

PRE-INVESTMENT SURVEY FOR NATURAL RESOURCES DEVELOPMENT IN NORTHERN PAKISTAN

by

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Summary. *With increase in population, pressure on land for cultivation, grazing and timber supplies is also increasing in the north-western hilly part of Pakistan like everywhere else. But these mountainlands also constitute a major portion of the watersheds of Indus river and are thus vitally important as the primary source of the country's water for agriculture, domestic and industrial uses as well as for power. The quantity, quality and seasonal distribution of the water-flow from these areas is, therefore, of paramount importance for the national economy.*

With a view to conserving and developing these watersheds, a project known as the "Pre-investment Survey Project for Natural Resources Development" was launched in 1965 to collect inventory data on topography, vegetation, soils, hydrology and climate and to interpret these data for the drawing up of land use plans relative to the needs of sound management of these watersheds and for the preparation of management plans for proper working of the forests situated therein.

The project covers one of the most difficult and inaccessible areas of the world. Altitudes vary from about 500 meters to well over 7000 meters above mean sea level. Communication is poor and the area remains covered either with snow or with clouds for most part of the year. Thus, there is a lot of difficulty in flowing aerial photography because of the short and not-too-certain spells of appropriate weather conditions as well as the non-availability of necessary equipment and material.

Despite these difficulties, good progress has been achieved on the project in the flowing of aerial photography, preparation of maps and drawing up of integrated land resources reports. In some cases, even the follow-up operational projects have been put to implementation.

The procedure is that aerial photography is carried out on two scales. The small 1:50,000 scale is used for mapping and the larger 1:20,000 scale is used for photo interpretation and for photo measurements. Some of the photo plots are visited in the field for verification and establishment of correlation as well as for recording of additional information. The data collected through photo interpretation, photo measurements and ground measurements are analysed for the preparation of integrated land use plans.

The results of land use surveys in so far as these indicate forest areas in some of the watersheds have been checked with the observations recorded from the LANDSAT images.

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It has been found that the two compare favourably well. With more training, equipment, and material, it is hoped to compare the results already achieved on the project and to apply the use of LANDSAT images in solving the basic problem of mapping and of carrying out forest inventory in the in-accessible part of the country.

Introduction. The northern mountain areas of Pakistan constitute a major portion of the catchment area of the Indus river, and are thus vitally important as the primary source of the country's water for agriculture, domestic and industrial uses, as well as for power. The quantity, quality and seasonal distribution of water-flow from these areas is, therefore, of paramount importance for the national economy. Consequently, the watersheds need to be rehabilitated wherever necessary and managed properly to minimize soil erosion and siltation, and to maintain optimum water yields.

The country is deficient in forest resource. Out of its total area of 79.6 million hectares, about 6.9 million hectares or 8.7% are classified as forestlands. But, the actual area under forests is 2.85 million hectares, i.e., 3.6% of the total land area and the productive forests are only about 1.7 million hectares or about 2% of the total area of the country. This forest resource currently is and for the foreseeable future will continue to be the country's primary source of timber for all purposes. At present, the total annual demand of timber in the country is estimated at 1.46 million cubic meters; the gap is met with through imports. This calls for increasing the productivity of the country's natural forests which are situated mostly in these northern hilly areas to help meet the growing demand for timber and other forest products.

These northern hilly areas are heavily populated and there is a great pressure on the land for cultivation by the local people. The cultivation is sometimes practised on steep slopes and extends even above 3000 meters altitude. Also, the area is being over grazed by the local cattle as well as the migratory herds.

Thus, the population depends entirely on the use of the local land resources yielding forest products and food grains, vegetables, fruits and nuts as well as livestock and livestock products. The resources husbandry practices are generally primitive and invariably harmful for sustained production at optimum level. Moreover, per capita income are among the lowest in the country and needs to be increased through programmes aimed at more effective utilization of the natural resources of the region.

