NATURAL RESOURCES INVENTORY FOR DEVELOPING COUNTRIES

Demographic statistics show that the population of the world will increase from 3 billion in 1962 to about 6.5 billion in the year 2000. This means that in less than 40 years, more then twice as many people as today will have to be fed and will have to be provided with the essential commodities of life. Never before has mankind witnessed such a tremendous rate of growth and never before has it had to face so large a problem and had to solve it in so short a time. The actions necessary to cope adequately with this problem will likewise be unprecedented, and revolutionary methods of research will have to be used.

It is of particular importance to note that the rate of growth occurs principally in the developing countries with an economy which is often primarily based on subsistence agriculture. The opening up of these countries in the past decades brought the benefits of modern medical science to even the remotest areas, and as a result there has been a sharp decline in the death rate – especially of infant mortality – with the resultant increase of population. The postwar health campaign in Ceylon, and especially the country-wide spraying with DDT resulted in a decrease in mortality from 22.0 per thousand per annum in 1945 to 9.1 in 1960. It is estimated that there will be about 18–20 million Ceylonese in 1980, which is about three times as many as the 6.8 million of 1945. In many other, less spectacular, cases the population of developing countries has doubled in about 30 years. This rapid increase could only be of benefit to a few sparsely populated areas, but for the majority of the developing countries such a rapid population increase poses an almost insurmountable problem. The only possible solution is to open up large virgin areas and also to make more intensive use of the existing cultivated land.

Enlargement of the acreage of subsistence farm land is certainly no answer to the problem, and the impetus for the economic development will have to come from industry and mining. This is even more so because it is the aim of the national governments not only to cope with the population increase, but also to raise substantially the standards of living in their countries. Improved nutrition and sanitation, better education facilities and housing, and many other improvements, will be necessary for this purpose.

The much smaller growth of the more industrialized countries, where a similar population boom occurred at an earlier period, is best demonstrated by the fact that the doubling of the population of England will take about 230 years. This discrepancy in the growth of the world population has the effect that the industrialized countries will have about $^1/_5$ of the world population in the year 2000 instead of the $^1/_3$ of 1950. Most of the investments for the aforementioned development schemes come from these countries, and it is therefore evident that the per capita financial burden on them will become increasingly heavier. It is therefore absolutely necessary that the developing countries become more and more industrialized and thus find a firm economic footing themselves, which will enable them to take a larger share in the huge costs which will be involved in their future development.

The question is essentially whether all our aims, which are to raise the standards of living, can be reached in time. It appears from United Nations reports that nowadays a considerably higher percentage of the world population has a diet of under 2200 calories daily than was the case in 1939. Are our numbers not increasing faster than we can organize our food supplies? I have already mentioned the aspect of the necessary investments. Another aspect which may become a bottleneck in an unknown number of cases is the training of the scientific personnel to carry out the essential research and the technical personnel to carry out the projects. An efficient planning on a world wide scale of all the available resources will be indispensable if this task is to be brought to a satisfactory conclusion.

The developing countries, in raising the standards of living of their rapidly increasing populations, will create a great demand for raw materials and the need for planned development of industry and transportation. The agrarian economy, in particular, must also be developed to meet these ever increasing demands. Rapid progress of thorough scientific investigations is necessary as a basis for these projects: the mineral wealth, the fertility of the soils, the value of the forests, *etc.* should be known in advance. Aerial survey is one of the most important means of investigation of a country's potentialities. Much data regarding geology, soils, vegetation, *etc.*, can be derived from aerial photographs. The accuracy and the amount of detail obtained in this way, and the saving of time and money, are the reasons why nowadays almost every inventory of natural recources is carried out with the aid of aerial photo interpretation. The greater efficiency of the field investigations reached by this approach is essential to ensure a sufficiently rapid progress of development projects. It is not too much to say that the interpretation of aerial photographs has become a much more important part of aerial survey than the preparation of photogrammetric maps. The latter should only be considered as a prerequisite for the natural recources survey.

Mineral resources development has a high priority in the economic planning of many countries, because most industries are dependent on minerals. This is especially so for heavy industry, but the power necessary for other industries, which may be partly based on agriculture, also comes almost exclusively from mineral resources. Photogeology is comparatively well developed as far as areas of sedimentary rocks are concerned. This is a result of the extensive use made of aerial photograph interpretation in oil exploration. Areas of igneous and metamorphic rocks have been much less intensively studied, however, and much remains to be done in this field. It is therefore important that at this Symposium, the working group on geology will concentrate especially on this subject. The approach of aerial photographic studies of such areas is different, because structural features usually play only an minor role. The interpretation centres on a detailed study of the characteristic landforms developed in the various rock types. The determination of the lithology often is a special difficulty, which is sometimes best solved during a subsequent field survey.

