COMMISSION OF THE EUROPEAN COMMUNITIES

COM(94) 332 final
Brussels, 19.09.1994

REPORT FROM THE COMMISSION

REPORT OF THE FIRST PHASE 1989-1993

OF THE PILOT PROJECT ON REMOTE SENSING

APPLIED TO AGRICULTURAL STATISTICS

INDEX

REPORT ON THE FIRST PHASE OF THE PILOT PROJECT ON REMOTE SENSING APPLIED TO AGRICULTURAL STATISTICS

1. INTRODUCTION

This document is the final report on the first five years of the Pilot Project on Remote Sensing Applied to Agricultural Statistics, 1989-1993. A final report on the conduct of the project is provided for in Article 3 of Council Decision 88/503/EEC of 26 September 1988, to be presented to the Council in the first half of 1994. It also covers work done in 1987 and 1988 in relation to the project. Following a proposal by the European Parliament, funding was granted as early as 1987 for preparatory work on the project.

The ten-year programme for the application of remote sensing to agricultural statistics was initiated by DG VI Agriculture in cooperation with the Statistical Office of the European Communities (SOEC) following work by the Joint Research Centre (JRC) in this field. The JRC is responsible for implementing the programme in close cooperation with national laboratories and organizations. The Council Decision has a budgetary impact on only the first five years, during which the project was covered by a special technical appropriation.

The objective set for the project was to develop methods for improving agricultural statistics in the Community through the use of remote sensing techniques. Such methods were to be tested on fairly large areas and were to be developed to a stage where they could be put into operational use. This entailed the use of satellite data for which there would be guaranteed continuity.

The priorities set for the projects were as follows:

- inventories of acreages;
- inventories of production;
- production forecasts.

In this last action, the prediction of foreign harvests, which was initially one of the priorities, has been postponed to the second phase.

The crops targeted were the ones in which there is the biggest market, to the exclusion of crops consumed on the farm, such as fodder crops.

Representativeness was sought not only at Community level, but at regional and national level too.

In order to meet these objectives, the pilot project was organized into seven actions shown in the above table.

TABLE I: OUTLINE OF THE AGRICULTURE PROJECT

Action	Methodology	Geographic localization	Input
1. Regional inventories (acreages)	Regression estimator	5 selected administrative regions	High-resolution satellite data (SPOT, Landsat-TM)
2. Vegetation conditions and yield indicators	Spatial or temporal comparison of VI and Ts (integrated indices)	Selected regions and sampling of sites, then all of Europe	Low-resolution satellite data (mainly AVHRR)
3. Models of yield prediction	. Improvement of existing agrometeoro-logical models . Integration of satellite data in agro-meteorological models . Deriving agronomic parameters (AET) . Direct relationships		Meteorological data Agronomic information Low-resolution satellite data High-resolution satellite data
4. European rapid estimates of acreages and potential yields	Computer-assisted photointerpretation	Sample of some 50 sites throughout Europe	High-resolution satellite data
Backup activities			
5. Advanced agricultural information system	Comparison with previous years		Integration of all available results
6. Area frame sampling; associated surveys	Estimates obtained by integration of the above methods with conventional ones		Stratification, segmentation, sample surveys on the ground in conjunction with farmers
7. Long-term studies	Backup documents or data for other actions		Using new sensors; Geographical Information Systems

Each of actions 1 to 5 corresponds to a specific operational objective, action 6 is a backup action and action 7 involves a number of long-term studies with no specific link with any particular operational objective. As regards the transition to practical applications, various schedules have been set for the different actions:

- short term (3-5 years): actions 1, 2 and 4;
- medium term (5-10 years): actions 3 and 5;
- long term (over 10 years): action 7.

The project team, comprising nine members supplemented by national experts, was recruited in 1987 and 1988. Action 1 got under way in 1988 and the rest of the work in 1989, the first year of the project. The setting-up of institutes within the Joint Research Centre in December 1988 gave an official structure to the project team, which was grouped together in a special agriculture unit reporting directly to the Director of the Institute for Remote Sensing Applications. This restructuring was the result of a desire to direct the JRC towards scientific and technical activities targeted at clearly identified external users, in particular the other departments of the Commission. This facilitated relations both between Commission departments and between the Commission and the national authorities and consultancy companies.

These close links were provided for in both the legislation and the technical guidelines for the project. The bulk of the work was to be done by national companies and agencies. In addition to receiving regular reports on the progress of the project, the statistical services or ministries of agriculture occasionally had the opportunity to participate directly in certain actions. In this way, they obtained a more practical view of the project.

The validity of the 1993 results can only be verified when the official figures will have become available (in early 1994). A first evaluation indicates that the Action 4 estmates of acreage and production are, for most crops, in agreement with the EUROSTAT estimates. However, the total cereal production, and mainly of soft wheat, appeared to be difficult to asses in 1993. This is probably due to the new Common Agricultural Policy, particulary is related to the set-aside regulations. If this analysis is confirmed, it would mean that the lands put into fallow during this first year of CAP, were generally the lest fertile ones. The common models used to estimate yield, without taking into account this shift, were therefore difficult to apply.

2. ACTION 1: REGIONAL INVENTORIES

2. 1 Objective and methods

The aim of this action was to meet the need for accurate and objective annual information on acreage and production at regional level covering the main crops. The method adopted was to establish close links between satellite data and observations on the ground. Development and evaluation was to focus on the so-called regression estimator method. This action comprised two separate components:

- objective observations in the field with a sample design established or enhanced by remote sensing;
- automatic classification of the satellite data in order to improve the estimates generated by the above-mentioned surveys on the ground using the regression method.

Remote sensing also came into play in providing the enumerator with documents enabling him to identify plots of land accurately on the ground.

The first component was developed as part of backup action 6 because the method was standardized for all project work involving ground-based monitoring, particularly action 4. However, it is presented here.

2. 2 Works

This action was implemented in three separate stages:

- first phase: 1988-1989, in which strictly identical methods were applied in five regions;
- second phase: 1990-1991, in which local adaptations were made and the active participation of the regions and national bodies was required;
- third phase: 1992-1993, in which the project was used as a basis for national and regional initiatives.

First phase: 1988-1989

This action was able to start as early as 1988 thanks to a European Parliament decision, which provided for finance and setting up a project team.

It was implemented in five administrative regions in Germany, Spain, France, Greece and Italy. These areas (see Fig. No 1), were very representative of the most important annual crops and presented a variety of climatic conditions and farming practices. They covered a total area of about 100 000 km2.

In 1988 and 1989, the work was carried out independently of the national statistical services and regional authorities, using strictly identical procedures and methods, by national services companies (see Annex 1: list of contractors).

The method used in 1988 was as follows:

- stratification on the basis of existing topographical documents and maps;
- selection of a sample of 600 square segments of 50 hectares;
- survey on the ground on the basis of aerial photographs;
- simultaneous acquisition of full coverage of the region by both Spot and Landsat TM;
- automatic classification of the satellite data;- analysis of the results.

In 1990 the following changes were made:

- improvement of the stratification using 1988 satellite images;
- further improvement of the effectiveness of the sample by reallocating it into strata using the 1988 results;
- a single coverage was introduced giving preference to Landsat;
- a yield component was added by selecting points in the segment, for which the farmer was identified and interviewed;
- a yield by remote sensing component was added by establishing a relationship between vegetation indices drawn from satellite data and reported yields.

<u>Second phase: 1990-1991</u>

The study areas were extended with the cooperation and joint financing of national and regional authorities (see Fig No 2). Methods were slightly modified to accommodate local characteristics or programmes, such as the use in Italy of segments from the Agrit programme, Teruti photographs in France, etc.

Methodological studies were carried out to solve particular problems or extend the statistical system to data on the structure of holdings: weighted segments as opposed to the so-called closed segments used for acreage and yields, use of Corine Land Cover data in Portugal for stratification purposes, etc.

<u>Third phase: 1992-1993</u>

The work was carried out on the initiative of the Member States and the level of participation in the project varied widely (see Fig. 3).Activity tended to be limited to the provision of technical and scientific support, either directly to local or national authorities or more often to services companies working for them. Several requests were received for the development of methods for countries outside the European Community.

Internal work, relieved of the administration of the actions, which was very time-consuming in the first years of the project, concentrated on certain aspects, computer programmes, stratification, and methodological research. However, coordination and even the mere provision of information on work accomplished became more difficult.

