DDDR:IAR/75/19 RESTRICTED
JUNE 1975

CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH

TECHNICAL ADVISORY COMMITTEE

Tenth Meeting, Washington, D.C. 22-26 July 1975

APPLICATION OF SATELLITE SENSING TO AGRICULTURAL RESEARCH AND DEVELOPMENT

(Background Paper)

(Agenda Item 7)

TAC SECRETARIAT

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

ROME 1975

WS/H0343

1.0 INTRODUCTION

1.1 The World Food Conference in its recommendations requested (Resolution IV) that, in early action to achieve goals related to food and agricultural research, extension and training, "the Technical Advisory Committee and the Consultative Group study the feasibility of an international programme on the use of remote sensing techniques in agriculture, including data from the earth resources satellites".

1.2 As a follow-up to this recommendation, this paper provides a brief overview of the present state of the art and science of remote sensing applied to agricultural research and development and draws attention to potential international co-operative programmes. Special emphasis is placed on remote sensing by satellite (satellite sensing), as it is the facet of remote sensing most promising to international cooperation, as it is the newest of the remote sensing techniques needing adequate support with research and training programmes and as, due to its inherent ability ot sample sequentially in time, satellite sensing is likely to play an increasingly important role in agriculture.

2.0 BACKGROUND

2.1 Remote sensing is concerned with the detection of objects on the Earth's surface using a sensing device not in contact with the objects being sensed and includes the evaluation of the collected data. In practice, remote sensing is more often confined to the electro-magnetic spectrum, to collection of data which can be presented as imagery and to the collection of data from a space platform (whether aircraft, helicopter, rocket, balloon or satellite). However, non-imaging sensors are increasingly used in mineral exploration, pollution studies and atmospheric and oceanic studies. The imaging device (or "tool") is usually an aerial camera or mechanical scanner; and with the exception of side-looking airborne radar (SLAR), which is necessarily an active system, remote sensing of the Earth's resources is confined to passive systems in which the signal sources are emitted energy or reflected solar energy from the Earth's surface.

2.2 Thomas writing in Nature, as early as 1920, drew attention to the role of aerial photography by aircraft in the study of the Earth's resources. Also in the 1920's, black-and-white (panchromatic) aerial photography was used experimentally in various agricultural activities. For example, Taubenhaus et al.(1929), used aerial photographs to detect Phymatotrichum omnivorum on cotton in the Sudan. However, it was not until about a decade after World War II, that aerial photography began to be used widely in agriculture and attention was given to understanding the basic reflective characteristics of healthy and diseased plants (e.g. Colwell, 1956).

2.3 This was followed in the 1960's by a period in which not only black-and-white but also infrared colour and panchromatic ("normal") colour aerial photography were increasingly applied to agricultural problems (cf. Manual of Photo Interpretation, 1960) and greater attention was given to understanding the emmissive and reflective properties of plants (e.g. Gates in U.S.A., Rossetti et al in France; Howard in Australia). Also new sensing techniques were tested for agricultural purposes, including side-looking airborne radar (SLAR), thermal sensing and optical mechanical sensing in the ultra-violet, visible and near-infrared.

2.4 At the present time, the principal space platforms used in agriculture are light aircraft at low altitudes and larger non-pressurized aircraft at medium altitudes. Of the several sensors, the single-lens aerial camera with its various film-filter combinations remains pre-eminent, although the mechanical scanner with its multi-spectral capability and much greater coverage of the electro-magnetic spectrum is likely to gain in importance. Multi-spectral photography, although restricted by a small photographic format, has been successfully used in activities ranging from the identification of fields of opium poppy to avocado pear attacked by Phytopthora (vide Wenderoth et al, 1974).

2.5 Thermal scanning by mechanical scanner has been found particularly useful in forest fire operations, in fresh water studies, in river and tidal pollution studies and experimentally for detecting differences in soil moisture and in combination with other spectral bands for improved species discrimination. Side-looking airborne radar (SLAR), despite its unique cloud penetrating capability and its ability to discriminate between some plant types and stages of plant growth by differences of surface roughness and of die-electric constants, has not received the attention it might in its application to agriculture. This may be due to the small scale of most SLAR imagery (i.e. 1:250,000 to 1:400,000), to the theoretical high cost of survey by SLAR and that the equipment used and results obtained are often militarily classified. Further, airborne television is being tested operationally in Brazil to assess coffee production. As often with mechanical scanning techniques, the system relies on recording the received signals directly onto magnetic tape; and, in turn, facilitates the analysis by computer of the large amount of data - a problem facing satellite sensing in the near future.