Another aspect which is becoming increasingly important is the utilization of aerial photographs in hydrogeological investigations. Water is an extremely important item in a great many development schemes, not only within the arid zone, but also elsewhere. In compiling maps of the availability of construction materials, the geologist renders services to the engineers engaged in the construction of roads, dams or other engineering works. Photogeology is thus at present rather rapidly widening its scope by covering these fields.

The basis for the new trend is the experience gained in oil exploration since the nineteen thirties. The geological exploration and mapping is today carried out more extensively than at any time in the past. Accurate geological information is needed for the search for minerals and to meet the increasing oil demands. The need for rapidly surveying large areas, has stimulated the various methods of research, and photogeology is now an essential part of geological exploration everywhere. It should be borne in mind that the photogeologist, in most cases, cannot indicate immediately where exactly a certain kind of mineral deposit can be found. He can, however, point out adequately where the greatest likelihood exists for the occurrence of such a mineral deposit. It frequently occurs that extensive areas to be surveyed can be eliminated immediately, or can be reduced considerably. Sometimes areas of particular interest, where an intensive field survey is highly desirable, can be pointed out directly. The priorities of the field investigations can thus easily be established, and planning for the field parties can be done. The best sites for test wells can also be selected. The photo interpretation thus pays off during the subsequent field survey.

The amount of geological information which can be derived from the aerial photographs varies considerably from one area to another. More details can usually be obtained from areas of sedimentary rocks than from igneous or metamorphic regions. The arid zone is evidently in a more favourable position than the humid tropics, where geological data is easily obliterated by dense vegetation and thick soil cover. Intensive land use, as in western Europe, also can interfere considerably with geological photo interpretation. The absolute amount of information obtained is not always decisive for the usefulness of photogeology. The field geologist working in the tropical jungle will usually follow the river courses and his survey will be far from complete. He will be very glad, therefore, to have any additional information that can possibly be obtained. Though the absolute amount of detail provided is less, its relative value for the exploration may be even higher. The economical rewards of photogeology actually are not in systematic mapping, but in the discovery, from the air, of unknown mineral deposits and promising geological structures.

The accent of photogeological studies for oil exploration will be on the structures present and on the measurement of dip and formational thickness. Oil exploration in recent years has been becoming more and more centred on the discovery of subsurface structures, because of the fact that most of the easily detectable features have already been explored. Indirect evidence, such as vegetation, drainage pattern, *etc.*, is consequently gaining in importance. The lithological interpretation is especially important in the search for ore deposits. Geomorphology plays an important role in this respect, and also in the study of alluvial (placer) deposits. The hydrogeologist will concentrate on the estimation of surface run-off and infiltration, because the permeability/porosity of the rock is an indication of its value as an aquifer. Possible water reservoirs can thus be located on the strength of structural geomorphological and vegetational evidence. The engineering geologist will concentrate on the surface materials and their engineering properties, such as drainage, bearing strength, compressibility, *etc.*

Although each of the above mentioned types of photogeological studies has its own aim and its own characteristics, all of them are most valuable contributions to the inventory of natural resources, and especially for the development of mining and industry, which is a prerequisite for the raising of the standard of living above the subsistence level.

Development of agriculture, of course, is also a need for every country. Only a small part of this development can be arrived at by introducing some improvements into the existing system of subsistence farming. In many cases subsistence farming, even in the least densely populated countries, is doing its utmost by producing all the food and some raw materials which can be produced under the prevailing technical and economic circumstances. In many cases even more than that has been done, and this has resulted in very serious erosion damage and in the breaking down of the age-old cycles of shifting cultivation. Of course, the talk is always about the opening up of new lands, which are still under "virgin forest". But the surface area of these is extremely small, and even then it is found that, in most parts of Asia and Africa, only those areas are still virgin forest which are not suitable for subsistence farming and which are sometimes not even suitable for any farming whatsoever. Only some parts of tropical America may be more promising in this respect.

A different aspect is seen in considering the reclamation of virgin alluvial lands, whether forested or not. Here, certainly, we find areas in many parts of the world which can be made suitable for the agricultural production of food and of some raw materials for industry. But in general this can only be done with considerable investment, because dams and dikes must be built, drainage and sometimes irrigation systems must be constructed and various other institutional and technical means must be provided.

We may, therefore, conclude, that the development of subsistence farming as such will never give a lasting solution to the problems of development of agriculture. This means that the traditional systems of agriculture must be modified, and sometimes even totally changed, by bringing into use the technical inventions of the modern world, such as insecticides, fungicides, chemical fertilizers and machinery. Only in this way can agriculture be made to give a definite contribution to the national economy. However, fulfilment of all needs will only be possible provided modern methods of research are used as a sound foundation.

