Remote Sensing Application in Agriculture and Hydrology

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A.A.BALKEMA / ROTTERDAM

PROCEEDINGS OF A SEMINAR HELD AT THE JOINT RESEARCH CENTRE
OF THE COMMISSION OF THE EUROPEAN COMMUNITIES
IN THE FRAMEWORK OF THE ISPRA COURSES / ISPRA (VARESE) / ITALY

Remote Sensing Application in Agriculture and Hydrology

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Published for the Commission of the European Communities,
Directorate General Scientific and Technical Information
and Information Management, Luxembourg

A.A.BALKEMA / ROTTERDAM / 1980

The texts of the various papers in this volume were set individually by typists under the supervision of each of the authors concerned.

EUR 6611 EN

ISBN 90 6191 081 1

Distributed in USA & Canada by MBS, 99 Main Street, Salem, NH 03079

Printed in the Netherlands

Preface

Within the framework of Ispra Courses, an Advanced Seminar on Remote Sensing Applications in Agriculture and Hydrology was held in November/December 1977 at the Joint Research Centre of the European Communities, Ispra - Italy. The Seminar was intended for:

- officials responsible for planning and management in public administration (agriculture, forestry, environment, land engineering and equipment, etc.) wishing to acquire the technical knowledge necessary for their work;
- data handling and information specialists desirous of improving their understanding of the applications of their studies;
- specialists in agronomy, forestry, botany and hydrology wishing to complement their knowledge in this new and rapidly evolving field;
- specialists in development of sensors and data acquisition systems;
- students in the earth sciences and agronomy seeking to begin or continue a specialization in the application of earth-remote observation techniques to their specific fields.

Of the twenty-six lecturers asked to contribute to this Seminar, twenty-three are well-known specialists in European universities and institutes, and three are scientists from the U.S.A.; their presentations, accordingly, reflect research and developments internationally. Many of the contributors directed themselves to the difficulties inherent in trying to extrapolate from the wealth of proven remote-sensing techniques as applied in America those appropriate to the quite different structural and ecological conditions existing in Europe.

Of the many seminars and symposia in the field of remote sensing, the Ispra Seminar is one of the very few to date which has limited itself strictly to agricultural and hydrological applications; the success of its formula is proven by the many requests we have received from people who could not attend the 1977 Seminar for copies of the lectures. In response to this flood of requests, and with the support of the Directorate-General of the Scientific and Technical Information of the European Communities at Luxembourg and the organization of the Ispra Courses, we asked the authors to re-write and update their contributions for presentation here. All of them enthusiastically accepted this supplementary task, some even rewriting their contribution completely in order to reflect the rapid progress in this field. We would like to thank all of them for their cooperation.

Our thanks go also to the Directorate-General of the Scientific and Technical Information offices, the Division Ispra Courses and the publisher for their help in the production of this volume. We believe that it reflects the scope and the coverage of the Seminar and trust that it will constitute a useful tool for all those involved in remote sensing of agriculture and hydrology.

Ispra, July 1979

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Potential applications of remote sensing in agriculture

1 INTRODUCTION

One is tending today to regard agriculture as one of the main potential users of remote sensing. It would be interesting to examine the reasons for this trend which incidentally is also beginning to show itself in the United States. At any rate one of the main reasons for the trend would seem to be the need for regular information on the growth cycle of crops, and their sequence in time and space. Agriculture is a dynamic system whose control and management call for rapid and regular acquisition of a great many data on the agronomist's familiar triad : plants, soil and climate. This need is all the more pressing in Europe on account of the diversity of products and production structures which make up a relatively complex pattern, which changes from year to year in response to market demand and the competing claims on land for purposes other than agriculture.

Despite the many constraints, Community agriculture is expanding in real terms, mainly due to technical progress and higher productivity : mechanization, selection of crop varieties, intensive use of fertilizer, improved methods of combating disease and parasites and development of tillage techniques, etc...

