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REMOTE SENSING TECHNIQUES APPLIED TO SUGAR BEET DISEASES IN GERMANY AND ITALY : INTRODUCTION TO THE RESULTS OF A EUROPEAN PROJECT.

Abstract

Partial results of the project (to be presented later by several participants) are here briefly introduced within the general framework of the crop diseases problem in the European Community.

1. Significance of crop diseases in the EEC. Concept of integrated control

In absence of any crop health inspection system, no statistical data are available so far which could allow to estimate the economic losses caused by crop diseases and pests to the agricultural sector of production.

It is generally accepted that a relative loss of 20 to 25% of the total value of the agricultural crops should be accounted for (with a rough distribution, according to the factor of damage, of $\frac{1}{2}$ attributed to fungal, bacterial and viral diseases, 1/4 to weed infestations and 1/4 to insect infestations).

Table 1 provides the most recent data (1978) about the agricultural areas occupied in EEC by the most important crops as well as by the total vegetal production (excluding permanent grassland): a total area of 50 Mio ha of cultivated crops provides a final production amounting to a value of about 40,000 Mio UCE (equivalent to 100,000 Mio DM), with around one third for cereals alone. The total economic losses induced by crop diseases and pests could then be roughly estimated to be close to 10,000 Mio UCE per year (1978 value).

On the other hand, very few data exist concerning the economic incidence of the cost of pesticide applications on the value of final production. For sugar beet in Italy, these costs amount to 5% of that value in the case of the cercospora leaf spot and would be prohibitive in the case of the nematode infestation (27%) (De Carolis, personal communication). This last disease may cause a reduction of production which may amount to 65% in Italy and 45% in Germany (De Carolis and Reichert resp., personal communications).

These figures illustrate the potential economic benefit of an efficient crop health monitoring system which would render possible the detection of diseases at an early stage prior to their wide propagation, thus acting as a prevention measure and allowing to decrease the level of agrochemicals application.

Table 1: Inventory of the main agricultural crops in the EEC, 1978 (Commission des Communautés Européennes 1980)

Crop	Area (Mio ha)	Final production Mio UCE	% of total
Cereals	26.7	12,100	31
of which: wheat	11.0	6,400	16
barley	9.5	3,200	8
grain maize	2.9	1,600	4
Potatoes	1.3	1,700	4
Sugar beet	1.8	2,500	6
Vegetables-Horticulture	1.0	4,800	12
Fruit	1.3		
Vineyards	2.7	2,000	5
Olive growing	1.1 (pure) + 1.2 (mixed)	800	2
Total vegetal production	50.4	39,300	100

On the other hand, such a system should include the quantitative assessment of the diseases level in order to be integrated into the more general system of crop production forecasting.

Beside its economic interest, an efficient health monitoring system would allow to decrease the ecological impact of prescticides as well as the level of contamination of foodstuffs by pesticides. These two aspects have stimulated in the last decade the development of "integrated control" techniques, i.e. a strategy based on a better knowledge of the environment, of the behaviour and of the dynamics of the infestating populations and aiming at keeping the latter at economically acceptable levels. In this approach, it is expected to limit the application of pesticides thanks to the use of combined biological, genetical and agrochemical techniques.

2. Potentialities of remote sensing for detection of crop diseases

Application of remote sensing techniques to crop diseases could insert itself into the general framework of the integrated control strategy by two different approaches:

- identification of the potentially endangered zones, likely to be most vulnerable to a specific disease, owing to the prevailing ecoclimatic conditions (soil humidity, air humidity, surface temperature, evapotranspiration ...) which could play an active role in the propagation of the disease
- early detection of the first nuclei of infestation prior to the appearance of generalized evident symptoms.

The present paper will exclusively deal with the second approach.
Owing to the large areas to be controlled, remote sensing technology seems actually to represent the only realistic way to perform a generalized crop health monitoring system.