2.6 However, most commonly the agriculturist relies on the manual interpretation of imagery. Many of the aerial photographic applications available nowadays have been developed and proved technically and economically sound over one or more decades. Careful choice of the film-filter combination, season of photography in relation to plant growth and photographic scale (as expressed by the focal length of the camera lens and flying height) enables crops (including cereals) to be identified (cf. Brunnschweiler, 1957; Bomberger et al, 1960; Anuta and Macdonald, 1970), their areas measured, their condition and yields assessed (e.g. Howard and Price, 1973), insect infestations located (Spurr, 1960) and the presence, absence and development of disease determined (e.g. Brenchley and Dadd, 1962). Frequently photographic scales between about 1:8,000 and 1/20,000 are used, but much smaller scales are satisfactory for land-use and land capability mapping (e.g. 1:80,000 in Australia). Infrared colour photography at 1:120,000 was used in the study of maize blight in the U.S.A. which included crop identification. In comparison, low-level strip, pin-point and oblique photography is favoured in insect, disease, wild-life and livestock studies (e.g. Jolly, 1969).

3.0 STATE OF SATELLITE SENSING APPLIED TO AGRICULTURE

3.1 Although the first man-made satellite was launched in 1961 by the USSR and some "normal" colour photographs from space were available in the mid-1960's (e.g. Gemini-4), it was not until the advent of Landsat-1 (1972) that the potential role and impact of satellite sensing on agriculture was generally appreciated. As compared with aircraft sensing, remote sensing by Earth resources satellites (i.e. Landsat-1 and 2) has the advantages of being able to provide a synoptic view of large ground areas which can be covered at frequent intervals. The repetitive capability, not normally available by aircraft sensing due to cost, offers the agriculturist a new and powerful method for approaching major problems (e.g. crop forecasting; monitoring extensive areas of disease and insect infestation; up-dating statistics on the area of cultivated lands). In addition, Landsat (18 day orbiting cycle) can be supplemented at daily or shorter intervals by lower resolution meteorological/oceanographic satellite imagery. Lower resolution imagery is providing a major in-put to the screw worm control programme of the Unites States and Mexico (vide Barnes and Forsberg, 1975). As compared with aircraft imagery, however, even

Landsat imagery has the disadvantage of a fairly low resolution (i.e. 0.4 ha.); but this is partly offset by the sensing being simultaneously recorded in four spectral bands (0.5/6u, 0.6/0.7u, 0.7/0.8u, 0.8/1.1u).

3.2 Particularly in high rainfall areas, the imagery may be partly or completely cloud covered. A recent FAO estimate of Landsat-1 coverage (1972-1974) of Africa indicated about 9% had not been covered with scenes of less than 10% cloud cover; but it must be borne in mind that coverage at 18-day intervals was not attempted continuously and that the United States (with its own receiving stations) is covered by Landsat-1 imagery. Also, most of the world is likely to be served by regional Landsat data receiving stations within a few years. These stations have a range of at least 3,000 Km. and by early 1976 stations will be operating in Zaïre and Iran in addition to Brazil, Canada, Italy and the USA.