Agriculture makes an important contribution to the general economy of the Community and has fully justified the creation of an agricultural policy which, since 1962, has unfortunately constituted the only genuinely common policy of the Member States.

It would seem, therefore, that much can be said for seeking new tools to facilitate the ordering of such a significant aspect of European affairs and thereby meet the ever-growing needs of administrators and decision-makers.

The question arises as to whether in this search such high performance technology as remote sensing should be used. To determine whether remote sensing can solve agricultural problems in Europe, let us first have a look at the context in which it would be used.

2 BIRD'S EYE VIEW OF THE EEC

It extends over 3.000 kilometres from the hills of Scotland in the North to Sicily in the South. The landscape is very varied and the agriculture equally so. For example, there is little in common between a large industrial grain farm in the Paris basin, a farm in the Netherlands or a small holding in Calabria or Sardinia. The Community covers a total of 152.80 million ha with a total UAA of 93.83 million ha, about 60 % of the total area. This area in the Community is broken down as follows :

arable land (% UAA)	50 %
permanent meadow and pasture (% UAA)	45 %
permanent crops (% UAA)	5 %
woodland and forest (% of total area)	21 %

Holdings in different categories are very varied in size. In the United Kingdom there is a predominance of very large holdings (over 50 ha) whereas in Italy holdings of less than 5 ha are in a majority. There is also considerable difference in the breakdown of UAA from one country to another. In Denmark it is mostly arable land whereas in Ireland 75 % is permanent meadow and pasture. Permanent crops are of most importance in Italy and France. France contains 35 % of the Community's UAA, the United Kingdom and Italy each about 20 % and Germany about 14 % (Table 1).

Thus the crop pattern is complex and the size of farms very varied with over 41 % of holdings between 1 and 5 ha and only 6.2 % over 50 ha (Table 2).

Table 1. Principal categories of land use 1974.

COUNTRY	Agricultural used area		Arable land	Permanent graslanc
	000 ha	% of total area	% of Agricultural used area	
EUR 9	93.484	61,2	55,7	44,3
Fr. Germany	13.344	53,7	60,5	39,5
France	32.439	59,1	58,2	41,8
Italy	17.503	58,1	70,2	29,8
Netherlands	2.101	56,9	40,3	59,7
Belgium	1.553	50,9	53,0	47,0
Luxembourg	132	51,0	47,1	52,9
United Kingdom	18.637	76,4	38,4	61,6
Ireland	4.846	69,0	26,3	73,7
Denmark	2.928	68,0	90,5	9,5
World	4.551.000	34,0	33,0	67,0

Table 2. Agricultural holdings of 1 ha and over by size groups EUR 9.

Size groups (ha)		Number of holdings (X 000)	X' 000 ha
1	5	2.222 (42,5 %)	5.635 (6,4 %)
5	10	924 (17,7 %)	6.606 (7,5 %)
10	20	914 (17,5 %)	12.963 (14,8 %)
20	50	847 (16,2 %)	25.793 (29,4 %)
	50	321 (6,1 %)	36.781 (41,9)

Despite this, the Community's level of self-supply is satisfactory, though changes will need to be considered to meet the needs of a growing population.

3 THE ROLE OF REMOTE SENSING IN AGRICULTURE WITHIN EEC

Seamingly, the scope for further improvement of crop yields in Europe is not great; the use of fertilizers which is now widespread may be discouraged by higher costs following the energy crisis; the same applies to pesticides.

Future policy will have to take account of these factors and include :

- continued efforts to improve productivity in an ever more dificult and costly energy supply situation,
- optimum use of the soil to produce the crop for which it is best suited,
- improved management of water resources for agriculture,
- improvement and care of the Community's marginal land,
- more effective protection of good farmland against the demands of urban development, road construction and industry through regional development plans,
- improvement and care of the Community's forest resources.

Under such a policy, we do not dissociate agriculture from its environment : we regard it as one of man's essential activities and not as a separate entity.

Let us see what information is needed to manage agriculture on these lines and to what extent remote sensing can help.