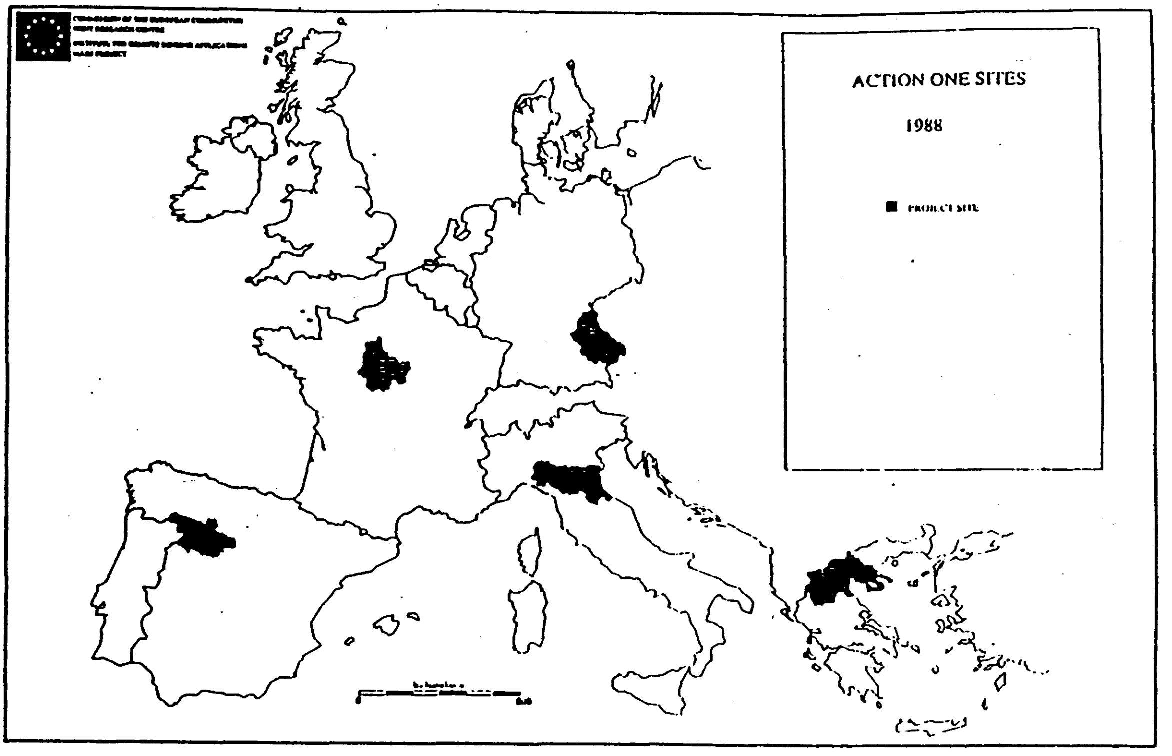


Figure 1: Action 1 study areas, 1988-1989 phase

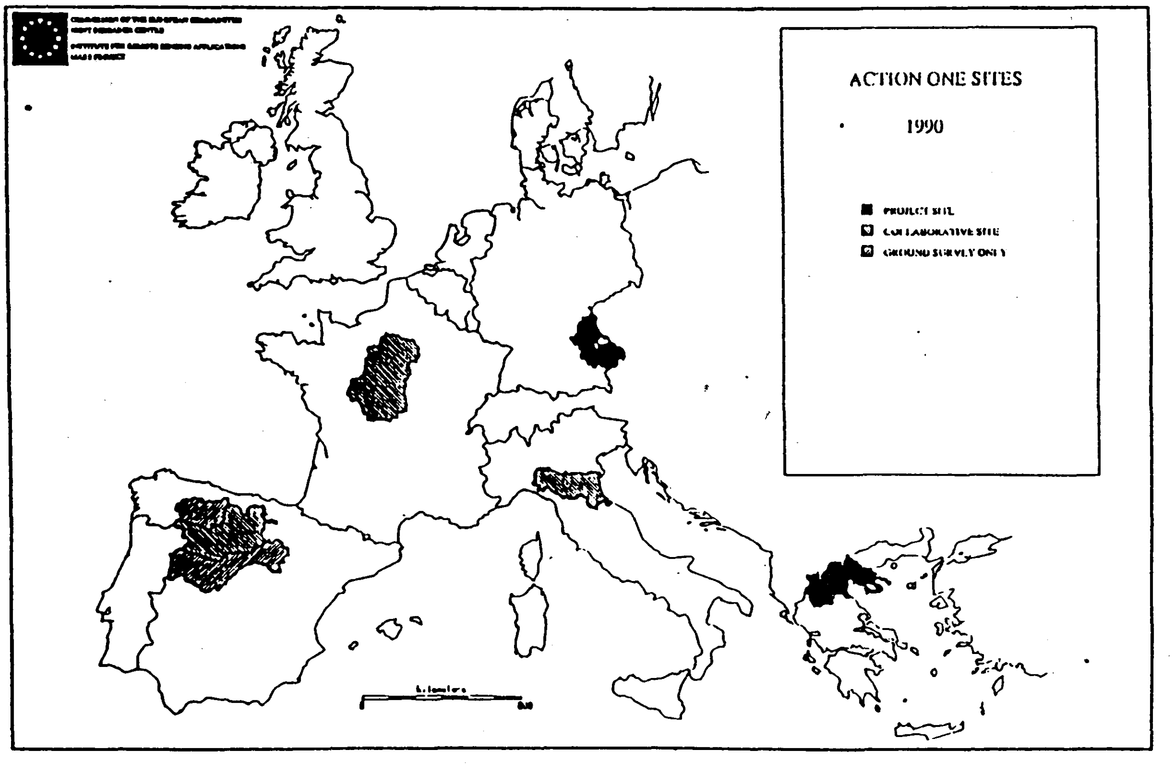


Figure 2: Action 1 study areas, 1990-1991 phase

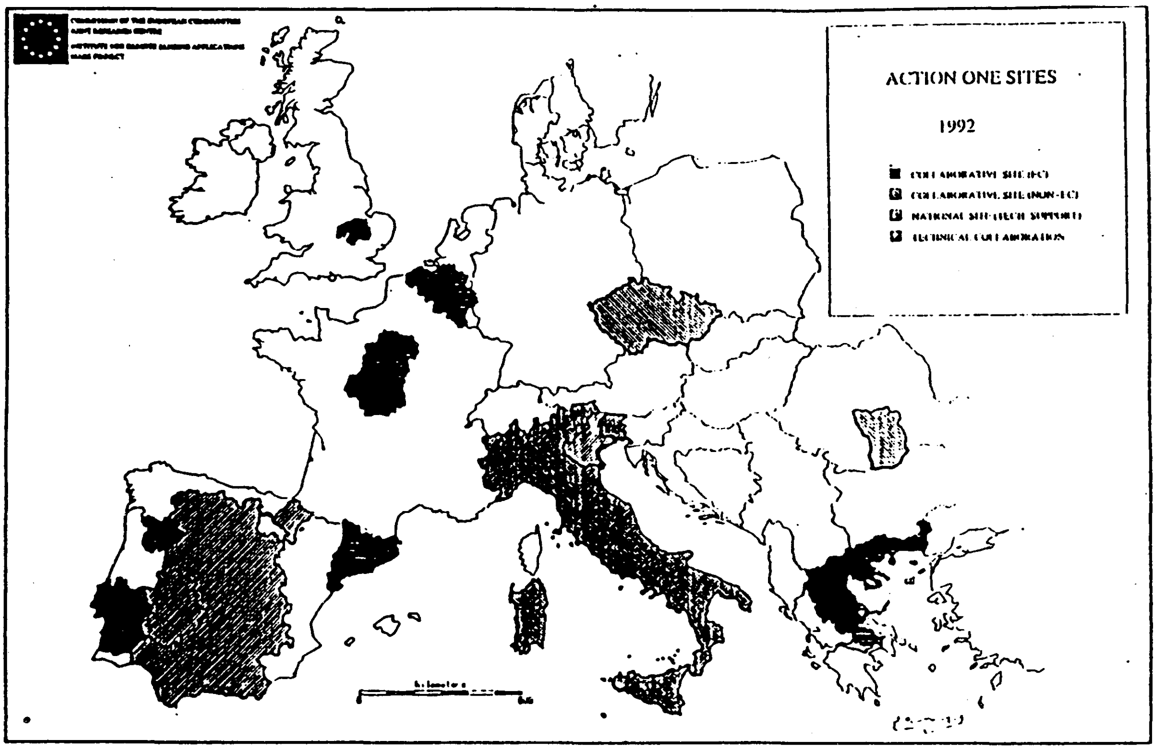


Figure 3: Action 1 sutdy areas, 1992-1993 phase

2.3 The results

A distinction must be made between the results of the two stages mentioned above: stratification and ground surveys on the one hand, and automatic classification of satellite data on the other.

1. Component 1

Stratification is very economical as, generally speaking, it reduces the cost on the ground by a factor of two for the same degree of precision. It pays for itself in the first year and can be used for several years in a row. Satellite images are the ideal means of detecting homogeneous areas of land use and physical boundaries, such as roads, rivers, paths and the edges of forests, for selecting segments and assessing in advance difficulties arising from the number of plots. Since the period in which the images are obtained is not critical, the method is applicable throughout Europe.
The square segments method is quick and effective. The best tool for the enumerator is an enlarged aerial photograph, but nearly everywhere the use of a 1/10 000 enlargement of the Spot images of the segment means this can be dispensed with if there are problems using it.

The identification of the farmer followed by a normal interview survey can be carried out to provide a complete survey system not restricted to crop acreage.

The results of component 1 were published in Teleagrinews Nos 1 to 5 (see above example of Macedonia taken from Bulletin No 3 of May 1990).

Culture	Official statistics (x 1000 Ha)	M.A.R.S. estimate (x 1000 Ha)		relative efficiency: with stratification		with T.M.-		Crop
	1988	1988	1989	1988	1989	1988	1989	
Blé tendre	195.5	158.5 (11.7)	163.6 (11.0)	1.25	1.39	1.84	1.99	Common wheat
Blé dur	150.3	175.4 (12.3)	161.1 (10.0)	1.17	1.49	2.17	2.13	Durum wheat
Orge		60.4 (6.4)	65.5 (5.5)	1.12	1.29	(*)	1.67	Barley
Légumes secse	5.0	0.6 (0.3)	2.2 (1.0)	1.44	1.72	3.56	(*)	Dried pulses
Maïs	30.4	27.5 (3.3)	22.5 (2.0)	1.70	1.99	1.67	3.11	Maize
Tournesol	16.3	16.6 (3.5)	4.0 (1.2)	1.16	1.09	1.38	1.41	Sunflower
Pomes de terre	4.0	6.0 (3.0)	0.9 (0.7)	0.67	1.10	0.99	7.61	Potatoes
Betteraves	10.3	15.9 (3.8)	13.9 (1.2)	1.36	1.99	1.23	7.16	Sugar beet
Riz	12.0	14.1 (1.1)	9.9 (0.5)	7.04	6.27	6.31	18.86	Rice
Coton	57.7	73.9 (6.2)	60.5 (0.4)	2.26	2.47	1.54	3.19	Cotton
Tabac	20.5	31.7 (4.7)	17.7 (2.2)	1.30	1.60	1.06	2.21	Tobacco

The figures between brackets are standard errors.
(*) The regression correction has not been applied

Table 2: Results for Macedonia

2. Component 2

The regression estimator method was applied in all the regions. The Spot and Landsat resolutions are very suitable for automatic processing, which is easier with Landsat. However, this method is subject to strict constraints, both technical and financial, e.g. regarding the acquisition of the images.

With the exception of Greece in 1989, it was, in practice, never possible to cover the whole of a region of 20 000 km2 within the optimum period, which was about 40 days, with a single type of satellite.It was nearly always possible to cover the region by using both Spot and Landsat, which complicates processing, and by straying outside the optimum period for certain portions of the territory, which reduces efficiency. The technical aspect of the operation also caused some problems.

The services companies selected for the first phase did not have major problems with the technical aspect of the operation; however, such problems arose when national constraints affected the choice. The technique of automatic classification over a vast area was technically difficult for government agencies or services companies not specialized in remote sensing. For this reason, costs were high for results that were not reliable for all crops. Except in favourable conditions, such as in Greece, for example, with the current state of technology,the cost of images, etc. component 2 should not be recommended from an operational point of view for regional or national statistical services.

2. 4 Technical spin-offs for other programmes

The methods developed in action 1 had many positive spin-offs for other programmes and work, whether statistical or not.

PHARE programme

The Commission of the European Communities has set up a programme of assistance to central and eastern European countries. Component 1 led to the development of a certain number of indicators for agricultural statistics, trends in crop acreage and the transformation of farm structures. A method based on a list of holdings would not be very effective in view of annual changes in holdings. Following two test studies, this method is being widely adopted under the PHARE programme.

CORINE programme

In support to the CORINE Landcover Update programme of DGXI-EEA-TF, the methodology for the updating of the CORINE Landcover data base was established in 1991. It relates to the stratification method. On the basis of the methodology, a prototype informatic s system was redalized. In 1993, the test of this system were ongoing. The final system will be distributed to the Member (schedule for 1994).

Management and monitoring

Agricultural statistics are a means of monitoring applications for individual subsidies at a fairly general national or regional level. As statistics are usually obtained by interviewing farmers, bias may creep in. It was possible to bring such distortions to light in the case of the 1990 statistics on durum wheat in southern Italy and northern Greece.

Under the new common agricultural policy, there is a danger that farmers' statistical returns will be biased. A more objective method applied periodically could prove essential.

Assistance for services companies

National services companies often answer calls for tenders from international organizations for statistical work in developing countries. These may be one-off operations or involve setting up more routine programmes. The methods developed are very suitable in certain conditions. The project personnel often act as consultants, thus enhancing the expertise of European services companies.

2.5 Conclusions, future developments

Statistical services are now fairly familiar with the potential of remote sensing in the area of crop inventories at regional or local level. The introduction of remote sensing entails the adoption of area sampling techniques, previously little used in Europe, where the prevailing method is surveys based on lists of farmers.

Putting the methods developed in action 1 into operational use means, in practice, supplementing structural surveys and compulsory censuses with an area survey generating more rapid, objective and accurate vegetation statistics. This appears to be an attractive alternative in countries where there are occasional weaknesses or where current systems do not fully meet the demands created by the new measures of the common agricultural policy. In practice, it is the countries of southern Europe that experience such difficulties owing partly to the large number of farmers. It is also in these areas that remote sensing is the most effective, and the system of area surveying is therefore to be recommended. It is also in southern Europe that operational programmes have been set up: Greece, Spain, Italy, etc.

The regression estimator method is not to be recommended per se, not for reasons of technical feasibility, but because it requires too big an effort to implement, unless highly specialized services companies are brought in, for results that are not particularly outstanding frm an economic point of view, except perhaps in Greece and southern Spain.

The project has generated a body of technical know-how among both statistical services and services companies which will enable them to respond and adapt to unforeseen developments. By using statistical systems based on lists of farmers or area systems based on either points or segments, through familiarity with the operational potential and limits of remote sensing, by stratification or automatic processing of satellite data, it is possible to select the method best suited to the case in point.

It is recommended that limited action should continue in support of national statistical services that are engaged in putting these methods into operation. This should cover methodological aspects, but also the development of operational software and training.

It is also expected that EUROSTAT will provide good coordination of these actions.

Technological developments relevant to component 2 of this action on regression estimators should be monitored in order to identify changes that might be introduced by the use of new sensors, such as radar.

3. ACTION 2: VEGETATION CONDITIONS AND YIELD INDICATORS

3. 1 Objective and methods

The objective of action 2 was to use satellite meteorological data for monitoring vegetation conditions and providing indicators of the yields of the main crops. In addition to the objectivity of the method, the main attraction was the possibility of providing such indicators at various geographical levels: local, regional, national and European.
The method consisted in processing the satellite data to generate two indicators: a vegetation index and surface temperature. Since these indices are directly related to the state of vegetation and crops, a spatial and temporal comparison of these data with other years or areas should make it possible to assess comparative yield levels.

3. 2 Work

Two types of work were done independently:
- the development of application methods;
- the pre-processing of AVHRR data, which in raw form are unsuitable for ground observation.

These studies were carried on in parallel as they are interdependent; however, the bulk of the work on methods was done at the beginning of the project and the bulk of the work on processing at the end.

Application methods

The development of application methods was carried out under contract (see report SP-I.89.04 EN and the map below showing the various study sites and the corresponding research teams).

Subject 1: Exploration of agronomic applications
The study was carried out by analysing two types of data on a multi-annual basis: the vegetation index (NDVI), which is composed from data on visible and near infra-red radiation and its development profile, and thermal infra-red radiation, with the calculation of surface temperatures (Ts) and the search for drought indicators.

Subject 2: Generating models of vegetation response on the basis of NOAA-AVHRR data. This is done by incorporating external data, either in the form of high-resolution satellite images, or more traditional data, such as those from weather stations.

Subject 3: Definition of useful products for a centralized agricultural information network. The first product identified so far is the classification of NOAA-AVHRR data according to land use.

At a later stage, some more basic research work was carried out, particularly to derive actual evapotranspiration figures using data drawn from the thermic bands of the AVHRR sensor and air temperature.