3.3 As indicated by the increasing range of publications on the applicational uses of satellite imagery (vide NASA Proceedings, 1973, 1974; Abstracts NASA Survey Symposium, 1975; Proceedings, Remote Sensing of Environment, 1973, 1974; 1st/2nd Canadian Remote Sensing Symposia), Landsat imagery is proving increasingly useful in different parts of the world in the preparation of thematic maps at scales upto 1:200,000 related to geology, landforms, hydrology, soils, broad land-use classes and land capability (cf. Stewart and Fleming, 1974). Examples include the following. An information system has been set up by the Louisiana State Planning Department, which provides for the continual up-dating by Landsat imagery at 1:250,000 of land-use maps and a 48-hours read out of the 1975 floods In coastal Alaska, Landsat imagery has been used to delineate the major pathways of sediment distribution. In Nebrake, biomass estimates covering 52,000 Km^2 has been shown to be a viable method for making decisions on grazing management, including stocking. Studies in Pennsylvania indicate that digital processing of Landsat data can be used to analyse and map the progress of defoliation by Gypsy moth. In part of N. Dakota, the area under small grains has been recently inventoried with an accuracy of 96.5%. Also the Large Area Crop Yield (LACY) programme in the USA is using Landsat imagery to estimate experimentally the area under cereals (commencing with wheat) and to assess the continuing condition of the crop. Temporary imagery composites, combining two or more bands in time sequences, are proving essential to the study of seasonal changes occurring over large areas (e.g. pastoral savanna burning in Africa). Spectral band combinations have been found useful in showing up hitherto unknown large-scale natural patterns on the Earth's surface, the significance of which are yet to be determined. In Thailand, Landsat-1 imagery was used to determine the rate of de-afforestation - between 1961 and 1973, the forest cover decreased from 50% to 37%.

3.4 Based on the experience of the life of Landsat-1 and the recent US announcement on Landsat-C (Frutkin, 1975) global coverage by these satellites seems secure until nearly 1980; and by that time an Earth-shuttle and space laboratory may be operational. Further, Landsat-C is likely to be equipped with a thermal scanner and have a ground resolution of 35/40 m, which is twice that of Landsat-1. An assessment made from various published sources indicates that space technology is sufficiently advanced to be able to provide satellite imagery with a resolution of 5-7 m. or better.

4.0 OVERVIEW

4.1 At the present time satellite sensing is still very much at the applied research stage of development as compared with aerial photography, but its operational uses are rapidly increasing. These are more and more computer assisted, although the cost of developing computer software programmes is considerable. Further, an increasing range of nation-wide regional and global surveys are likely in the future to rely on satellite based data.

4.2 As may be expected, most research and development has occurred in the developed countries; and this unfortunately is leading to a widening of the gap in knowledge and applications between the development and developing world. SLAR equipment is usually only available on hire from the USA; and, with very few exceptions, thermal sensing equipment is only available in developed countries or from survey companies based in the developed countries. However, satellite imagery is readily obtainable and inexpensive (e.g. US$2 per black-and-white Landsat print covering an area of about 34,000 Km^2); and many developing countries have aircraft and aerial cameras suited to photogrammetric mapping. In fact, some developing countries produce their own planimetric and topographic maps, although few have the equivalent experience with colour photography. This may indicate not so much a lack of funds for capital equipment, but primarily a need for the educational transfer of knowledge related to remote sensing research and its applications.

4.3 Techniques less spectacular than those resulting from the development of satellite sensing, and perhaps eclipsed by the availability of satellite imagery at low cost are those provided by light aircraft and inexpensive aerial photographic equipment and developed only recently. They are well suited to research and applications in agricultural crop forecasting, forestry, hydrology, land-use, livestock surveillance and insect and disease surveys. For example, light aircraft have been used in a livestock surveillance of S. Kordafan Province (Democratic Republic of the Sudan), where an area of 145,000 Km^2 were covered in less than 4 weeks at a low cost.

4.4 In general, however, initial cost of collecting remote sensed data is considerable; but it represents only a small part of the total cost of most well planned surveys including the collection of field data (cf. van Asch, 1961; Stellingwerf, 1963; Lyons, 1964). On the basis of reduced overall costs and/or improved greater efficiency and accuracy, the application of remotely sensed data has come to be recognized as essential to most large-scale surveys. Also the type of information collected may be difficult to obtain or is unobtainable by ground survey alone.

5.0 NEED AND POSSIBILITIES OF INTERNATIONAL COOPERATION

5.1 As mentioned, a widening gap exists between the developed and developing countries in the applications of remote sensing. Steps need to be taken, therefore, through international cooperation to improve the know-how of the developing countries and to associate the applied research of the developed countries with the problems of developing countries, particularly those related to the survey of resources, crop forecasting and the monitoring of pests and disease. Although attention has been directed in the past to resources survey using aerial photography, several major projects have used other sensors. These include the US Brazilian RADAM programme using SLAR, which has enabled most of the Amazon basin to be mapped despite cloud cover; and at the present time an FAO/UNEP programme is being planned for the monitoring of tropical forest cover using satellite imagery as an important input.