Recognising the importance of conserving and developing these watersheds, a project known as the "Pre-investment survey project for natural resources development" was started in 1965 to collect inventory data on topography, vegetation, soils, hydrology and climate and to interpret these data for the drawing up of land use plans relative to the needs of sound management of these watersheds. Also, it is intended to collect data on forest areas, forest species, forest quality and forest measurements, and to analyse these data for the preparation of sound management plans for the working of those forests. Specific objectives of the project are:

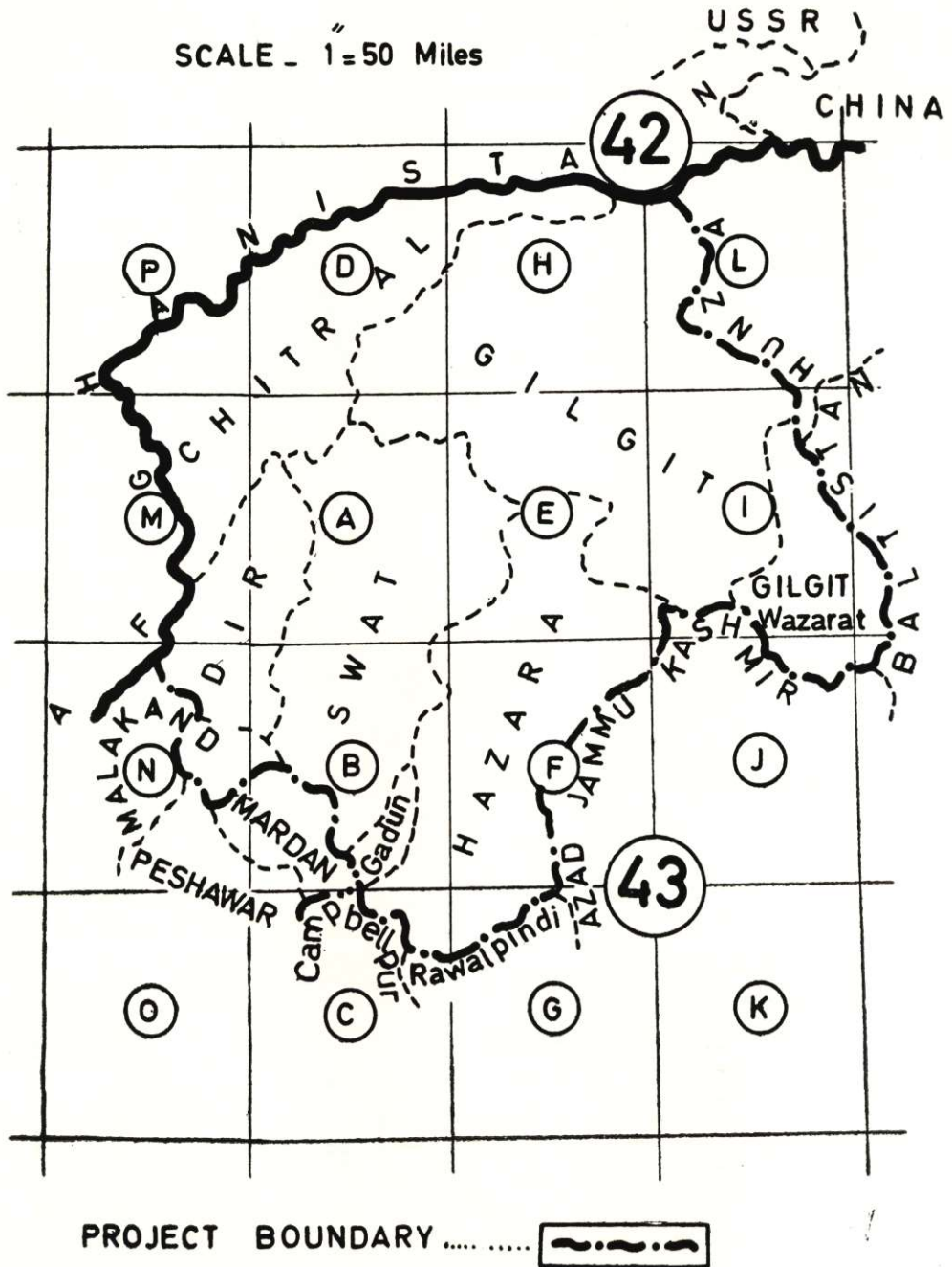


Figure 1. SKETCH MAP OF PROJECT AREA

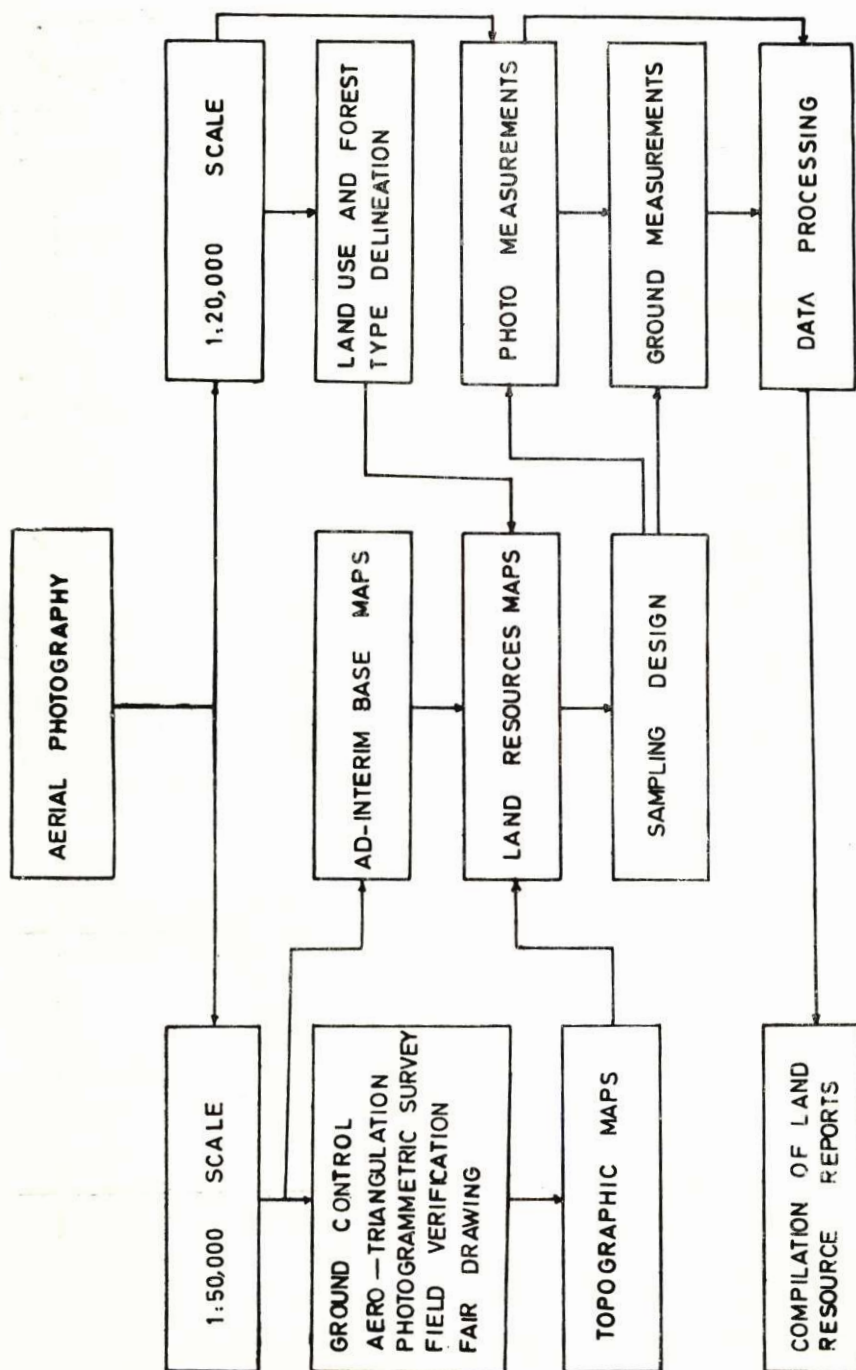


Fig.2. FLOW CHART SHOWING VARIOUS PHASES OF INTEGRATED RESOURCES SURVEY

- (i) Carry out aerial photography on 1:50,000 and 1:20,000 nominal scales;
- (ii) Prepare topographic maps on 1:50,000 scale,
- (iii) Prepare land resources maps;
- (iv) Prepare more accurate volume tables for the coniferous species;
- (v) Collect inventory data on forests;
- (vi) Conduct feasibility studies for the development of land resources; and,
- (vii) Help draw up operational projects for land resources development in the watersheds.

The project covers an area of about 65,000 square kilometers with wooded area estimated at 12,500 square kilometers. The area falls between 34° and 37° north latitudes and 71° and $75^{\circ} 15'$ east longitudes. A sketch map of the area is given in Figure 1.