The development of methods covered only data from the NOAA-AVHRR satellite. Research work tended to demonstrate the importance of data from the Meteosat satellites, which were left out of the project in order to simplify matters and avoid spreading efforts too thinly.

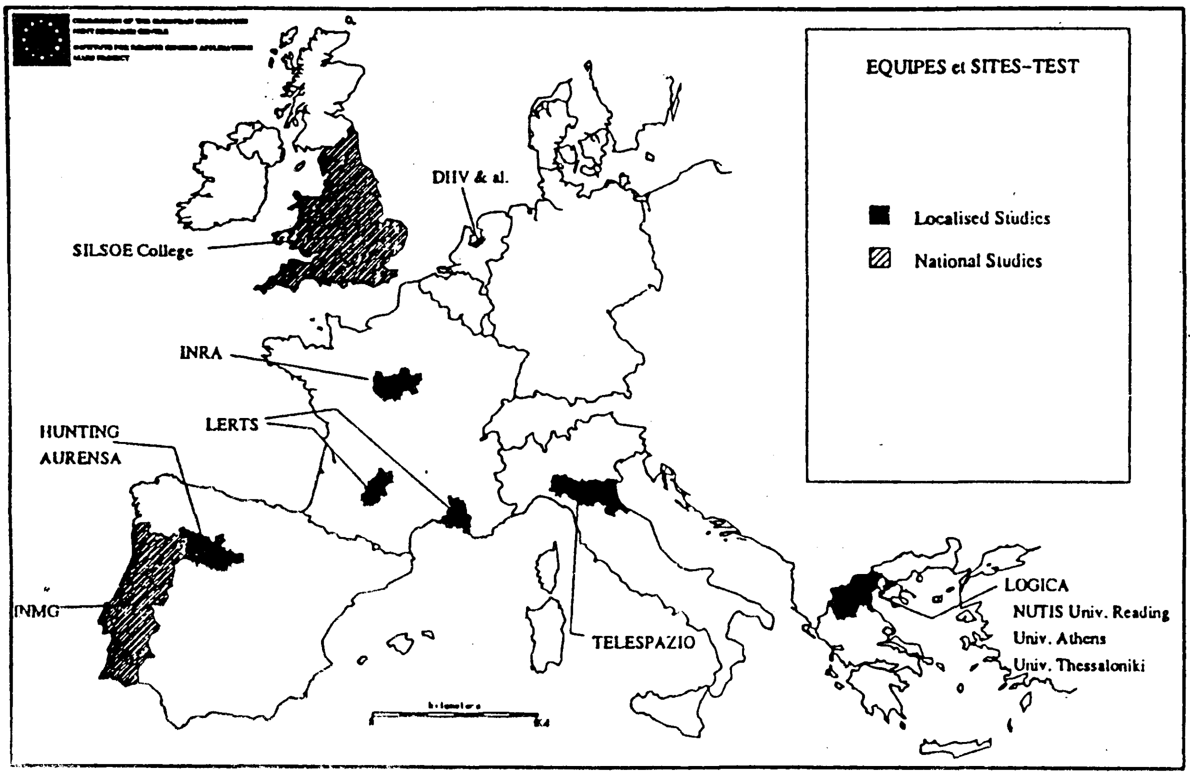


Figure 4: The sutdy sites and research teams related to Action 2

Processing of data

The development of processing and flow procedures for NOAA-AVHRR data was done in cooperation with the European Space Agency (ESA), which was responsible for the acquisition and storage of data, which entailed coordination with the receiver stations. The ESA undertook to acquire and store all the data needed for daily coverage of Europe and a series of historical data.The project undertook to develop processing algorithms with the highest possible degree of automation for transforming the raw data into a geometrically and radiometrically adjusted product (level 2) in which the initial image is stored. This would be supplied to the ESA and the national stations belonging to the network. In 1989, the precise specifications of the algorithms were defined. External contracts were signed for writing the codes and determining certain coefficients for the algorithms, e.g. calibration coefficients of the sensors of various satellites. These elements were delivered at the end of 1990.

Starting in 1991 a second processing phase got under way to generate the required products:

- daily mosaic of the Community generated from NOAA-AVHRR data (level 3);
- database for incorporating data for a homogeneous area or a given period, e.g. ten days, and for generating a more elaborate synthetic product (level 4). These could be time profiles for a given area or cartographical products for a given period.

Since 1992, the improvement of the software has gone on in parallel to the operational processing of historical data.

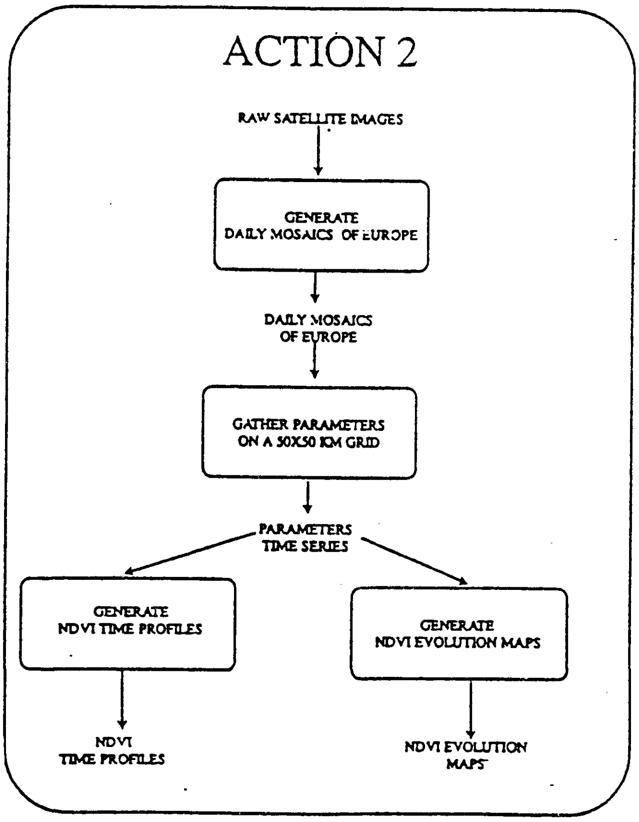


Figure 5: The NOAA-AVHRR data flux and processing

3. 3 The results

The results of these studies were very satisfactory, but it proved much more difficult than expected to convert them into operational procedures, which entail automated operational sequences.

The studies

The qualitative and quantitative results of the studies are particularly good in that they faithfully reflect crop and vegetation conditions. A spot validation of the results is impossible owing to the very low resolution of the NOAA-AVHRR sensors (1km); however, the variations in the vegetation indices faithfully reflect the variations in the yields of annual crops that occupy fairly large land areas. (See reference of reports in annexe).

However, these results must be placed in perspective, in that they are still obtained retrospectively, by which time the variations sought are already known, and the processing procedure is very variable and unstandardized. As the results are very sensitive to the choise of images and to the processing of the data, doubts persist as to their validity in operational terms.

The pre-processing of the data was the most laborious part of the studies, while the quality of the results depended very much on the ability to process a large number of images.

The results are particularly interesting when an exceptional event occurs, such as a major drought.

The data are enhanced by linking with agrometeorological models, which could be envisaged in a subsequent phase of the project.

Processing the data

By the end of 1993 the data are processed internally. There is no obvious error in the software and it is fully automated. Not only it is possible to process the satellite data practically in real time, but there are facilities for processing existing files from 1982 onwards. The sensitivity of the results in reflecting variations in the state of vegetation is not known, and neither are the response times. At present, we do not know whether the software is able to eliminate certain factors of disturbance. Parameters suchs as the thickness of the atmosphere, the viewing angle and the angle of the sun can all influence radiometric quality. Cloud cover in certain areas can reduce the number of ground control points, which can in turn reduce the geometric quality of the images.

The software itself is difficult to transfer owing to the lack of detailed documentation and the fact that it was developed by trial and error. The products generated are nevertheless interesting and can start to be used, though the software requires a period of validation and industrialization.

On the above map, the anomaly observed in Spain corresponds to the drought of 1992, which appears in the country's time profile. The two products reveal the areas most affected and the period of drought in 1992.

This analysis could be refined by profiles of more localized areas and cartographic reference to an average year rather than the previous year.

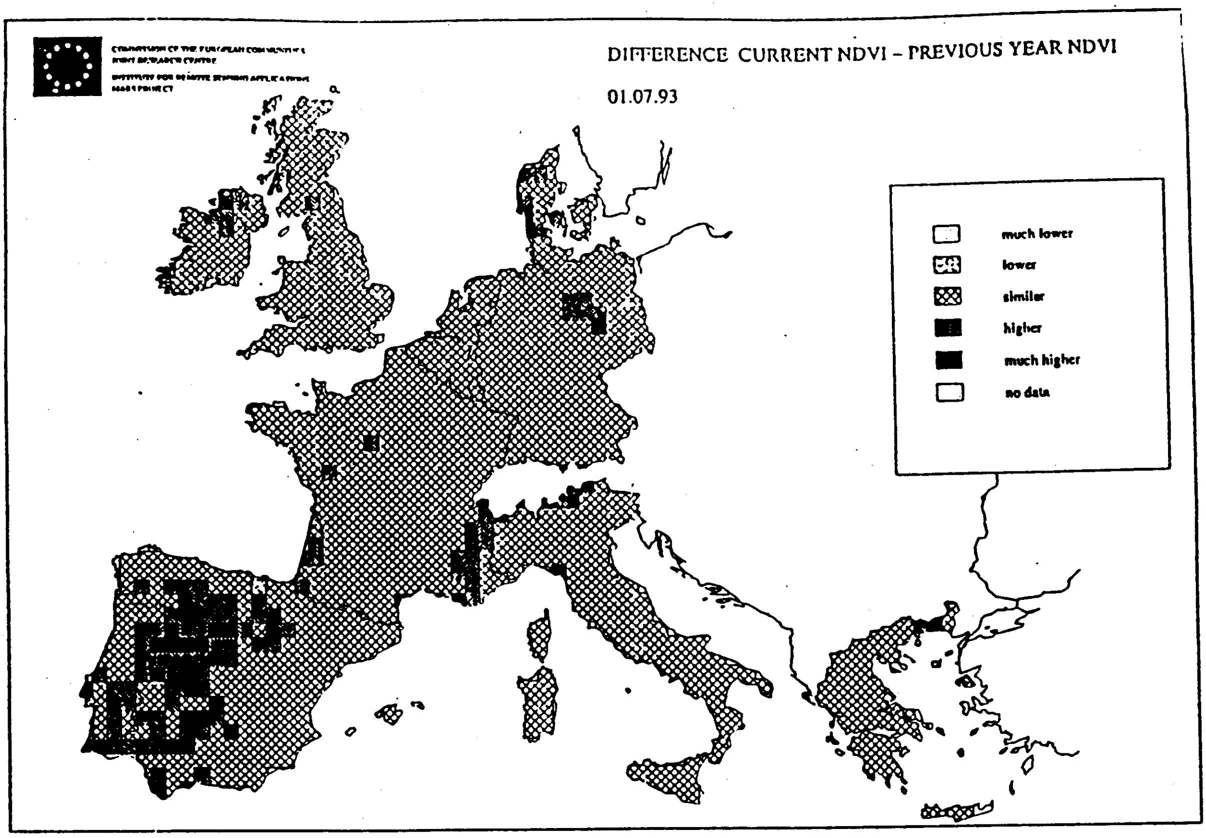


Figure 6: The difference between the NDVI vegetation index between 1 july 1993 and 1 july 1992. (NDVI=" Normalized Difference Vegetation Index". The index is represented on a 50Kmx50Km grid.)

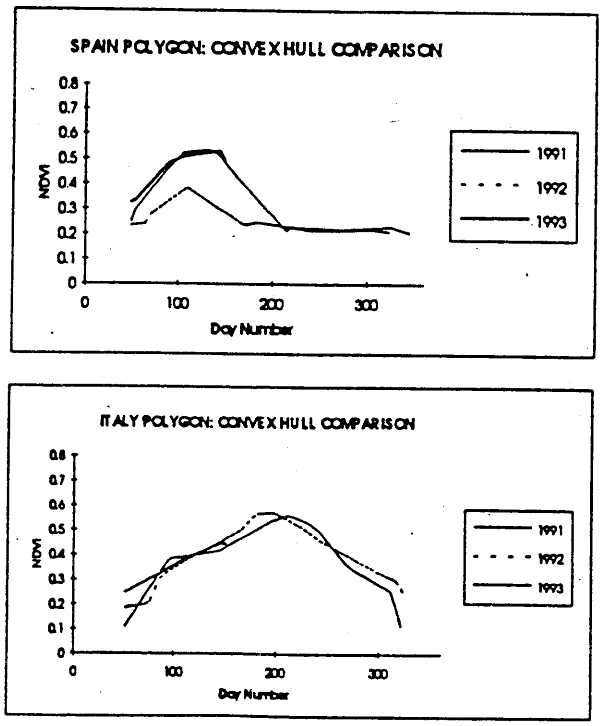


Figure 7: Examples of time profiles of the NDVI Vegetation index

3. 4 Technical spin-offs for other programmes

The result of the automatic processing of NOAA-AVHRR data in near real time up to level 2, defined above, is unique in Europe. Current non-meteorological applications involve a limited number of data processed image by image and not, as here, using an on-going automated procedure. The two types of processing each have their advantages and disadvantages, but automatic processing is well suited to the demands of monitoring over time.It could have many applications, particularly for environmental problems .As part of the project, there are plans to study applications involving forage crops and forests in particular.