At the same time, the development of industry should provide the population with money to buy the products of their developing agriculture, and in addition absorb that part of the population inevitably displaced from the land. Apart from the most undeveloped types of subsistence farming, food and all other agricultural products must be bought. Only if the farmers will receive in the near future a sufficiently high price for the food which they produce, can agriculture be developed in a sound way. Even then, the international funds being made available will be urgently needed, since they must provide the large amounts of money needed to start this uplift. This money must provide for research as well as for the construction of works for soil conservation, irrigation and drainage, and possibly also for the first gifts of chemical fertilizers to start the increase of production on soils which have almost always been depleted by past methods of farming.

Soil survey, land use survey, land classification survey, soil erosion survey and soil conservation survey are all urgently needed to give a sound foundation for this development. They are urgently needed for various aspects such as: 1. the general inventory of the soil resources of a country to find the best way for their development, 2. to indicate the priority of their development with regard to related projects, including those in the industrial sphere, and to the social and economic needs of the country, 3. to put the development projects on a sound basis which prevents the investments for development being put in the wrong place at the wrong time and in the wrong way, 4. to make it possible for the farmers who are going to be settled on these projects to attain a higher standard of living and a more economic production. Only if these conditions are fulfilled will the farmers be able to contribute continuously to the food production and the general economic development of their country.

These needs put a heavy burden on the soil surveyor who must provide the basic data and who must cooperate with his colleagues in agronomy, soil conservation and plant breeding for the evaluation of his data for practical agriculture. Furthermore, this task must proceed with sufficient speed in order that the execution of development projects is not hampered by a lack of data. The aerial photograph is therefore an essential tool in improving the efficiency of these surveys. Only by making an intelligent use of this tool in connection with the necessary field work can the development of a country be achieved in such a way that rural development will have maximum benefit from the data provided by modern science, in the shortest possible time.

A particular part of the agricultural domain is the forestry branch. Especially for the tropical regions we may expect a considerable increase in the value of the forest in the future. To demonstrate the justification of this statement I will quote some data obtained from a recently published report of the FAO.

According to this report the tropical forest area constitutes about 45% of the total forest area in the world. The total removal of forest products in the tropics so far has been only 24% of the world total. Further, this 24% was mainly fuel, which was 47% of the estimated world consumption of firewood. The total contribution of industrial wood obtained from the tropical forests was only some 6% of the total world timber production.

This extremely low output of the tropical forests can be attributed to several particular circumstances, as for instance:

a. Most primary forest areas in the tropics are only to be found in very inaccessible regions. Here the best possibility for economic exploitation of timber is water transport. This means that both river banks can be exploited to a certain extent, whereas the far remote areas remain untouched by the wood-cutter. Also the floating of the felled logs is mainly a question of river size which is further determined by such obstacles as rapids and waterfalls.

b. The economic exploitation of most tropical forest is greatly hampered by the large variety in species-composition, as only a small percentage of this has any value for timber production.

c. And last but not least, the amount of information needed to start a new lumber industry in tropical regions is still in most cases largely insufficient.

Although the forest composition of these areas has been an important subject for special research for some time past, more detailed information will be required about the occurrence of valuable tree species and local topographical conditions in order to plan possible transportation methods.

If we put the question: is this form of special forestry research justified, considering the unfavourable tropical conditions, then the answer must be, yes, considering the rapidly increasing demand for forest products for industrial and home use. According to the information provided by FAO-officials we may assume that by the end of the current century the consumption of industrial timber will be at least twice as great as at present. It is even likely that this situation will be reached by 1980/1990. Taking this into consideration, it is clear that the tropical forests must make a greater contribution to the world's timber production in the very near future. For this to be achieved current forest inventory methods in the tropics must be improved, and more complete inventories carried out where local circumstances seem favourable for new lumber industries. For this purpose aerial photographs have proved to be an excellent means of obtaining, in a relatively short time, and without much physical effort, general information of the existing local forest conditions. Based on this information it will be possible to select those parts of the forest, which may be more favourably exploited, according to the general appearance of the crown cover and topography.

Within such selected areas a start can be made with the terrestrial survey necessary to obtain a more accurate estimate of the species composition and the timber volume. Until now all efforts to get a direct estimate of the timber volume by aerial photographs of tropical regions have been unsuccessful but it is hoped that this Symposium will be able to make some contribution in this respect. If so, this will be a new point in favour of aerial photography, but even without a complete direct photo inventory technique, photo interpretation has already been proved to be of great value. Aerial photography is particularly useful in those regions where no detailed topographic maps are available. They provide the only solution to obtaining, by simple photogrammetric techniques, a good forest map of the region of sufficient accuracy. This map can be used to locate the existing producing forests or to indicate those areas where timber production looks favourable for the future.