The area is extremely difficult and inaccessible. It is characteristically rugged and rocky with deep gorges flanked by very steep ridges which present large variation in altitude ranging from about 500 meters to well over 7000 meters above mean sea level. Communication is extremely poor and the area remains covered either with snow or with clouds for most part of the year. Such difficult country, obviously, does not permit easy movements in the field. Thus, ground surveys are too costly and time consuming. Also, there is a lot of difficulty in flowing aerial photography because of the short and not too-certain spells of appropriate weather conditions and because of the limited availability of appropriate material and equipment.

Methodology of Survey. Aerial photography is flown on two scales—the small 1:50,000 scale photography is used for mapping purposes and the larger 1:20,000 scale photography is used for interpretation and forest mensuration purposes. The photo-interpretation details are transferred to maps and further investigation is carried out through sampling. First, the necessary measurements are recorded on the photo plots and then some of these photo plots are visited in the field for verification, for establishing correlation, and for recording additional information. The data collected from photo interpretation, photo plots, and ground plots as well as from all other available sources are analysed in the drawing up of integrated land use plans which are subsequently interpreted into operational projects for the development of land resources in various watersheds.

A manual of instructions (4) has been compiled on the lines of those prepared for forest inventory of Nepal (5) and survey of forest areas in Greece (6) and on the basis of experience gained in the field highlighting the local requirements of land use surveys and forest inventories. These instructions are summarized in the succeeding paragraphs; and, the various operations are illustrated in Figure 2.