3. 5 Conclusions, further developments

The link with the ESA entailed a certain number of constraints regarding formats, computer equipment, data flows, etc., but these constraints, which affected completion deadlines, guarantee a more operational service in the long term, all the more so as level 2 processing has many applications and should in future be covered by a joint service. Only level 3 and 4 products are dedicated Community agricultural statistics applications.

In contrast to action 1, which could be put into operation sooner than planned in the project, the work schedule here is proceeding according to plan.

A number of potential applications have been demonstrated by retrospective studies, which often required specially adapted processing of data.

Standard processing software has been developed and should enable these applications to be created. However, they have not been validated with the new sequence, the sensitivity of which has not yet been determined with any degree of accuracy.

The whole sequence for obtaining and processing the data is still rather labour-intensive, and it is necessary to industrialize for more operational use. However, the procedures would then have to be formalized, which is not yet possible.

There need to be close links with the other project actions concerning crop monitoring, i.e. actions 3 and 4. These links, which were planned when the actions were devised, are only in their early stages, since the production sequence for level 3 and 4 products began only in 1993.

A period of at least three years will therefore probably be required to put action 2 into operational use, i.e. to make it suitable for transfer, like action 1. On the other hand, everything is in place for the full-scale testing of the applications in real time and for links with the other actions in order to incorporate them into the advanced agricultural statistics system.

4. ACTION 3: YIELD PREDICTION MODELS

4. 1 Objectives and methods

Yield prediction is one of the essential aims of the project. The yields of the main annual crops are targeted, as well as those of the main perennial crops: vines, olives and citrus fruits.

So far, yield prediction is done mainly by qualitative methods, or information from correspondents. Only a few countries make objective observations on the basis of a specific statistical plan, and only for certain targeted crops.Models exist based mainly on data from ground meteorological stations; however, they are not very satisfactory in practice.

At European level, the Agromet model has been used by Eurostat for annual crops, but its main contribution concerns trends. Prediction models exist locally and have been developed by research bodies, but they cover mainly annual crops and the input data for the models are generally not available at European level.

Existing prediction models using data from remote sensing have proved to be either unfeasible, e.g. as part of action 1, or relatively complicated to implement, see results of action 2.The objective of action 3 was therefore to develop yield prediction models using ground data, particularly meteorological data available throughout the European Community, that can be enhanced at a later stage by data from remote sensing.

A particular effort was to be made and special techniques developed for perennial crops, for which the advantages of remote sensing are less obvious.
Action 3 was divided into three separate sub-actions:
-the development of a semi-deterministic agrometeorological model for predicting annual crop yields;
- the extension of Eurostat's Agromet model to perennial crops;
- the development of a model for the prediction of vine (and olive) yields based on pollen count methods.

The main effort went into the semi-deterministic agrometeorological model, i.e. one that simulates plant growth, in contrast to the Agromet model, which is purely statistical.For this model, the aim was to use daily meteorological data to produce a yield prediction for target crops that would be sufficiently accurate at regional, national and European level. The models were to generate quantitative data for vast areas, supplemented by local qualitative data from action 2.

The development of the model entailed the compilation of a database on soils, climate and plants as well as yields. It also involved harmonising, at European level, sub-models such
as potential and actual evaporation and water balance. Phenological stages and the quantitative parameters relating to these stages, such as leaf area indices, grain weight, etc., are then established by correlating the basic structural data with current meteorological data.
The yield predictions are obtained by a statistical relationship between the historic series of yields and the historic series of the parameters defined above (see Figure 8).

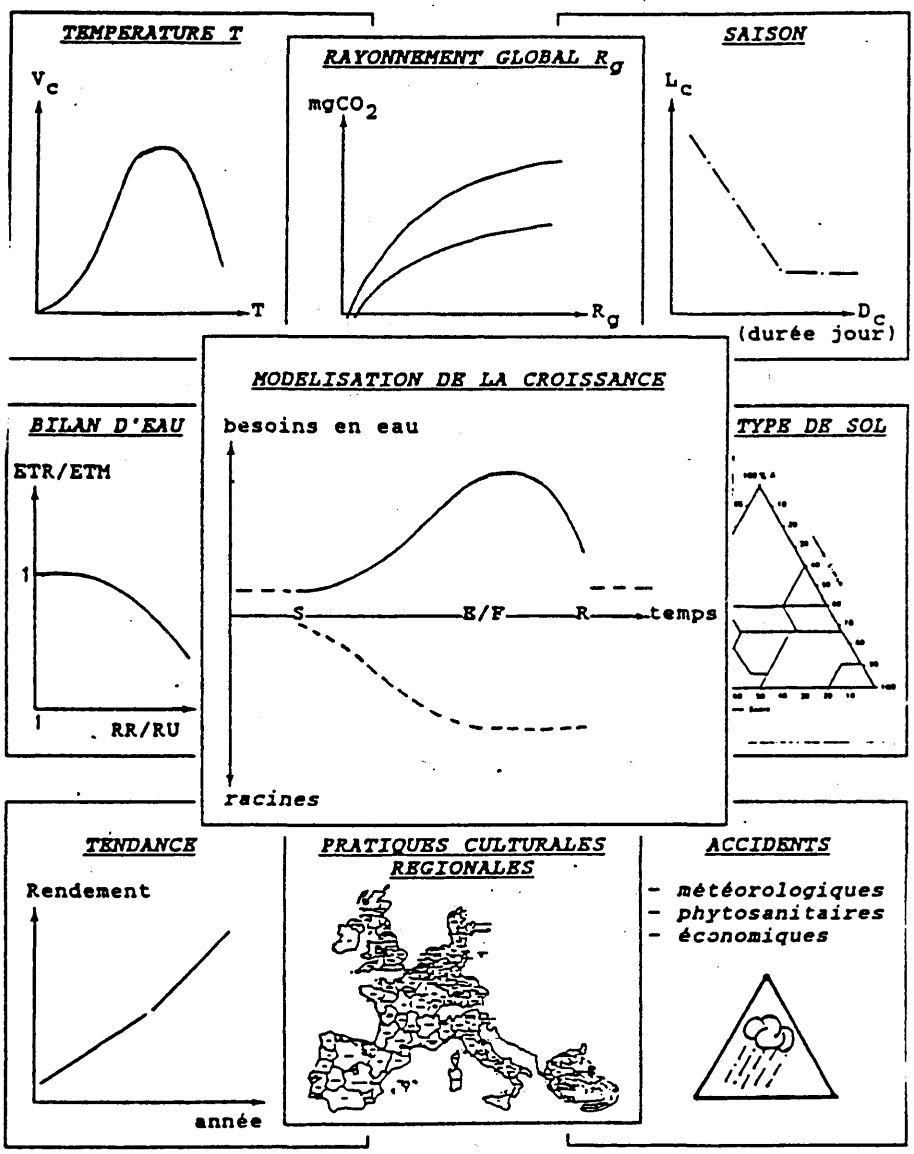


Figure 8: Example of a general agrometeorological model.
(With: MET and AET = maximum and actual evapotranspiration; UR and AR = usable and actual reserve; S = sowing; CE = crop establishment; F =flowering; YM = yellow maturity; CM = complete maturity; D_c = critical daylight hours; T = temperature; T(b) = sum of temperatures, base b.)

4. 2. Work

4 .2. 1. Agrometeorological model

The working framework was finalized as early as 1988. During 1989 and 1990, the main job was compiling the database, which was later gradually improved.
The harmonization of the sub-models and the construction of the models themselves was done in two stages: qualitative models, then quantitative models.

Database

This included data relating to soils, plants and climate (see figure 9).

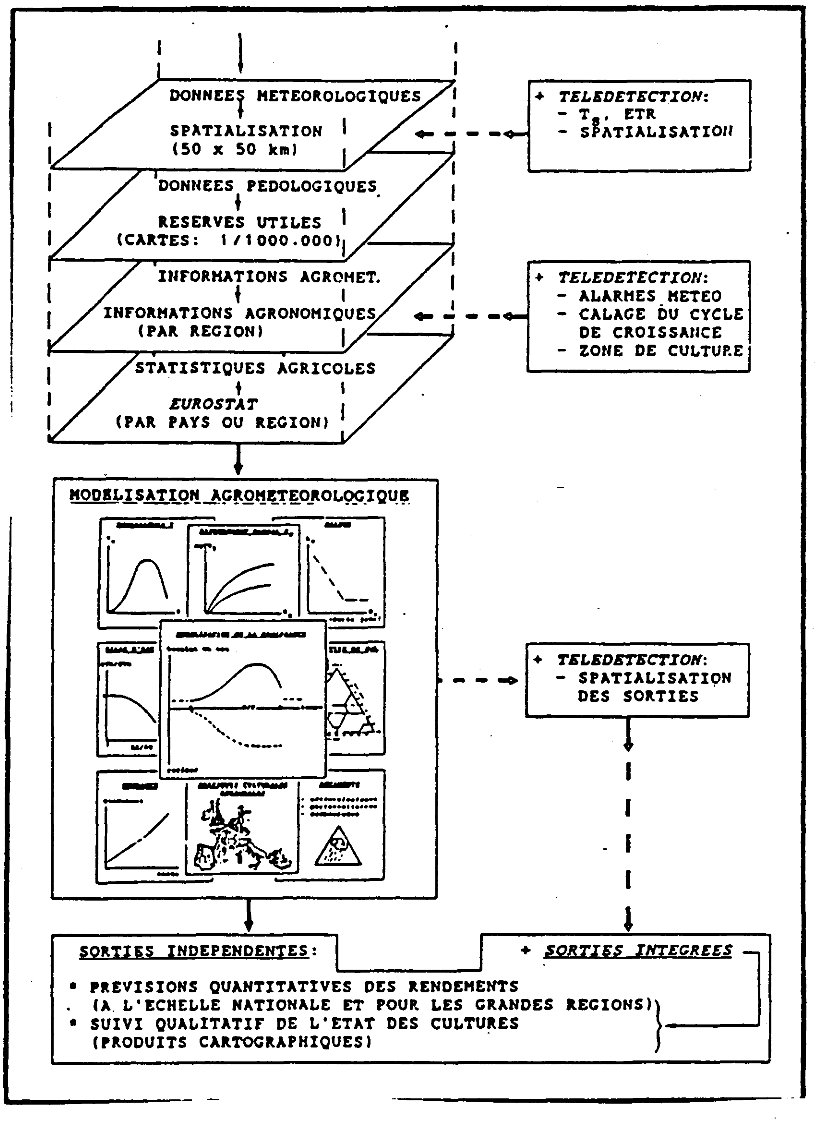


Figure 9: Organizational plan of Action 3(yield prediction models for the Agriculture Project)

For the *soil data*, cooperation with the Orléans National Agronomy Research Institute (France) and the setting-up of a "support group on soils and geographical information systems" led to the production of a 1/1 000 000 pedological map of the European Community, from which information on "usable ground water reserves" was extracted. This stage has been completed for the requirements of the model.

Various contracts were signed for the collection of *agronomic data* for each of the target crops, or, to be more precise, the agrometeorological parameters relating to each crop (see annex). Details of optimal, acceptable and harmful conditions for each phenological stage of durum wheat, for example, were received and generally published.

Historical meteorological data were obtained for stations that had kept records for a fairly long time (25 to 30 years). The data collected were those usually available through the GTS (Global Telecommunications Systems) network and were used as input for the various models and sub-models. They include daily data on:
- rainfall;
- maximum and minimum temperatures;
- water vapour pressure or relative humidity;
- average wind speed;
- hours of sunshine or cloud cover.

Such data were obtained for 350 European weather stations.The real-time data are identical but are obtained for a different group of ground stations, comprising some 700 stations.

The *historical yield data* were obtained from Eurostat's Regio database.

The sub-models

Potential evapotranspiration sub-model

The various meteorological services use different formulae. In preference to measurements in lysimeters, the working party adopted the proposal by Choisnel et al. (1992), i.e the use of the original Penman formula, and not the often proposed Penman-Monteith formula. The adjustments are very good for the most important period March-October. Daily data are required.

Global radiation sub-model

The preceding sub-model requires figures on hours of sunshine, however, the data recorded by the ground stations often include a cloud cover indicator at various periods and not the hours of sunshine. A conversion formula is therefore required. This was tested in some 20 stations which made both types of observation.