In this context it is difficult to analyse separately the three elements - plants, soil, climate - that form the basis of agricultural production.

But as the cultivated plant is our main concern here it is natural that the discussion should be centred on it.

Most crops grown are annuals if one excludes permanent meadow and pasture and permanent crops. There is thus rapid turnover of sown areas and the crop cover varies appreciably from one year to another.

The crop distribution pattern within arable areas is relatively important having to be linked with rotation. It becomes more important taking into account the large number of small holdings and consequent fragmentation even assuming a reasonably static proportion of arable land as a % of UAA.

This situation necessitates the permanent presence of specialists on the land to revise the statistical data each year.

I won't dwell on this aspect of agricultural statistics which Mr Thiede from the Statistical Office of the Commission will go into later.

When the crops are sown various factors influence their growth and development and consequently the yield : soil, water, climate, diseases and parasites play essential roles that man cannot always anticipate or control.

It is, however, essential to attemt to control and correct at least some of these parameters on a permanent basis. It is known for example, that the amount of water needed by crops is not the same at all stages of growth; the correction of a shortage or maybe an excess at a critical period of growth can have a positive effect on the final yield. Many more examples of this kind could be given to demonstrate the advantage of having a data on yield factors which man can influence available on a continuing basis.

- soil water - a thorough knowledge of the water network of a region is essential for the management of agricultural land, indeed of land in general; it also helps in the siting of pumping stations for the irrigation of areas short of water,
- the water retention capacity of the soil depends on its structure and texture. Information about this capacity over several consecutive years could influence decisions as regards sowing dates, dates for irrigation, even choice of the type of crop best adapted to the water balance of the growing year,
- the wind is an important factor in the evapotranspiration of plants and soil. Hedges used as windbreaks can considerably reduce evapotranspiration and thus completely alter the water balance of the soil and consequently even the type of crop grown on it.

All this is perfectly familiar to agronomists and farmers but if the data are to influence decisions they must be :

1. readily accessible
2. and representative of a sufficiently large region.

I believe I am right in saying that neither of these conditions today is completely fulfilled and one may well wonder whether a special effort should not be made in this area of bioclimatology.

Other biological factors could also be brought under better control if the relevant data could meet the two abovementioned conditions. In particular, if diseases or attacks by parasites could be checked in the early stages when the first symptoms appear on the crop, quick remedial action could be taken. Thorough-going plant health inspection is impracticable with present means so that insecticides and herbicides

Table 3. Yields of some principal crops (X 100 kg/ha).

Product	EUR 9	
	1950	1975
Wheat	19,2	36,4
Barley	22,5	35,9
Maize	15,0	47,4
Total cereals	19,4	37,0
Potatoes	182,0	244,0
Sugar Beet	339,0	401,0

Table 4. Production of cereals - Average 1972-1974.

Country	Total of cereals ('000 t)	Wheat	Barley	Maize
EUR 9	105.676	42.663	34.366	14.724
USSR	185.629	93.230	48.688	11.717
USA	218.994	45.780	8.341	134.488
Canada	34.274	14.656	10.103	2.636
World	1.017.000	361.000	165.000	304.000

Table 5. Population and estimated population growth - Middle of 1975.

Country	Population '000	Projected pop. ' 000 1980	1985	%
EUR 9	258.462	261.377	264.752	2,4
USSR	254.382	267.459	280.884	10
USA	213.611	222.769	234.068	9,5
World	3.968.000	4.326.000	4.769.000	20

Table 6. Wooded area and timber production 1974.

Country	Wooded area ('000 ha)	Total prod. of roundwood ('000 cu.m)	Production of sawn softwood ('000 cu.m)	Production of sawn hardwood ('000 cu.m)
EUR 9	32.041 (0,0077) %	78.219	16.169	7.956
World	4.126.000	2.511.381	327.056	96.147

are usually sprayed as a matter of routine during the growing cycle, thereby considerably increasing the quantity applied, with undesirable consequences for production prices and the environment.