5.2 Often what appears to be an identical applications problem in developed and developing countries assumes a different priority in developing countries (e.g. thematic mapping at 1:250,000, using Landsat imagery); and, also, a different approach is needed if the infra-structure and know-how are to be built up and retained in the developing countries. Too frequently, a problem existing in a developing country, which requires the application of remote sensing, has been tackled with external expertise and little or no local involvement, including training.

5.3 Training in the wider-aspects of remote sensing is being provided at universities particularly in the United States, but this usually requires two or more years of study in association with other subjects. Short courses in photogrammetry and aerial photo-interpretation are provided at ITC in Netherlands and at similar centres in Colombia and India. Short courses in satellite sensing are given at INPE in Brasil, the US Geological Survey, EROS Data Centre in the USA and at the Purdue University; and occasional seminars/workshops in remote sensing are being held under bilateral and multilateral agreements with the UN and its agencies (e.g. UN/FAO Training Seminar in Remote Sensing, Indonesia, 1975). However, the remote sensing courses are not usually oriented towards the specific needs of agriculture, the meeds of developing countries and the particular problems of the tropics. There is therefore a definitive and probably urgent educational and training gap to be filled through international cooperation.

6.0 PROPOSALS FOR INTERNATIONAL CO-OPERATION IN REMOTE SENSING FOR DEVELOPING COUNTRIES

6.1 As indicated in previous sections, international cooperation is needed to assist developing countries in both the fields of remote sensing applications and remote sensing training particularly related to satellite sensing. There is, for example, no international co-operative programme in crop forecasting or the monitoring of insect pests and diseases; but, in recent months possibilities have emerged as follow-ups to the World Food Conference. FAO (1975) has already prepared a programme plan for developing the capability of international crop forecasting, and this will be reviewed by an expert consultation in September. In due course, their recommendations could be submitted to TAC for further consideration.

6.2 Further, the Desert Locust Commissions are examining the feasibility of improving the existing methods of locust control using Landsat and Metsat data to indicate areas within which breeding of the migratory locust is occurring. Satellite imagery is likely to help greatly in defining more accurately sandy outwash plains favourable to the breeding of locusts and within these areas sites having been recently inundated or having received substantial rain or run-off. Satellite imagery can also be used to follow-up the development of ephermal plant cover and the greening of perennial vegetation (e.g. Pedgley in Saudi Arabia, Muller in Mali) and the methodology developed in the screw-worm study in the USA and Mexico may prove useful. At this stage, there appears to be a need for international cooperation in the processing of the satellite data, in real-time analysis of the imagery, in determining the best means of telecommunication, in basic research to provide a better understanding of what is being observed and in providing training programmes for local staff.

6.3 The need for international cooperation in establishing a training programme in remote sensing was voiced recently by the UN Scientific and Technical Sub-Committee (UN Committee on the Peaceful Uses of Outer Space). In their 12th Session Report, it is stated that "The United Nations together with the FAO in Rome and the ILO in Turin should study the feasibility of utilizing the expertise of FAO and ILO and the existing remote sensing facilities of FAO to establish, on an experimental basis, an international centre to train and to, assist persons from developing countries to make the most effective use of remote sensing information. If the study demonstrated that such an experiment could be carried out without additional financial implications, the Sub-Committee was of the view that it could be undertaken immediately and a report on the results of the experiment should be made to the Sub-Committee at its next session".

6.4 In indicating Rome for the pilot international remote sensing centre, the Sub-Committee was influenced by FAO's leading role within the UN family in remote sensing and its experience in training and the close proximity of the data receiving and processing facility being developed near Rome by Telespazio. The international pilot centre was visualized to compliment the activities of future regional centres in remote sensing, the development of national data receiving centres with a regional function and to assist countries not covered by these centres (e.g. Sierra Leone, Senegal, Thailand, Colombia).

6.5 The establishment of the pilot training centre will require careful planning, international cooperation, and no doubt would benefit greatly by an international supporting network to cover its agriculturally oriented activities. Consideration could be given at the present time to establishing such a network which would assist in a number of matters including assistance with research and training and provision of follow-up studies for selected students.

BIBILIOGRAPHY

Anuta, P.E. & Macdonald, R.B. (1971) — Crop surveys from multiband satellite photography using digital techniques. Remote Sensing of Environment 2; 53-67.