Aerial Photography—Aerial photography has been planned at the following specifications.

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|--------------|--|
| (i) Material | Panchromatic black-and-white (infra-red and coloured photography is also available for training purposes). |
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|-------------------|--|
| (ii) Lens | Focal length of 6 inches (152.5 mm) ¹ for small scale and 12 inches (305 mm) for large scale photography. |
| (iii) Datum plane | Mapping: Average elevation on of the area under survey.

Photo-interpretation: 5,000 ¹ and 7,000 ¹ above mean sea level for chir forests and high hill forests respectively. |
| (iv) Scale | Small (minimum 1:50,000) for mapping, and large (minimum 1:20,000) for forestry and land use interpretation. |
| (v) Tilt | Less than 5 degrees. |
| (vi) Sidelap | 6-30 to 40 per cent. |
| (vii) Endlap | 60 to 80 per cent. |
| (viii) Season | May-June or September-October depending upon the availability of clear days. |

Preparation of Maps—After aerial photography on 1:50,000 scale is carried out, a net-work of ground control is established and topographic maps are prepared on the same scale. The preparation of topographic maps is time consuming process because it involves various operations, i.e., establishment of ground control, aero-triangulation, photogrammetric survey, field verification, fair drawing and printing. Therefore, pending the preparation of regular topographic maps, drawing up of adinterim planimetric base maps is resorted to in the first instance.