Numerous investigations have proven the potentialities of aerial photography (at scales from 1/4,000 to 1/10,000) for detection of areas affected by stress, microbial disease or insect infestation, both on forests (Murtha 1978, Larcher et Boullard 1977) and on agricultural crops (example of corn blight, NASA 1973). Among the European countries, Great Britain has first become conscious of the practical effectiveness of aerial observation aimed at a systematic monitoring of the main agricultural crops, by the use of B/W infrared photography (Hooper 1977).

3. Aerial photography and multispectral scanning

The advantages of aerial photography are essentially its high spatial resolution compatible with the small size of the areas to be identified, together with its characteristic to be a relatively easy tool to manage for biologists and agronomists. However the high spatial resolution becomes a serious drawback if large agricultural areas are to be monitored. At the same time, digital rather than analog signals would lend themselves to some kind of automation in the data processing phase, thus requiring less human assistance. Therefore a need for using multispectral scanning (MSS) in crop health monitoring has grown in the past few years, in spite of their present lack of spatial resolution (from a space platform) and of the numerous problems involved in their application which always require a multidisciplinary approach.

This MSS orientation does not mean at all a complete substitution of air photography by spectral measurements but the complementarity of the two methodologies at two different scales: detection by MSS techniques of extended zones partially infested via their abnormal spectral response, identification within these zones of the responsible smaller areas via aerial photography.

3. Spectral signature of plant stresses

In the attempt of using MSS techniques for crop health monitoring, the definition of the "spectral signature" of stressed vs normal crops represents an essential requirement. The spectral response (absolute reflected radiance as well as the relative value of the spectral reflectance factor $R(\lambda)$) is actually a mixed response resulting from the combination of the true spectral characteristics with the interferences due to the atmosphere and those caused by the variability of the illumination and observation angles.

Spectral signatures (for which the degree of dependency from the mentioned interferences is possibly established) should be derived from the empirical spectral measurements in view of the discrimination, via remote sensing techniques, of refined spectral characteristics of observed objects.

The most common way of deriving the spectral signature is by correcting the measured spectral values on the basis of adequate models of reflectance (Smits 1972, Bunnik 1979). Another method, to be applied on experimental basis, consists in a systematic analysis of the influence of illumination and observation angles on the spectral measurements (Reichert 1979). This method has been used in the sugar beet investigation to be described later.

The interference from the atmosphere in aircraft and space observation is a problem which has received too little attention up to now (Maracci and Sturm 1976) and is far to be solved.

4. Types of spectral modifications in diseased plants

Plant stresses and diseases may be caused by biotic (fungi, virus, insects...) as well as by abiotic factors (air pollution, nutrient and water deficiencies, secondary effects of pesticides). They result in several kinds of modifications (occurring mainly in the leaves) which induce at their turn various types of spectral modifications.

Three main kinds of foliar modifications should be considered, affecting pigmentation, internal structure and water content respectively, with the possibility of their combination at certain stages of evolution of the disease. Such a classification of foliar modifications is particularly valuable owing to the fact that the spectral modifications of leaves will be induced in three corresponding ranges of wavelength: visible range (0.4-0.7 /um) for pigmentation, near infrared (0.7-1.3 /um) for leaf structure, intermediate infrared (1.3-2.6 /um) as well as thermal infrared (2.6-25 /um) for water content. The various pathological groups of diseases (trophic, auxonic, necrotic, vascular, lytic, epiphytic) can be tentatively characterized by their probable spectral modifications (De Carolis et al. 1979).

Various comments should be added here:

- any attempt of early detection of diseases should be based on the water content modification prior to the occurrence of visible symptoms affecting the leaf structure and/or pigmentation. This remark emphasizes the importance of sensing the reflected radiance in the intermediate infrared range (1.3-2.6 /um with water absorption bands at 1.45, 1.95 and 2.6 /um) as well as the emitted radiance in the thermal infrared range (2.6-25 /um) where the radiative processes are strongly correlated with transpiration processes.