Satellite interpolation of meteorological data sub-model

Since the historical data were not obtained for the same group as the real-time data, and could differ for European or regional applications, notional stations have to be created by interpolation.

A grid of points 50 km apart represents the notional stations. The parameters are obtained from the surrounding stations. Between one and four stations are selected out of an initial total of seven by eliminating those which present dissimilarities with respect to the core defined by all seven.
For example, stations close to the sea or at very high altitude, which are dissimilar, would be eliminated.

The Agrometeorology Support Group (SuGrAm), created in 1990, has validated the network of meteorological stations and the interpolation method, and the sub-models to calculate the potential evapotranspiration and the total insolation. This group is coordinated by the World Meteorological Organisation.

The parameters are then obtained by weighting the values from the selected stations, except for rainfall. The rainfall parameter is obtained only from a station selected in the same manner: the one with the smallest difference with respect to the core defined above.

The development model or qualitative model

This is based on the WOFOST model (van Keulen and Wolf, 1986; van Diepen et al., 1989), developed by the University of Wageningen, which is a deterministic model based on the energy balance and the water balance. It was adapted to cope with the input data defined above obtained from the sub-models. Its output is in the form of the following data:

- abnormal weather conditions;
- development indicators:
  biomass
  grain production;
  actual water reserve;
  phenological stage;
  water balance;
  excess water;
  etc.

  for the decade and since the beginning of the cycle.
- related maps.

This model depends on agronomic parameters relating to each crop. In mid-1993 it functions for one typical crop: winter wheat.

The output is quantitative, but as the parameter sought is not primarily yield, it provides an initial qualitative approach to this.

The yield prediction or quantitative model

The input for this model will be a variable linked to the trend drawn from historical yield data and a variable drawn from the development model. Since various soil types and crop varieties coexist in a 50x50 km grid, yielding different results, the results for a basic square are produced by weighting the basic results of the model.

(4)

This component is in the process of development, but is not yet operational.

Computer systems

A series of programs or computer applications had to be developed.
On the recommendation of the Commission, the geographical information system used is Arc-info. As Arc-info's database system is not particularly good, only the Arc portion was used.
In particular we can mention the AMDaC program for the receiving, decoding, quality checking, replacing of missing values and filing of synoptic meteorological data. This program is the first of its kind to be applicable outside national frontiers and can be transported to other countries or regions within the E.C.

The data are stored in the Oracle database. The software was developed in FORTRAN or C and runs under UNIX. As it is still at the development stage, it will have to be industrialized to make it portable and easy to maintain, which would be difficult to achieve at present. The various sub-models and models were developed separately by different organizations, but are all incorporated into the project, at which level the statistical and cartographical output is generated.

4.2.2. Pollen count model

As this method was already used by groups of wine producers for their own forecasts, the work consisted in setting up a network of pollen sensors in the main wine-producing countries.

The difficulty lay in recruiting a network of people to collect the samples, maintain the filters and the station, etc. while ensuring a fairly objective choice of sites. This was coordinated by CEMAGREF of Bordeaux in cooperation with the CNRS's pollen research centre in Montpellier.

Calibrating pollen count to regional wine production requires about five years. However, after the first two or three years, the data can be used qualitatively. A higher pollen count will indicate a more abundant harvest, though it is impossible to quantify.

An important element in the results is the date of flowering, which is indicated by the pollen count curve. This provides a basis for establishing a phenological parameter for use in a future agrometeorological model. It also makes it possible to monitor the weather conditions at the time of flowering, in itself an important factor.

An exchange of results has been organized with organizations that set up such networks earlier, so that the method could be tested locally. There is a problem with the capacity for rapid processing of the pollen filters, which all come in at the same time.

The current state of the network is shown on Figure 10.

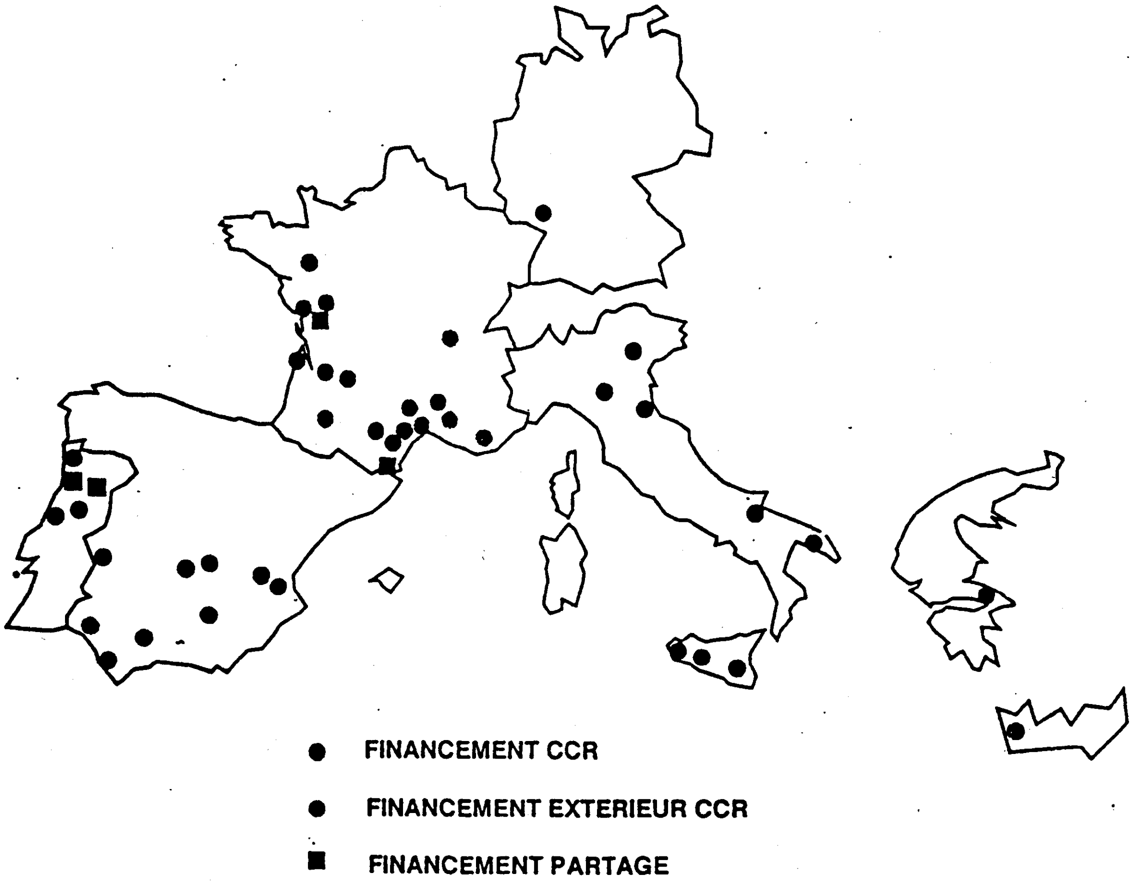


Figure 10: The pollen capture network of the Agriculture Project

4.2.3. Agromet model extended to perennial crops

The Agromet model for annual crops currently used by EUROSTAT was extended to cover perennial crops: vines, olives and citrus fruit. The only change to the yield prediction model for the current year is the introduction, as an explanatory variable, of the previous year's yield.

4. 3 Results

4. 3.1 Agrometeorological model

A single database was developed for all the agrometeorological applications.It contains not only daily meteorlogical data but also knowledge bases on the main crops, updated E.C. soils maps and estimates of useful land reserves in the different countries. It is fully harmonized throughout the Community's twelve Member States. It is complementary to the Corine database, which, for example, contains records from more weather stations, but on a monthly basis. and only contains interannual temperature and rainfall averages.
The water balance, phenological and yield prediction models have been conceived. For the non crop-specific part of the system, qualitative outputs are produced every 10 days. The software for the real-time processing of meteorological data is also operational (see figures 11,12,13 and 14).
These products can already be used by experts in conjunction with other information . The maps clearly highlight the problems encountered at the beginning of the 1992 season in Portugal and at the end of the season in Denmark and eastern Germany. The time curves for one of the grid squares in Denmark show the growth of vegetation in 1992 in comparison with a normal year, and also the deficit in biomass and grain weight.

The crop-specific yield prediction components have still to be implemented, but all the elements are there to do so.
Table 3 shows the first yield estimates for several crops, prepared by the Agriculture Project at the end of October 1993, compared with the 1992 yields (Eurostat figures). This table is an extract from the Y.S.P.R.A.('Yield Surface Production Report on Agriculture') newsletter, produced monthly since January 1993 by the Agriculture Project. This newsletter is an experimental product, with very limited distribution in DG VI and EUROSTAT. It is produced mainly for method validation and does not yet have the value of an operational product. Both estimates and the method, still need to be refined and validated.

Crop		May	June	July	August	Sept.	M (12.93)
(E)	Wheat	5.56	5.46	5.47	5.46	5.40	5.26
(Y)		5.35	5.36	5.35	5.29	5.27	
(E)	Common	6.22	6.08	6.10	6.10	6.04	60.1
(Y)	wheat	5.94	5.94	5.94	5.87	5.85	
(E)	Durum	3.02	3.02	3.02	2.95	2.95	2.41
(Y)	wheat	2.78	2.79	2.79	2.78	2.75	
(E)	Barley	4.13	3.96	3.97	4.14	4.13	4.19
(Y)		4.10	4.10	4.11	4.08	4.04	
(E)	Grain	7.67	7.68	7.68	7.73	7.79	7.73
(Y)	maize	7.54	7.55	7.51	7.65	7.66	
(E)	Sunflower	1.79	1.66	1.66	1.54	1.52	1.15
(Y)		1.63	1.63	1.61	1.50	1.49	

Table 3: Summary of the 1993 monthly yield forecasts for selected crops, as elaborated by the MARS Project. (yield = T/ha; E = EUROSTAT figures; Y = Action 5 estimates; M = EUROSTAT figures as updatesd on 9.12.93)

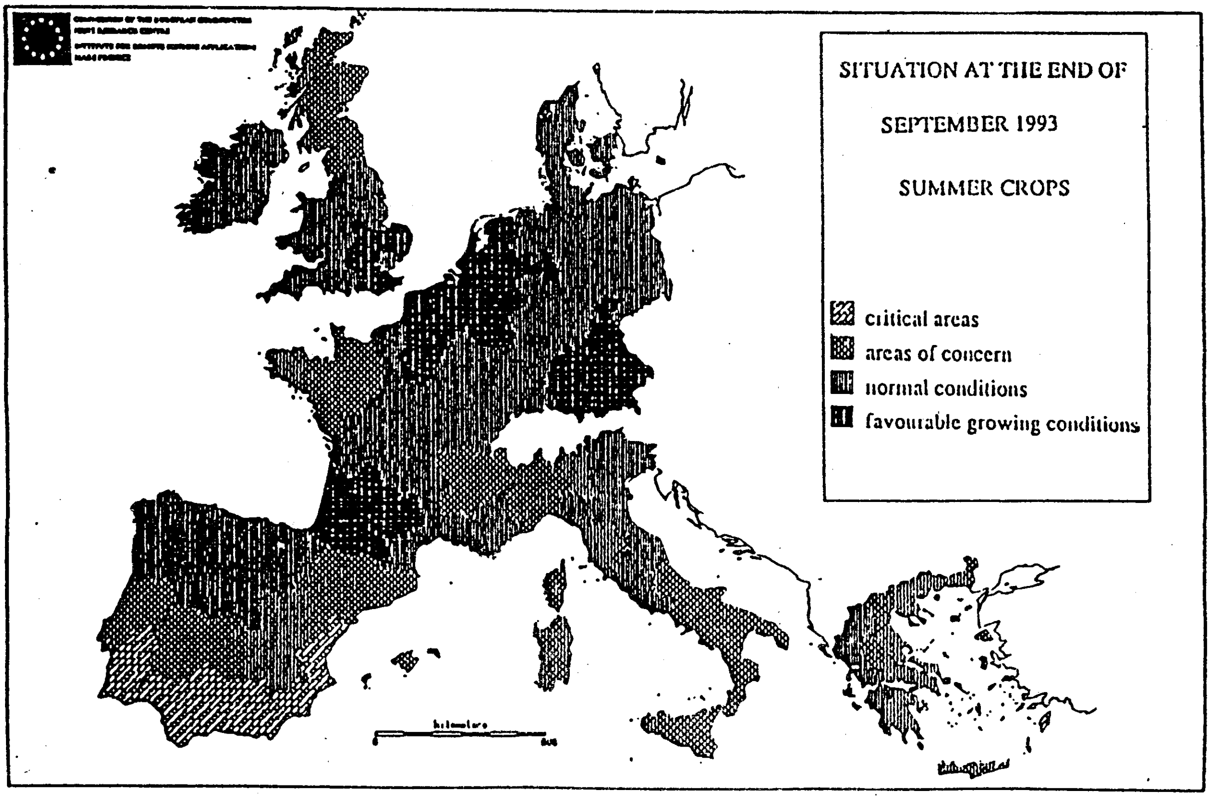


Figure 11: general state of the summer crops, at the end of the month of september 1993