The area is also flown for photogrphahy on 1:20,000 scale. Land use classes and forest types (of Land use and Forest Type Classification) are delineated on this photography and the details are transferred to base maps to prepare forest type and land use maps on 1:50,000 scale.

Land use and Forest Type Classification—A land use and forest type classification system has been developed. The minimum limit for land use classification has been fixed at one hectare, and that for forest type mapping at five hectares. The various forest types and land use classes are as follows:

(1) Forests

(a) Coniferous forests

(i) Chir pine forests

(ii) Blue-pine forests

(iii) Deodar forests

(iv) Fir and spruce forests

(v) Mixed deodar, kail, fir and spruce forests

(b) Hardwood forests

(c) Mixed coniferous and hardwood forests

¹ The country has adopted metric scales with effect from 1.7.1976

(2) Rangelands

- (a) Sub-mountainous rangelands, below, 1,000m elevation sub-divided into two slope classes, i.e., less than 50% slope and more than 50% slope.
- (b) Mountainous rangelands between 1,000m and 3,000m elevation, sub-divided into two slope classes as above.
- (c) Alpine pastures, 4,000 m elevation and above.

(3) Cultivated lands

- (a) Below 1,000m elevation, sub-divided into two slope classes, i.e., less than 50% slope and more than 50% slope.
- (b) Between, 1,000m and 2,500m elevation, sub-divided into two slope classes as above.
- (c) Above 2,500m elevation, sub-divided into two slope classes as above.

(4) Permanently Unproductive Lands

- (a) Roads
- (b) Habitations
- (c) Graveyards
- (d) River beds and lakes
- (e) Glaciers and snow screes
- (f) Rock precipices

The coniferous forests are further classified into density classes as 10-40 per cent, 40-70 per cent, and 70 per cent and over; and into height classes as 0-10 m high, 10-20 m high and 20 m high and over. The selection forests are classed in accordance with the height of the main crop in the stand.

Where 1:20,000 scale photography is not available, detailed land use classification becomes impossible. Therefore, the forests are distinguished into hardwoods and conifers; the latter are further classified into those of north and south exposures.

Area Calculation—Since the terrain is very rugged and uneven, displacement in the photography due to relief is bound to be considerable. All areal measurements are, therefore, recorded on the maps either through dot-counting or using the planimeter. Where, however, maps are not available the area is calculated by means of dot grids either from individual photographs or from mosaics, if available.

Forest Inventory—Two forms of sampling designs have been developed depending upon the availability of topographic maps and 1:20,000 scale photography. Where these two material² are available, a double (photo and ground) sampling with regression technique

²Double sampling is possible even if topographic maps are not available. This is explained as follows: Datum planes of (a) 5,000' and (b) 7,000' altitude are specified for the chir forests and high hill forests respectively. Using a 12-inch focal length lens camera, the 1:20,000 scale photography requires a flying height of 25,000' and 27,000' above mean sea level for datum planes (a) and (b) respectively. The altitudinal ranges will cause the scale to vary from 1:18,000 to 1:22,000 and 1:17,000 to 1:22,000 for datum planes (a) and (b) respectively. This variation in scale is small and can be ignored. Also, since photo measurements are correlated with those of ground, the regression equation will, to a great extent, account for the said variation in scale.

is adopted. A large photo sample is selected and measurements are taken on the photographs. Out of this photo sample, a sub-sample is taken for measuring and recording of data in the field. The data of sampling units, for which both photo and field measurements are available, provide a basis of adjusting the measurements of the too many plots. The photo and field samples are distributed in a systematic manner, because: (a) the location of sampling units in the field is easier and cheaper, and (b) the distribution of field sampling units is uniform. Also, it has been established that a sample deliberately spread over the entire population will be more representative and efficient than random sampling.

Where large scale photography is not available, but topographic or planimetric maps on 1:50,000 scale exist, a stratified (ground) sampling is employed.

