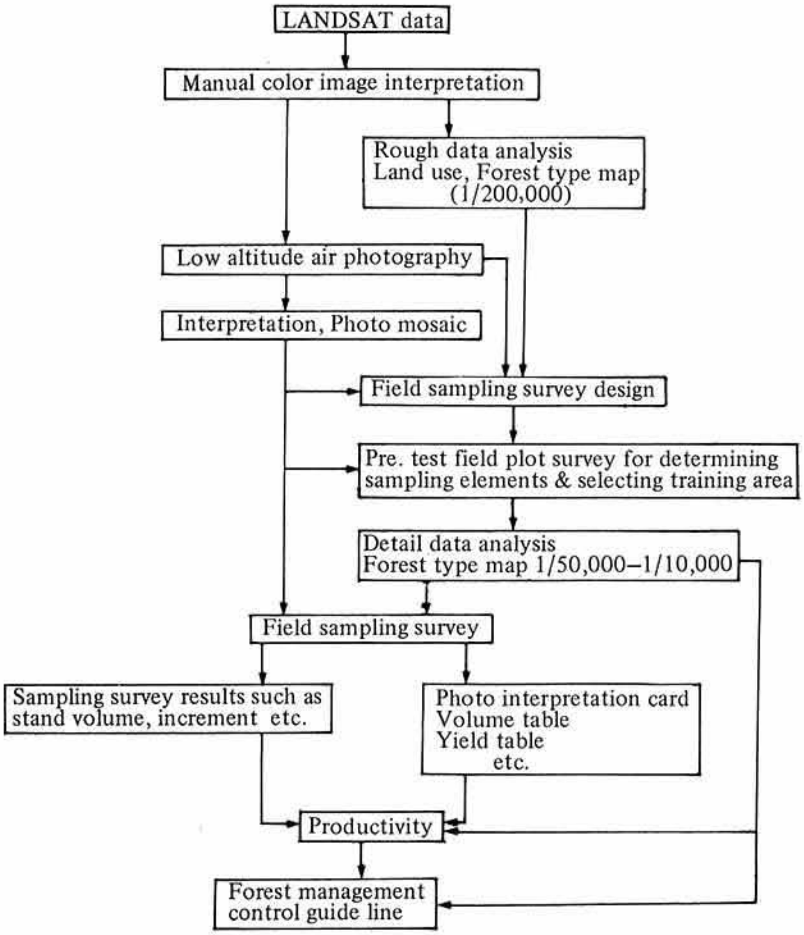

Fig. 1. Forest resources survey diagram

Conclusion and technological prospects

Information obtained by remote sensing by satellite serve to develop national and regional data banks which may contribute to set-up a global resources information system. In the countries, these information can be utilized to systematize the modernization of forest production.

At present, the development of remote sensing is in the second generation. Technical defects so far identified will certainly be overcome step by step, and in 1990s a new series of LANDSAT and practical earth sensing satellites of Japan and European countries will be launched.

A modernized forest survey method using satellite and computer, and a system to accumulate and utilize forest information to be obtained by it has to be established as soon as possible.

References

1) Japan Forestry Technical Association: Report of forest evaluation and environmental monitoring techniques by remote sensing. Tokyo 1–121 (1979) [In Japanese].
2) Nakajima, I.: Sensing by satellite for forest surveys. *JARQ*, 12, 168–172 (1978).
3) Nakajima, I.: Remote sensing—Basic knowledge for forestry application. J.F.T.A. 1–108 (1979) [In Japanese].
4) Nakajima, I.: Application of the remote sensing by satellite for forestry. United Nation Seminar on remote sensing application to land use planning, Tokyo, L-11-1—L-11-16 (1980).
5) Nakajima, I. & Ohnuki, I.: Computer-aided remote sensing application for forest planning. XVII IUFRO World Congress, Div. 605. Kyoto, Japan 195–210 (1981).

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