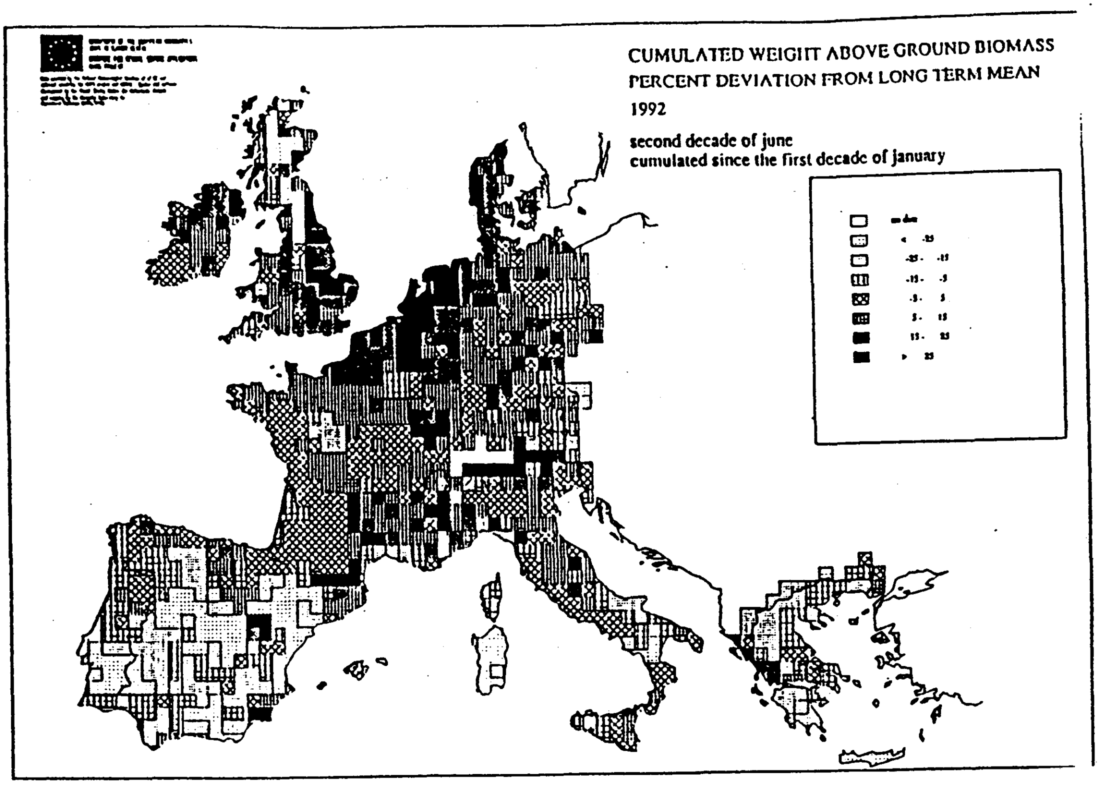


Figure 12: Simulated dry matter of winter wheat: difference as compared to the interannual mean (situation in mid-june 1992)

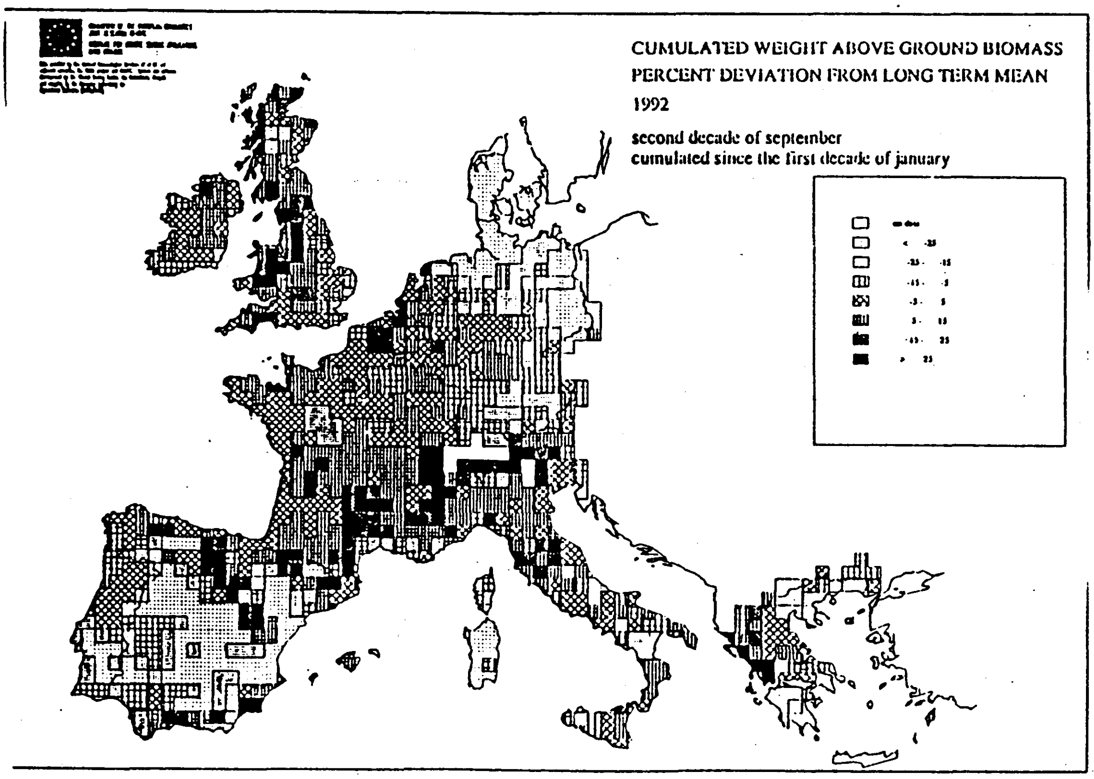


Figure 13:. Simulated dry matter of winter wheat: difference as compared to the interannual mean (situation in mid-september 1992)

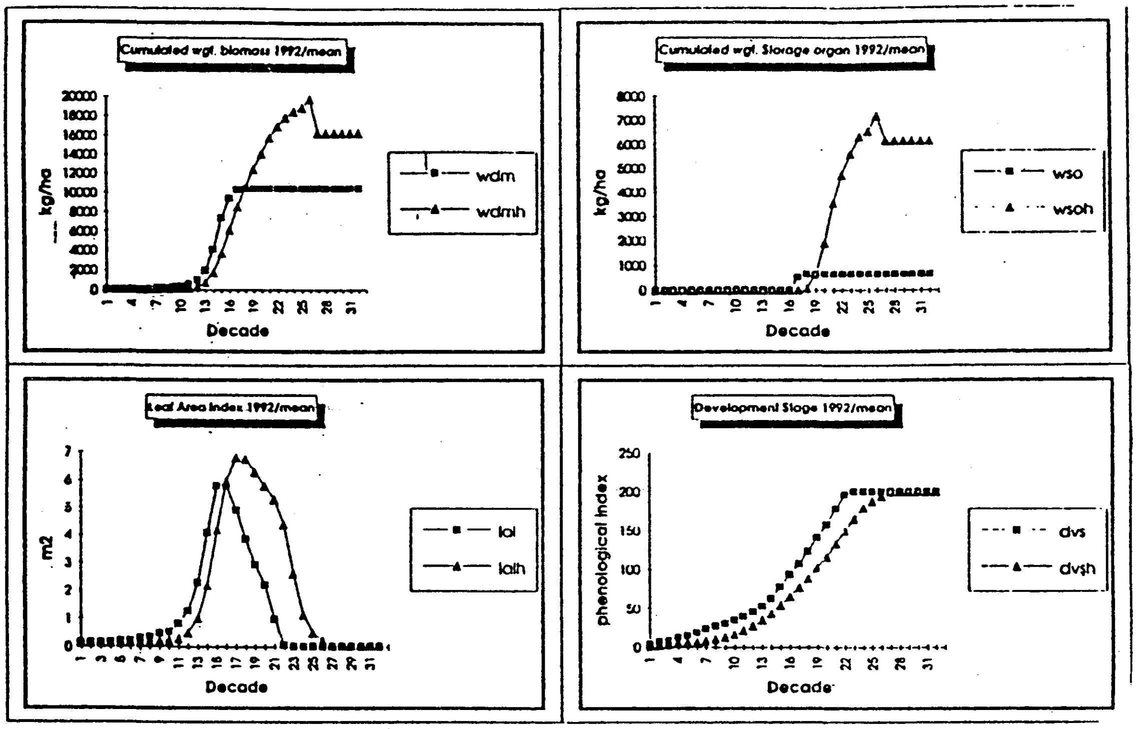


Figure 14: Time profiles of simulated winter wheat dry matter in Denmark, 1992.(wdm:1992 dry matter; wso:storage organ dry matter,; lai: leaf area index, dvs: development stage; h: inteeannual means)

4.3.2 Pollen count models

The raw annual results were obtained for each pollen station. The series does not cover enough years to calibrate the results and determine a reliable relationship between production and pollen count. However, the results analysed for certain stations are encouraging and the information obtained is already of great use to experts, who can collate them with other information. For example, in France, where the network is most developed and where the stations are the oldest, a group of experts who were shown these results together with the results of the qualitative models in action 3 predicted wine production in 1992 of 65 million hectolitres, within 300 000 hectolitres of the actual yield at the end of 1992.
In July 1993 the same group indicated a production prediction of 60 million hectolitres in 1993, while the official SCEES estimate, produced with a different and independant method, was also 60 million hectolitres.

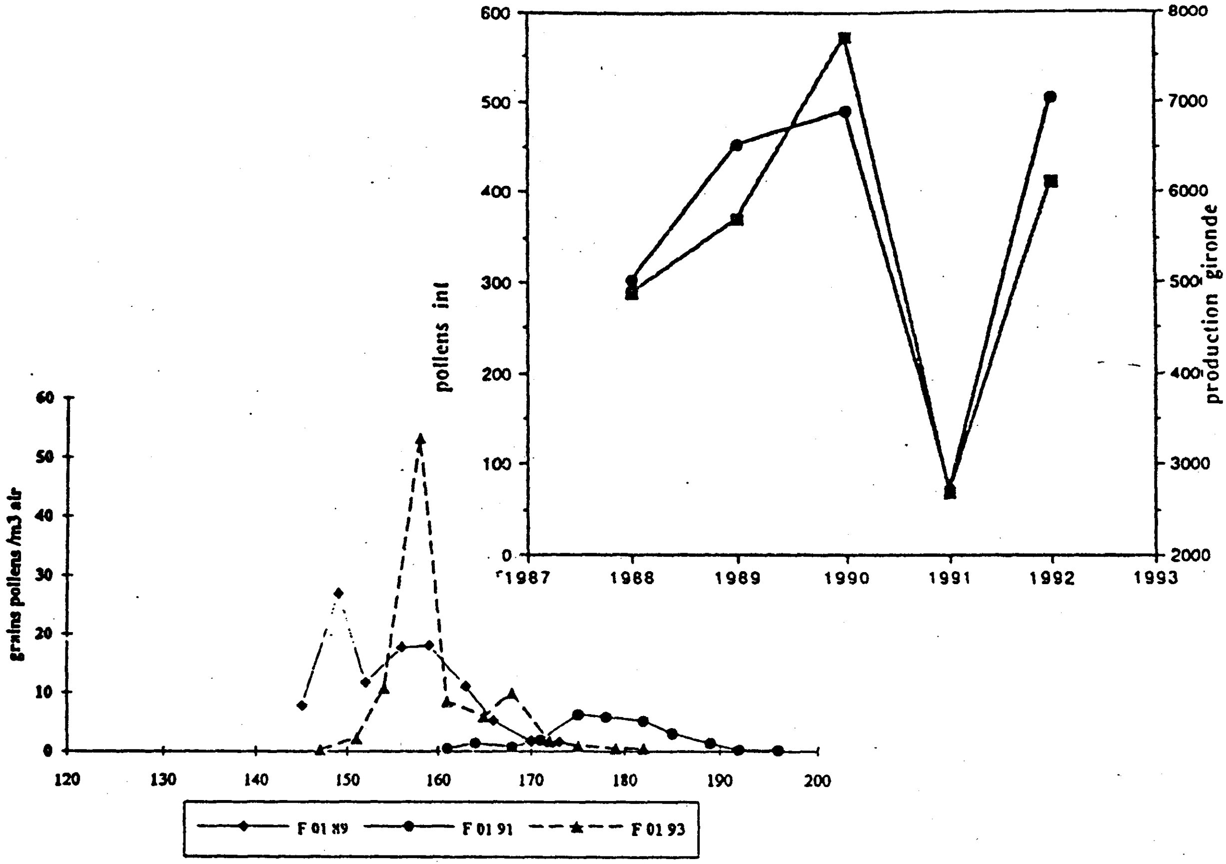


Figure 15: example of a pollinazation curve and of a relation between pollen/wine production

4.4. The technical fallout for other programmes

Through Action 3 a number of new products have become available, wich are useful both for the scientific world and as support for planning and taking decisions:
-the agro-pedo-climatological knowledge bases on the main crops (see also annex 3);
-the AMDaC software for the decoding, quality control, replacing of missing values and filing of synoptic meteorological data;
-an updated and corrected 1:1,000,000 soil map of the E.C.;
-a data base on "useful reserves of European soils";
-methods for standard calculation of potential evapotranspiration and total insolation from visual metereological observations.