The sample size for coniferous forest area is worked out through the use of the following formulae (2, 7):

$$n_g = \left(\frac{CV}{AE} \right)^2 \cdot t^2$$

and,

$$n_p = h_g (R)$$

where:

CV = coefficient of variation of the population;

AE = allowable sampling error in per cent;

t = a constant designating reliability of a given level of confidence;

n_p = number of photo sampling units;

n_g = number of ground sampling units; and

R = optimum sampling unit ratio for particular coefficient and sampling unit cost ratio as read from graph in Figure 3.

Further distribution of sampling units to various strata is carried out through proportional allocation for photo sampling and optimum allocation for ground sampling. The formulae are (2):

$$\left\{ \begin{array}{l} n_h = \frac{N_h S_h}{L} \\ \sum_{h=1}^L N_h S_h \end{array} \right\} n_g$$

and

$$n_p = \left(\frac{N_h}{N} \right) n_p$$

where

n_p = number of photo sampling units to be observed in the population;

n_g = number of ground sampling units to be observed in the population;

n_h = number of photo sampling units to be observed in stratum h

(h = 1, ..., L);

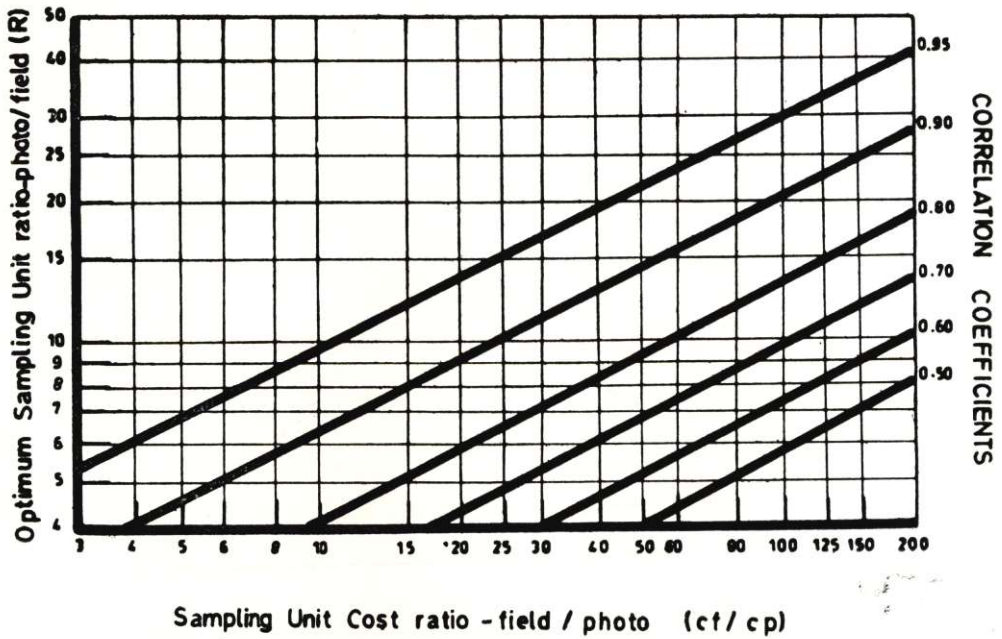
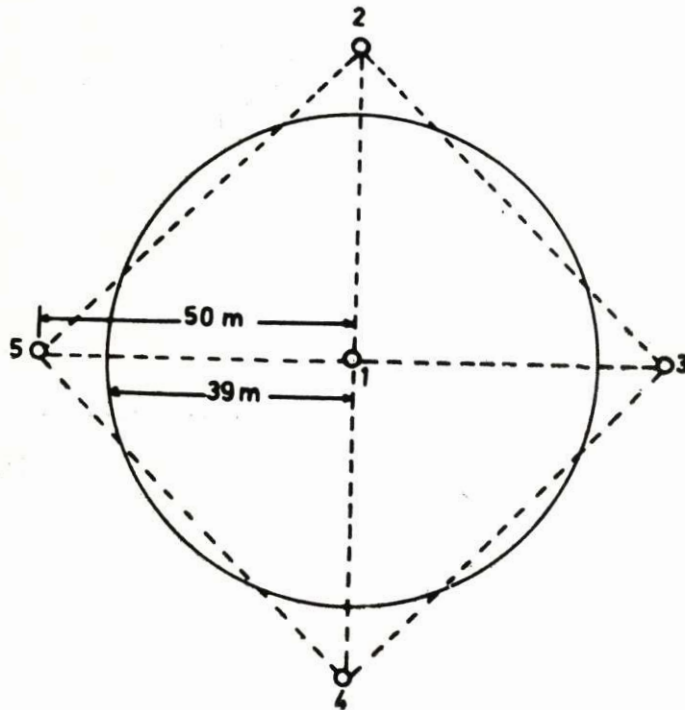