Asch, van P. (1961) — The growth of aerial survey and its effect on the work of the New Zealand private surveyor. N.Z. Institute of Surveyors.

Barnes, C.M. & Forsberg, F.C. (1975) — An overview of the development of remote sensing remote sensing techniques for the screw-worm eradication programme, NASA Survey Symposium, Houston, 21 pp (awaiting publication).

Bomberger, E.H., Dill, H.W. et al (1960) — Photo-interpretation in agriculture. Manual of Photo-interpretation, ch. 11, 561-666.

Brenchley, G.H. & Dadd, C.V. (1962) — Potato blight recording on aerial photographs. N.A.S.S. Q. Rev. 21-5. London.

Brunnschweiler, D.H. (1957) — Seasonal changes of the agricultural pattern. Photogramm. Engng. 23, 131-9.

Canadian Symposium on Remote Sensing (1974) — The applications of remote sensing and benefits to Canada. University of Guelph, Canada, 346 pp.

Colwell, R.N. (1956) — Determining the prevalence of certain crop diseases by means of aerial photography. Hilgardia, 26 (5), 223-86.

Environmental Research Institute of Michigan (1972,1974) — Proceedings of the 8th/9th international symposia on remote sensing of the environment. ERIM, Ann arbor, Michigan, USA.

FAO — Programme plan for developing the capability of forecasting crop production - (A.B. Park) unpublished, 39 pp.

Frutkin, A. (1975) — US Delegate, 12th UN Scientific and Technical Sub-Committee (UN Committee on the Peaceful Uses of Outer Space, New York, USA).

Gates, D.M. (1965) — Characteristics of soil and vegetional surfaces to reflected and emitted radiation. Proc. 3rd. Symposium of Remote Sensing. Report 4864-9-x. University of Michigan, Ann Arbor, USA.

Howard, J.A. (1970) — Aerial Photo-Ecology. Faber & Faber, London, 325 pp.

Howard, J.A. & Price, R.D. (1974) — Using aerial photography to estimate yield loss in oats due to barley yellow dwarf virus, Revue Photo-Interpretation, Paris.

Jolly, G.M. (1969) — The treatment of errors in aerial counts of wilflife populations. East African Agricultural and Forestry Journal, Vol. XXXIV - July 1969.

Lyons, E.H. (1964) — Recent developments in 70 mm stereo-photography from helicopters. Photogramm. Engng. 30 (5), 750-6.

Manual of Photo-Interpretation (1960) — American Society of Photogrammetry, Washington, D.C.

Muller, W. (1975) — Etude metereoligue. Report on Project PNUD/FAO/RAF/09/146. (unpublished)

NASA (1973) — Symposium on significant results obtained from the Earth Resources Resources Technology Satellite-1. (2 Vols) Washington, D.C.

NASA (1974) — Third Earth Resources Technology Satellite-1 Symposium (Sections, A,B), Washington, D.C.

NASA (1975) — Earth Resources Survey Symposium. Abstracts, Houston, Texas.

Pedgley, D.E. (1973) — ERTS surveys a 500 Km^2 locust breeding site in Saudi Arabia. 3rd Earth Resources Technology Satellite-1 Symposium. I: Technical Presentations: 233-46.

Rossetti, C. (1966) — Reflections sur l'utilization des photographies aériennes de la végétation. Photo-interpretation, 5.

Spurr, S.H. (1960) — Photogrammetry and Photo-Interpretation, Ronald Press, NYS, 443 pp.

Stellingwerf, D. (1963) — Volume determination on aerial photographs. ITC. Series B, No. 18, pp. 19.

Stewart, R.A. & Fleming, E.A. (1974) — Mapping activities: SKYLAB and ERTS imagery. 2nd Canadian Symposium on Remote Sensing, University of Guelph, Canada. 14 pp.

Taubenhaus, J.J. et al (1929) — Aeroplane photography in the study of cotton root-rot fungus. Phytopathology, 19. 1025-9.

Thomas, H.H. (1920) — Aircraft photography in the service of science. Nature, 105 (No. 2641), 257-9.

Wenderoth, S. & Yost, E. et al (1975) — Multispectral Photography for Earth Resources. University of Long Island, N.Y.S.