Action 3 has also supplied important scientific and technical support to the work of Directorate General VI, in updating the vine-growing areas of the E.C.. Algorithms to estimate the potential of ripening and phenological phases of the vine have been developed, validated and mapped.

At the end of 1993, some of the expertise acquired was also being transferred to a network of perispheral mediterranean regions, for the structural and combined monitoring of the water resources of these regions.

4. 5 Conclusions, future developments

The results of the yield prediction models obtained so far can be used, though with a certain amount of caution as they have not been validated in detail. This will require another two or three years.
The level of the results - by large region for yields, by 50x50 km grid for qualitative data - is not very satisfactory for certain regions or even countries, which would like to see a finer resolution. Work must be done on the sensitivity of the models to see what obstacles lie in the way of further precision. If precision is limited by the input data, which is probable, it will be up to the Member States or regions, which sometimes have more detailed data, to improve the model. The improvements wich could be introduced by the Agricultural Project and wich have already been envisaged include the introduction of the rising capillary water in the water balance and the taking into account of irrigated areas.

The link with remote sensing has not been tackled, even though the output of models such as the leaf area index is a parameter that could be linked to vegetation indices derived from satellite data.
Certain indicators such as global radiation, which are generated by a sub-model, could be derived from meteosat-type satellite data, but this has not been tackled either.
This type of link is necessary because it would make it possible to monitor the model with the use of independent objective data.

It is therefore necessary to finalize full operational procedures from the instruments and methods developed. It is also necessary to start perfecting them as of now. The type of semi-deterministic model used and the possible links with remote sensing data give us the means to do so.
The model developed is a minimal one, standard throughout the European Community. It can be enhanced locally where there are more reliable basic data. This can be done by transfer and local improvement of the model. At the same time, more general improvements can be made as part of the project.

5. ACTION 4: EUROPEAN RAPID ESTIMATES OF ACREAGE AND POTENTIAL YIELDS

5.1 Objectives and methods

The principal objective of this action was to provide early information at Community level on changes in crop acreage each year with respect to the previous year, as well as indicators of potential yields.
Another aim was to develop a forecasting method that could be applied to foreign harvests.

The method consisted in defining a sample of representative sites - about 50 for the Community (see Figure 16) - obtaining and interpreting high-resolution satellite images (about three or four each year) of the sites and extracting the required information.
For the European forecasts, the method uses no ground data for the year, but incorporates ground observations for the preceding year. This provides a basis for checking the validity of the method retrospectively. For non-Community countries, it is advisable to forgo any recourse to systematic surveying.

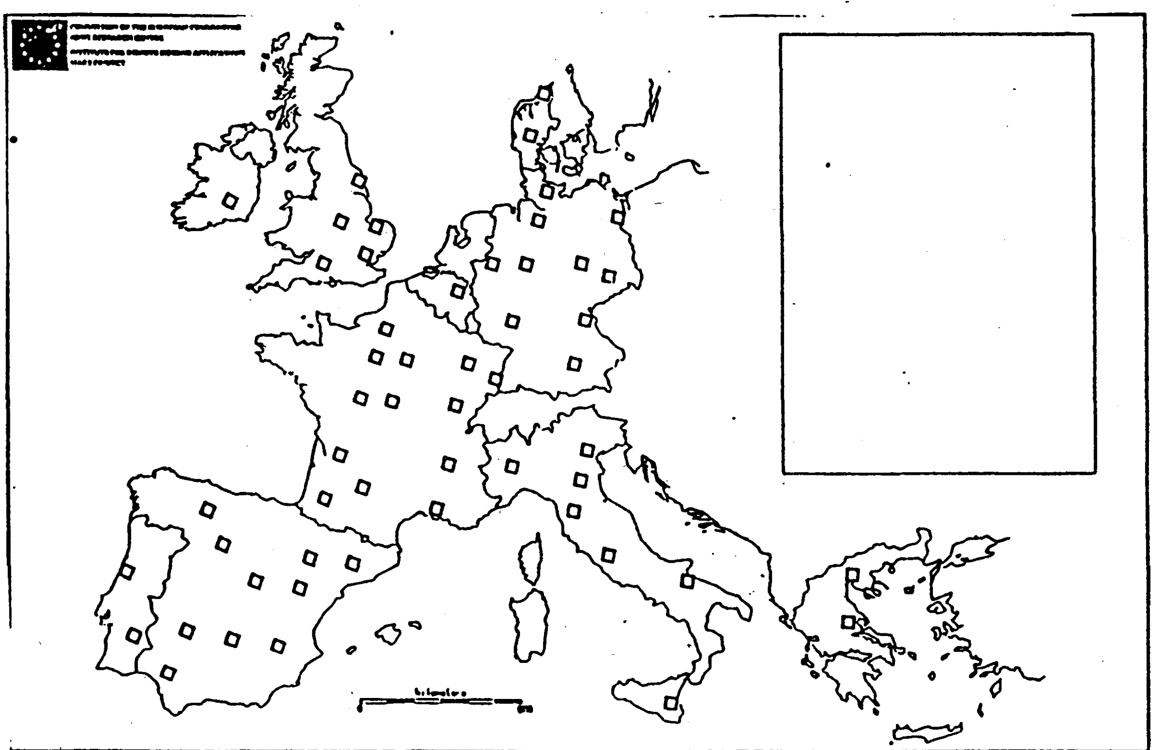


Figure 16: The sample of 53 Action 4 sites (rapid estimates)

The quality of the selection proved essential to the quality of the results, both in statistical terms and in terms of the acquisition of images.

Means of acquisition of images
The JRC cooperated with the producers of the images, Spotimage and Eurimage, in order to fulfil two essential conditions: obtaining three to four images per site over a period of about five months and reducing the delay in obtaining the images to five or ten days between date of acquisition and delivery to the analysis location. The principle was to acquire the earliest available image, whether Landsat or Spot.

Supplementary ground observations
The plan was to conduct ground surveys of 16 segments of 50 hectares each, selected systematically from the sites. For sites having a significant area with little agriculture a stratification was introduced. The survey data for year 'n-1' were intended to assist photointerpretation in year 'n'. The results of surveys in year 'n-1' were therefore to be available at the start of year 'n'. These were also to be used to monitor the remote sensing work retrospectively. They could also constitute an independent source of information, as the identification of the farmer was planned in 25 points per segment in order to collect information on the yields in year 'n' and crop projections for year 'n + 1'.

Computer-assisted photointerpretation method
To achieve a rapid analysis of a site in three to four days, it was not possible to photointerpret the whole site of 1 600 km2. The proposed method consisted in photointerpreting some 30 segments selected at random, including the 16 used for the ground surveys. The site was then classified automatically and the areas obtained extracted from the regression estimator method. This method was later abandoned in favour of the direct result extracted from the classification.

Statistical model
The variation n/n-1 was applied to the Eurostat statistics for year 'n-1', both at national level and at European level. The statistical model was later refined by the contractor to account for non-discernible crops and missing sites.

5.2.2 Implementation of the method

The analysis was carried out by a group of companies led by SCOT, a land observation consultancy company, including the French Ministry of Agriculture's central office for statistical surveys and studies (SCEES) and the French companies SGS and Geosys. The first phase of the work, which consisted in designing and writing the image-processing software, was completed in 1989. On the basis of an analysis of a number of sites, the photointerpretation experts defined their method of computer-assisted photointerpretation. During 1990, 20 sites were analysed. In this second phase, the aim was to bring the system into operational mode. However, final touches to the software and the photointerpretation method meant that the deadlines could not be met, and cannot be expected to until the end of the second phase and in preparation for the third phase.

The availability of images was satisfactory, even for areas in north-west Europe where there is frequent cloud cover. Delivery deadlines of about seven to ten days from the recording of the image were generally met.

The results obtained for the sites analysed were very encouraging for the validity of the method. The crop situation reports on the main crops analysed in each site using only the satellite images provided information consistent with data obtained from other sources.

The supplementary ground work does not call for particular comment, being identical in design to that described in action 1. It provided an opportunity to experiment with this type of survey in all the countries of the Community, which was not the case with the inventory actions. The statistical services or ministries of agriculture occasionally carried out the work directly in Portugal, France and Denmark. These surveys were particularly useful in cases where, for various reasons, such as the size of fields, remote sensing was at the limit of its operational viability.

5.2.3 Full-scale testing of the method (1992-1993)

Full-scale testing of the method was carried out under contract by a group of companies led by SCOT, including GAF, NRSC, Telespazio and CISI informatique. The test workshop was separated from the development sections by the creation of the company SOTEMA grouping together the French operators.

This stage was marked by the development of a large crop situation function, as results were obtained for all 53 sites (three sites were added for the former East Germany). The statistical model also had to be improved.

Changes had to be made to accommodate the new requirements of DG VI, such as the study of fallow land, which was not in the original plan.

In 1992, it was possible to cover all the sites with satellite images; however, at 9 August, two sites had still not been covered for 1993. In such circumstances, the statistical model attributes to these sites conditions similar to those observed in neighbouring sites.

The deadlines for obtaining the images were kept down to about four to five days and three to four days for analysis. The objective of incorporating all the data acquired, except that on the last ten days, into an information bulletin or fax has therefore been achieved (see fax in annex).

Improvements had to be made to the processing software, especially for the geometrical adjustment of the images in order to keep costs down and meet deadlines. Previously, this pre-processing was done externally.

In 1993, a more industrialized and portable software was produced in order to convert from the Vax/VMS system to UNIX. This was done to prepare for the transition to operational use.On the other hand, for financial reasons, it was not possible to do the field work in 1993.

This has no direct effect, since, in its final form, the method can operate without field work. However, an up-to-date information base is necessary for the photointerpretation experts and this matter must be looked into closely in order to maintain the quality of the system.

The data on crop acreage at site level are obtained directly from an analysis of the images. For yields, remote sensing is only a rough guide. Since 1993, the data from action 3 on each site have been incorporated and are a significant factor in the assessment.

5.3 Results

The results can be evaluated in more than one manner. The first is theoretical and consists in calculating the accuracy of the sample assuming that the estimate at site level is perfect, i.e. assuming that the photointerpretation method is perfect. For the main crops, the error in the trend due to sampling is in the region of 2%. That means that if there is a 5% change in acreage, the sample allows us to situate it between 3% and 7% (with 90% probability).

Another method consists in comparing the results at the end of the work with results from a source considered to be correct, i.e. with Eurostat statistics.

As it is a rapid prediction, what is important is the trend over time and the information being produced earlier than with other sources.

In practice, the Eurostat estimates can vary significantly six months after harvest and, for some ten faxes and ten crops, synthesis is not easy to achieve.

The following curves,(figure 17), for durum wheat and common wheat, two crops that are difficult to tell apart in regions where they coexist, show that they were correctly estimated as early as the fax of 9 June 1992 in both acreage and production, even though their respective variations between 1991 and 1992 were sharply contrasting. Once some hundred images had been analyzed, the variations were not subject to further adjustment. The estimates were significantly better than those of the professional organization, Coceral.

A comparison of the results at 12/10/1992 on the acreage of the various crops appears to yield better results than the theoretical 2% tolerance mentioned above, except in the case of sunflowers(figure 18). A detailed analysis has demonstrated that, for this crop, areas designated as sunflower fields were interpreted as bare ground, probably owing to the very low yield, which explains the very good result achieved by the production forecast on the basis of a very poor acreage forecast.

Where the results were very different, as for durum wheat production, which showed a gap of about 10%, it was not necessarily because of error in action 4. Here, a subsequent adjustment by Eurostat brought the final result to within a few percent.

Certain crops that are too localized, such as potatoes and sugar beet, are poorly estimated, however.

The presentation of the results and the related comments - two important features of the crop situation analysis - satisfy DG VI, which is the target user for this action. The lack of prediction data at national level is inherent in the sampling method. For countries that have ten or so sites, the prediction for two or three crops appears to be roughly valid. The cartographical representation of individual sites provides some information, e.g. on sunflowers in 1993, where the trend in the Iberian peninsula is contrasted with that in the rest of Europe (Figure 18). Such information at sub-European level, however, is very limited and must be viewed with caution, as the sample is not designed for this purpose.