Figure 3. OPTIMUM RATIO OF PHOTO SAMPLING UNITS TO FIELD SAMPLING UNITS

SCALE-1=1000



Note:- The $\frac{1}{2}$ hectare circle represents the ground sampling unit in the regression double sampling.

Figure 4 A SKETCH OF THE GROUND SAMPLING UNIT

- n_{gh} = number of ground sampling units to be observed in stratum h ;
 S_h = standard deviation of stratum h ;
 N_h = total size (number of sampling units possible) in stratum h ; and
 N = total size (number of sampling units possible) in the population.

For ensuring a better relationship of photo and field measurements, fixed plot sampling is employed in the double (photo and ground) sampling with regression. The sampling units, some of which are examined both on photos and in the field, consist of one acre (now half hectare) circles.³ A 1/100 acre (now 1/250 hectare) regeneration sub-plot is taken either at the centre of the sample location or at each of the five points in a cluster, whichever is applicable.

The assessment in the stratified (ground) sampling is carried out on the basis of frequency using angle gauge of variable plot sampling. Based on the rule of thumb devised by Beers and Miller (1), basal area factors (BAF) of 10 and 20 are used depending upon age and density of crop. The sampling units, which are examined only in the field, consist of five variable plots and are distributed in a systematic manner. A 1/100 acre (now 1/250 hectare) regeneration sub-plot is taken at each of the five points in a cluster.

A sketch of the ground sampling unit is given in Figure 4. A distance of 200 (now 50 m) is kept from plot to plot in the cluster. This is reduced where desirable, but it is never kept less than 50 ft. (now 10 meters).

Photo data comprise measurements on height of three dominant and co-dominant trees, crown closure, photo plot volume, and plot description such as forest type, aspect, slope, soil depth and erosion. For photo plot volume estimation, either any of the available aerial photo stand-volume table is used, or else the data collected for the forest inventory is utilised in developing local aerial photo stand-volume table.

Field data consist of measurements on dbh⁴ basal area and volume (worked out later in the laboratory) of each tree: stump height diameter, bark thickness, current annual increment and total height of first (starting from north) three desirable coniferous trees; total height of three dominant or co-dominant coniferous trees; count of old stumps on the plot; tree description such as species, tree quality and damage class; and plot description such as location, forest type, aspect, slope, density, underlying rock, soil depth, soil drainage, soil texture, soil colour, duff mull, erosion, regeneration and the suggested treatment for the sample location.

The data are finally processed and compiled in the form of write-ups and forest type maps.

Land use Capability Inventory—The sampling procedure and the size and shape of sampling unit remain the same. The photo sample for coniferous forest areas is enlarged proportionate to the area of different land use classes to facilitate laying out of the sample systematically on aerial photographs through the use of acetate template. Every third

³If it becomes difficult to ensure uniformity among the photo and field sampling units or to measure circle on ground, the photo sampling unit is a circle (for ensuring easy interpretation but in the field, variable plot sampling is carried out either at one point, the centre of the sample location or at a systematically distributed cluster of five points on the sample location).