In view of the role that European agriculture may have to play in a world context, serious attention should be given to safeguarding the heritage of cultivated land which for some years has suffered encroachments from property and highway developments and from industrial activities. It is obvious that the search for more intensive use of lands has lead sometimes to soil degradation either by superficial erosion or organic matter reduction.

Extreme examples of such phenomena are the wastage of some 1/4 mio acres of peatland in the U.K. from intensive arable cropping especially high value cash crops. In Ireland, where the proportion of arable land is limited the depth of peat remaining after mechanical and hand harvesting of approximately one mio acres of peatland will determine the use range of the resulting cut over areas. In an EEC context if sufficient depth of peat is conserved in these areas they could act as an important reservoir of land for horticultural croppings. The evergrowing needs of expanding populations cannot of course continue for ever to be met by an increase in crop yields alone, nor by excessive use of ever more costly fertilizers. Sooner or later Europeans will have to search for new arable land or new types of crops for marginal land, as has already happened in certain over-populated third world countries (Table 3 and Table 4).

It should be borne in mind that average population density varies considerably from one region of the world to another and that although estimated growth rates are low for Europe, they are high for the world population as a whole. Our population in Europe is about 258,462,000 compared with the world population of 3,168 million. In 1980 the figures will be 261,377,000 and 4,326 million respectively, rising to 264,752,000 and 4,769 million in 1985. This represents a growth rate of 2,4 % for Europe and 20 % for the world. Consequently the search for new agricultural land will have to be one of the main concerns of rising generations and the necessary means could therefore be thought of and developed as of now (Table 5).

Agriculture, while increasing its production potential must, as is becoming evident at the same time play a part in counteracting the increasing pollution associated with the proliferation of the human species. It is here that the role of forests in restoring disturbed ecological balances becomes obvious.(Table 6).

The search for land which is suitable for reafforestation and not wanted for agriculture is a long and difficult task and requires prospection that is costly in terms of both men and resources.

The above is no more than an outline sketch of the problems which these responsible for Community agriculture will have to deal with in the future : water and its management, soil conservation, weather factors, harvest forecasts, disease control, search for new land, the environment.

Data on these problems have already been obtained by remote sensing and put to practical use in the United States and it is safe to say will be used more in the future on this continent.

The purpose of this conference should be to define the scope and limits of a technique as yet little known by its potential users.

G. THIEDE [1]
Statistical Office, Commission of the European Communities, Luxembourg

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Agricultural statistics analysis of the main requirements
Conventional and new methodologies

Introduction

1. I am pleased to have the opportunity, at the very beginning of this seminar, to draw your attention to some of the specific requirements of future agricultural and forestry statistics. The discussion should give us an opportunity to define the needs, to examine the many projects already under way in some areas, and to identify the current operational possibilities as well as the areas requiring more research.

2. I have divided my talk into three main sections:

I. Which areas of study are suitable for remote sensing applications, and which are not
II. The requirements and problems of an EEC statistician
III. A very brief account of some statistical surveys based on aerial photography which have already been carried out in Europe

I. Areas of study suitable and unsuitable for remote sensing application

3. A large number of projects are currently under way in many different countries throughout the world. I do not know whether there is a central body for systematically recording (and possibly evaluating), (a) all the projects which have been carried out and (b) all ongoing and projected studies. This could be extremely useful for potential users of remote sensing techniques and of the resulting data. It would certainly be desirable from the point of view of the agricultural statistician making plans for the future

1) in collaboration with H.G. Andresen and T.B. Wilson

4. Given the circumstances obtaining in Europe the following areas of study would appear to be most suitable for remote sensing applications. But I would like to stress that these applications may not of course be immediately feasible, and may have to be tested for several years or even decades before practical statistical surveys can be conducted on a reasonably large scale (that is, for a whole country, or the whole Community). This list is therefore by no means exhaustive, and is simply meant to give examples of some of the most important, probable applications.