Besides maintaining or opening up production forests in our tropical areas there is still another aspect of the large value of our tropical forests which must not be underestimated. Everywhere in the world, and particularly in parts of the tropics having a high annual rainfall, forests act as a protection against erosion. In the upper reaches of river systems particularly, this forest cover secures a maximum absorbtion of rainfall which leads to a better regulation of streamflow and a prevention of flooding and silting. This automatically implies that existing forests in such areas have to be preserved for the future. When the original forest cover has been removed by overcutting, burning or grazing, steps have to be taken to establish new afforestation. In the preparation of adequate working plans for the improvement of watershed conditions, aerial photographs are an important tool since they provide the requisite information in the shortest possible time. The determination of the area to be preserved for this purpose must be made in accordance with other living requirements of the local population. This entails the study of the agricultural systems applied, grazing possibilities for cattle, *etc*. The result will be a sound system of land classification for the whole watershed region, and will provide the basis for the cooperation between agriculture, animal husbandry, forestry, *etc*.

Aerial photo interpretation also has become an important tool in the hands of experienced engineers for all phases of engineering construction, dealing with soil and rocks as surface materials. In a word, it may be said that vertical aerial photographs can be used to indentify soil and rock textures, to outline soil and rock areas having similar characteristics, to evaluate drainage conditions, *etc*. Their application to specific project developments makes it possible to appraise the suitability of site locations for dams, canals, highways, airports and railroads; to conduct construction materials surveys; to develop sampling and drilling programmes for detailed investigation of soil and rock materials; and to prepare land use, drainage, and engineering soil maps.

Admittedly, this same work can be accomplished by conventional field methods. However, the ease with which detailed information can be obtained from aerial photographs by well-trained and experienced engineering geologists permits engineering planning to proceed with a wider perspective and thus coordinates work that otherwise consists of a series of random and inadequate field investigations.

Once the soil and rock materials, groundwater conditions, and geological features have been identified on the vertical aerial photographs, it only remains to complete their interpretation by translation in terms of engineering problems. While aerial photo interpretation is applicable to some extent in practically all phases of engineering planning, the greatest benefits can be realized if aerial photo interpretation is employed at the outset, when the site for the project is being selected. The relationship of the site location to the ultimate success of the project, plus the ease with which favourable site locations can be distinguished from the less desirable locations on vertical photographs, permits this approach to fulfil the requirements of modern engineering planning at a lower cost.

Site locations having favourable foundation conditions and a natural supply of suitable construction materials lead to economical designs, lowered construction costs, and assured success of the project. The ability to evaluate these problems by aerial photo interpretation, assisted by a limited amount of field work, obviates a number of difficulties that are very often encountered when conventional field methods alone are employed in making site selections.

The most efficient approach to the overall economic development of new or extensively cultivated lands is by way of an integrated survey of the natural resources using aerial photo interpretation as a starting point. The region then is analysed simultaneously by a team of experts, such as geologists, geomorphologists, soil scientists, foresters, botanists, *etc.* and thus all aspects of the physical setting are studied and mapped. This method has become more popular in recent years and will certainly be of ever increasing importance in the future, since it is the only practical way by which the solution to the problem of rapid large scale economic development can be achieved. The method is, amongst others, applied by the C.S.I.R.O. in Australia, the Air Survey Branch in Ceylon, the Geographical Survey Institute of Japan, *etc.*

The starting point for the investigations is usually the present utilization of the various landform units of the region. The necessary data for this land use map – on which the vegetation often is also indicated – can be easily derived from aerial photographs in combination with a field check. Land use mapping from the air is therefore certainly one of the most promising subjects of geographical photo interpretation.

The second phase of the work will be the detailed analysis of the terrain in all its aspects, such as landforms, water features, soils, geology, *etc.* A separate map will be made for every aspect studied. These maps will give an insight into the potentialities of every part of the area and they will therefore be a guide for the planning of the most efficient future land use. The regional planner will find in this map series the essential information for his development scheme.

The regional complex and its interrelationships cannot be studied completely without a comprehensive aerial view. It makes no difference whether these photographs are used for studying changes in a longstanding cultural landscape or whether they are used to document a developing region. The further research necessary for the opening up of the country can be based on the indications obtained in the natural resources inventory survey, which enables the investigators to concentrate their efforts on the most promising parts. It is only in this way that the billions of tomorrow can be fed adequately and attain a better standard of living. May I express the wish that this Symposium, at which so many experts in the various fields of aerial photo interpretation are present, will contribute to the furthering of principles and methods of natural resources inventory for the benefit of mankind.