⁴dbh in variable plot sampling is used to find out the marginal in-trees and volume of all counted trees by using a local volume table.

sampling unit falling on non-coniferous forests area is then taken up for photo measurements. The ground sample is calculated at the rate of one sampling unit per 5,000 acres (now 2,000 hectares).

Photo data consist of information on existing land use, soil depth, soil drainage, slope and erosion. Ground data comprise information on land use class, rock formation, soil depth, soil drainage, soil texture, soil colour, slope, aspect (if necessary), erosion and the suggested treatment for the sample location. If the phot falls on hardwood forests, information on the species, frequency, dbh, and the state of regeneration is also collected for the sample location.

Apart from the above soil investigation is carried out with the courtesy of the Soil Survey of Pakistan over pre-determined cross sections to collect data on geology and parent rock formation; soil profile, soil colour, soil texture, soil structure, soil drainage, erosion is tensity and pH value; and, aspect and slope. This information leads to the identification of various soil groups which are distinguished on soil maps.

By nature of the system, errors detected in the field examination can be applied on a percentage basis to the larger number classified by photo-interpretation. Some of the data which could be collected in the field alone are projected as such to the entire area under investigation. The land use capability, determined from the treatment suggested for a field sampling unit, is projected to all the photo sampling units having adjusted data identical to the ground sampling units.

The information is finally presented in the form of write-ups, existing land use maps, and land use capability maps.

Achievements. Despite the odds of weather conditions, the difficulty of terrain, and the non-availability of necessary equipment, material and men, good progress has been achieved on the flowing of aerial photography, preparation of topographic maps and land resources maps, collection of forest inventory and land suitability data, and compilation of integrated land resources reports. The detail of progress achieved on the project is approximately given in Table 1.

TABLE 1
Detail of achievements made up to 30-6-75

Particulars	Targets (km ²)	Achievements (km ²)	Balance (km ²)
1. Aerial photography			
(i) 1:50,000 scale	50,000	42,000	8,000
(ii) 1:20,000 scale	40,000	19,000	21,000
2. Preparation of maps			
(i) Base maps	40,000	39,000	1,000
(ii) Topo maps	50,000	35,000	15,000
(iii) Resource maps	65,000	27,000	38,000
3. Soil Survey	40,000	7,000	33,000
4. Preparation of reports			
(i) Forestry inventory reports	12,500	6,000	6,500
(ii) Land use/integrated resources survey reports	65,000	27,000	38,000

Apart from the progress achieved as shown in Table 1, follow-up operational projects have been prepared which, in some cases, have also been put to implementation. Further-more, out of the five feasibility studies planned to be carried out, one has already been completed and a second feasibility study has since been taken up. Similarly, fresh volume tables have been prepared for all the five coniferous species which have already been usefully employed in the management of forests in these watersheds.

Application of Satellite Imagery. Of late, considerable work has been carried out on the use of satellites in communication, disaster prediction, disaster relief, and land resources analyses. Hallor has analysed the problems and promises of LANDSAT imagery in relation to forestry (3).

LANDSAT—1 images (36" × 36" enlargements, 1:250,000 scale, black and white prints) were acquired from EROS Data Centre, Sioux Falls, South Dakota in May, 1974 and then in May, 1975. In all, there were 16 prints, 12 of MSS band 5 and 4 of band 6. The resolution presented difficulty in delineating forests from the non-forestlands but, with the help of magnifying lens, efforts were made to identify forestlands in two watersheds already surveyed by the project using the conventional aerial photography. The results are given as follows:

Name of Watershed	Forest Area as determined from	
	Aerial Photograpy	LANDSAT Images
Swat	1,28,000 hectares	1,77,000 hectares
Kunhar	48,000 hectares	63,200 hectares

These results seem to be encouraging. It is hoped that with more training, equipment and material; it would be possible to develop techniques and apply the LANDSAT images in solving the basic problem of mapping and carrying out forest inventory in northern Pakistan. For this purpose, the facilities of equipment, material and expertiso available at the Space and Upper Atmosphere Research Committee in Karachi will be made use of.

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