(A) Agricultural weather data

5. In a paper (Symposium Tel Aviv) which he presented in Tel Aviv last June, G. Fraysse suggested the setting-up of an AGROMET System whereby information on local weather conditions would be collected from a large number of ground stations and transmitted by satellite to a central station for immediate processing. A reporting system of this kind could replace the system already developed by the SOEC (Statistical Office of the European Communities, series "Crop production") for the collection of meteorological data for agricultural purposes in the Nine. Such data on weather conditions can be extremely valuable for short-term crop forecasts, and even have a bearing on agricultural policy especially in extreme situations of the type created by the drought in 1976 in some farming areas of Northern Europe.

(B) Land use statistics

6. One day not too remote it may be possible to compile statistics on land use by means of remote sensing techniques. Obviously, the land use statistics obtained

in this way would only show relatively rough general categories of land use. The categories could be limited in number and probably correspond to the nine level I groups of the Anderson Land Use/Cover classification of the U.S.A. (J.R.Anderson 1977) The emphasis would be on Land Cover rather than Land Use.
At present, surveys of this kind do not have a high priority, are in most European countries only held rarely, and are always very labour-intensive. This sort of general land use survey might be effected by analysis of aerial photographs or other remote sensing of the entire area to be covered (i.e. a complete census). Thereafter the changes occurring over the years could be recorded with the help of suitable sampling methods (with relatively small sampling fractions). These sampling methods could be devised on the basis of information from the basic aerial surveys.

(C) Statistics on areas cultivated

7. Annual surveys of the areas under main crops are essential for harvest and production reports each year. The question arises as to whether remote sensing data such as aerial photographs can be obtained and processed rapidly enough. This information on areas cultivated has to be made available very rapidly, as it forms the basis for calculation of harvest data for the year concerned, and because those responsible for agricultural policy must be provided with approximate harvest figures at an early stage (if possible actually before harvest date). The statistician aims to have as soon as possible data on the last phenological stage which makes a significant contribution to the final biological yield. It would be necessary to include the largest possible number of different crops. Unfortunately the specificity of the remote sensing methods developed so far is limited; and the agricultural and climatic conditions in Europe are not the most suitable for remote sensing but I shall come back to this problem again in the next section.

(D) Statistics on the progress of crops and harvest predictions

8. A further possible application would be the provision of continuous and extremely prompt information on the state of growth of the main crops and the degree of damage caused by pests, disease and other agents which affect the actual harvested yield.

We are all aware that in the past few years so-called "spy satellites" have been successfully used to provide very rapid estimates of the probable grain harvests, including fairly accurate estimates of the harvest in the Soviet Union before the relevant data were published by the official Soviet bodies.

(E) Forestry statistics

9. Some remote sensing techniques are already fairly common in the forestry sector, as most forests cover large areas with more uniform vegetation than is the case in the farming sector. This makes for greater ease of differentiation. I shall come back to this topic later on in my talk.

(F) Fishery statistics

10. Finally, it is claimed that remote sensing surveys could under certain circumstances be used to determine the abundance of stocks in the fishing grounds.

11. However, the types of agricultural statistics mentioned above represent only a small part of our day-to-day work on agricultural statistics. It is therefore worth making some brief mention of the other types of statistics, for which aerial photographs and other remote sensing techniques are out of the question, at least in Europe:

- livestock censuses cannot be conducted by means of aerial photography because a large proportion of the livestock in Europe is kept indoors;

- qualitative features, such as grapes "grown for home consumption "in vineyard surveys, or the varieties of apples "grown for cooking" in orchard surveys, have to be recorded by on-the-spot inspection or questionnaires. Aerial photographs would, at the most, provide rough divisions into categories such as young, medium and old trees from the observation of vigorous or weak vegetative growth;

- surveys of the structure of holdings, which entail the collection of data from individual enterprises on the number, size and structure of holdings, with details of land tenure fragmentation, and many other aspects.

- Figures and utilisation data relating to production factors in agriculture, that is, machines and equipment, fertilizers, plant protection products, etc.