- the spectral modifications induced by a disease in a canopy does not necessarily coincide with that induced in leaves, as a result of several factors like canopy structure, sun illumination, leaf area index leaving a certain fraction of base soil between the plants ...
- in order to enter into the more general framework of crop production forecasting, information on crop diseases obtained by remote sensing should be related quantitatively to losses in crop yield. Therefore the remote sensing approach (relation between disease and spectral characteristics) needs to be complemented by an intensive agronomic approach (relation between disease and yield).

5. Identification of diseases

If adequate remote sensing techniques are likely to allow the discrimination of stressed agricultural areas, the question remains open whether the diseases could be specifically identified. According to the preceding discussion, the pathological group including a specific disease might be recognizable from the type of spectral modifications observed in the leaves. However, the multiplicity of diseases affecting certain crops (like vineyard and sugar beet for ex.) is such that their identification will result rather from the integration of observed biological and remote sensed parameters than from the latter alone.

5. European remote sensing project on sugar beet diseases

Owing to the economic incidence of sugar beet diseases in the EEC countries, a joint project has been set up aiming at integrating the results of investigations carried out on a German test site (Rhine Valley) within a national programme with results acquired on an Italian test site (Po Valley), under quite different ecological and epidemiological conditions.

Identical methods have been used in the two test sites, at two stages of plant and disease development, for the quantification under field conditions of the spectral behaviour of diseased and healthy sugar beets. These methods allow the measurement of the spectral characteristics of the crops in the whole range of the electromagnetic spectrum, from the visible up to the thermal infrared.

Four sugar beet diseases could be investigated: rhizomania (fungal + viral agents), cercospora leaf spot (fungal agent), nematode disease (Heterodera Schachtii), yellowing virus (only in Germany). The observations included also some fields of sugar beet affected by water stress, in order to allow a comparison with the water stress induced by the disease itself.

The partial results of the project are to be presented at this Congress by the various participants.

References

1. Bunnik, N.J.J. (1979) Relations between spectral signatures and physical properties of crops, Comm. Eur. Communities, Ispra-Course Oct. 1979, 31 p.

2. Commission des Communautés Européennes (1980) La situation de l'agriculture dans la Communauté. Rapport 1979, Bruxelles-Luxembourg, Janvier 1980.

3. De Carolis, C. and Amodeo, P. (1980) On the hypothetical response of classified plant diseases to visible, near and thermal infrared (in course of publication).

4. Hooper, A.J. (1977) The use of aerial photography in crop, pest and disease studies in England. Colloque Soc. Française de Phytopathologie: Télédétection et Protection des Plantes, Paris, 9.12.1977.

5. Larcher, G. et Boullard, B. (1977) Photographie aérienne fausses couleurs - Carte phytosanitaire d'un massif forestier. Colloque Soc. Française de Phytopathologie: Télédétection et Protection des Plantes, Paris, 9.12.1977, 5 p.

6. Maracci, G.C. and Sturm, B. (1976) Measurements of beam transmittance and path radiance for correcting LANDSAT data for solar and atmospheric effects. Fifth Conf. on Space Optics, Oct. 1975, Marseille (France).

7. Murtha, P.R. (1978) Remote sensing and vegetation damage: a theory for detection and assessment. Photogrammetric Engineering and Remote Sensing, 44, 9 : 1147-1158.

8. NASA (1973) Corn blight watch experiment. Final Report, Vols 1-3, Johnson Space Center, Houston, Texas.

9. Reichert, P.G. (1978) The multispectral scanner as a research tool for signature measurements. Proc. Int. Symp. Remote Sensing, July 2-8, 1978, Freiburg FRG, 10 p.

10. Suits, G.M. (1972) The calculation of the directional reflectance of a vegetative canopy. Symp. Remote Sensing of Environment, 2 : 117-125.