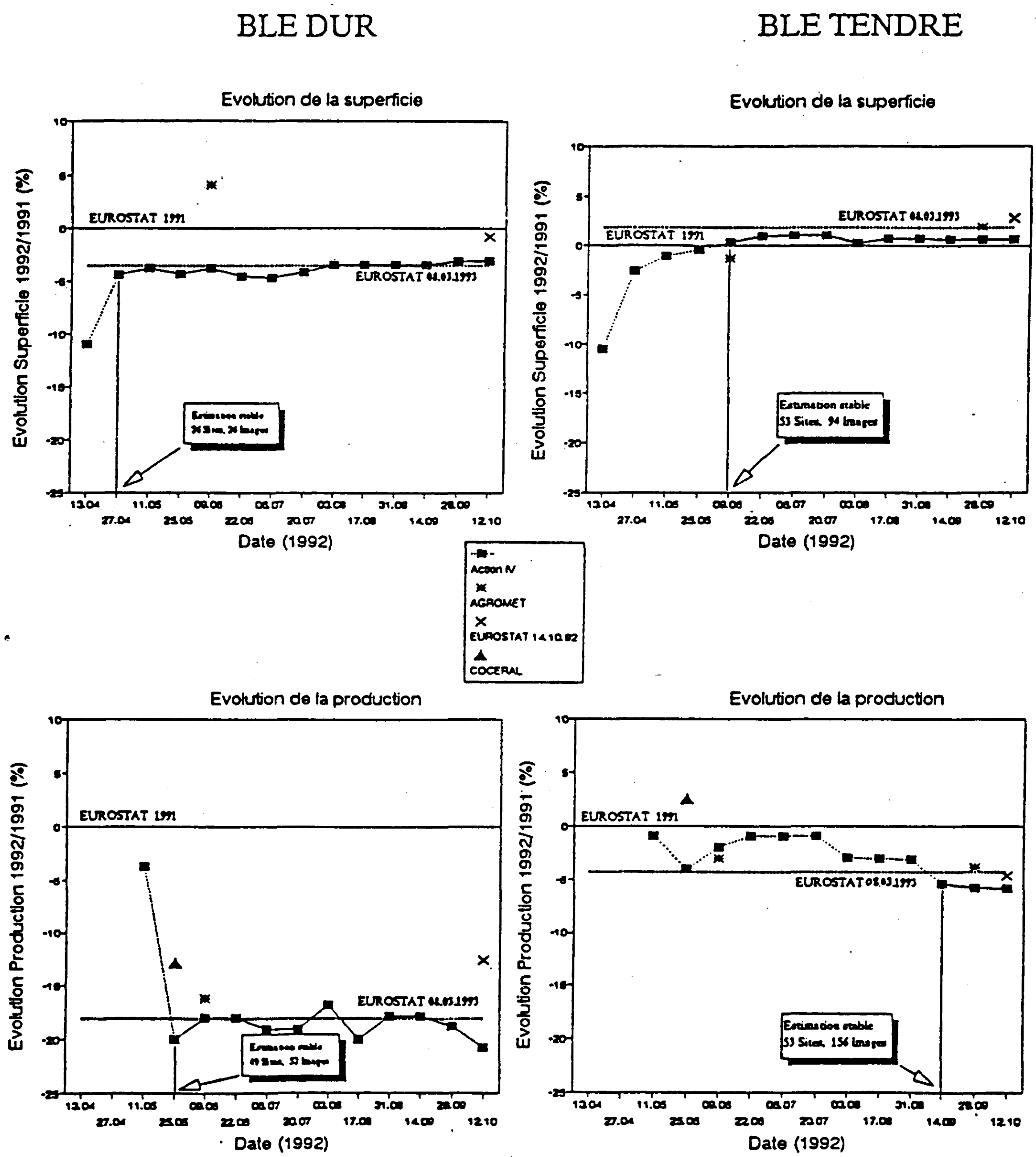
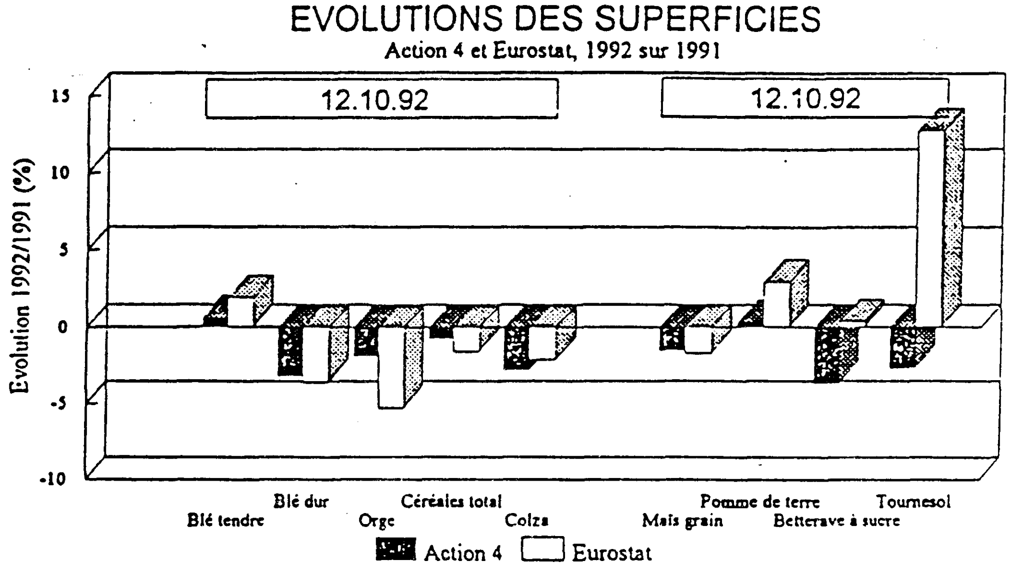


Figure 17: Evolution of the wheat average and production during the 1992 season: comparison of the Action 4 with the EUROSTAT estimates.

The validity of the 1993 results can only be verified when the official figures will have become available (in early 1994). A first evaluation indicates that the Action 4 estimates of acreage and production are, for most crops, in agreement with the EUROSTAT estimates. However, the total cereal production, and mainly of soft wheat, appeared to be difficult to asses in 1993. This is probably due to the new Common Agricultural Policy, particulary is related to the set-aside regulations. If this analysis is confirmed, it would mean that the lands put into fallow during this first year of CAP, were generally the lest fertile ones. The common models used to estimate yield, without taking into account this shift, were therefore difficult to apply.



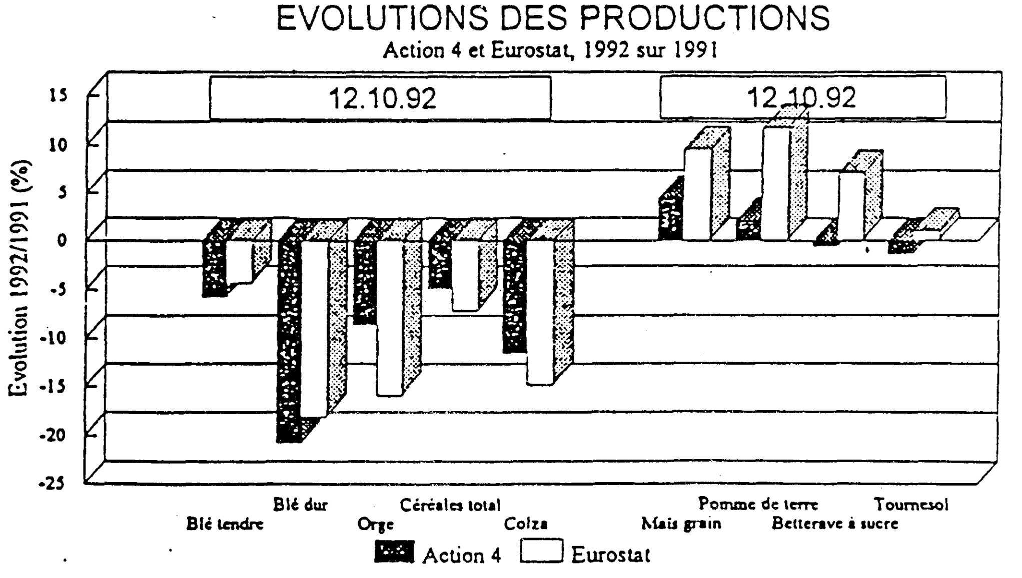


Figure18: Evolution of the average and production of the principal crops in 1992: comparison of the Action 4 estimates with the EUROSTAT estimates

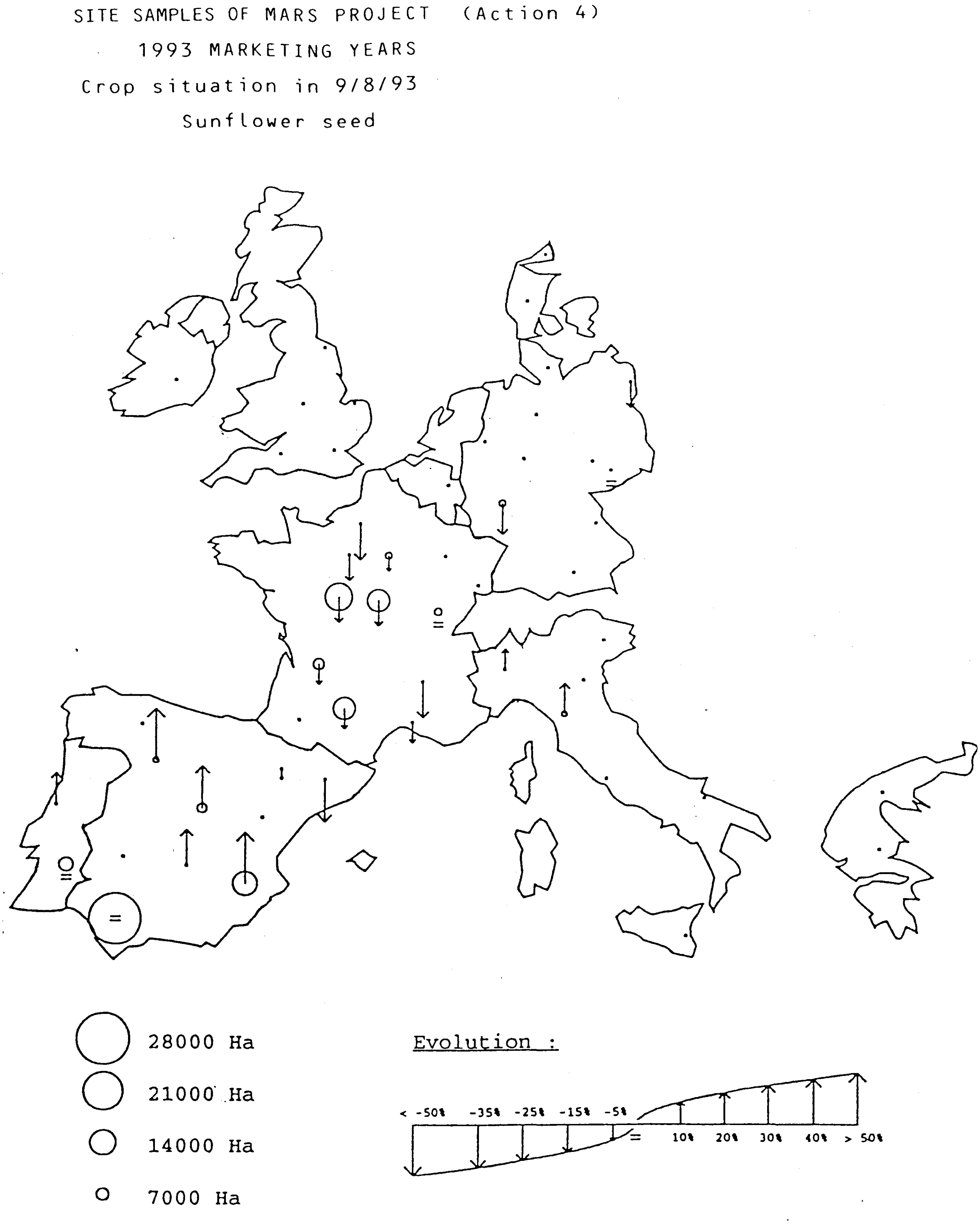


Figure 19: Map for sunflower, as published in the Crop Status Fax of 9 January 1993.

5. 4 Conclusions, future developments

If the quality of the 1993 results is as high as that of the 1992 results, the method developed may be considered operational throughout the Community without major changes.

Further improvements must be incorporated, e.g. the introduction of the analysis of ERS.1 radar images in order to enhance accuracy and reliability over time.

The links with other sources must be improved, particularly for the yield predictions.

More varied applications will probably be introduced, as was the case with fallow land and the setting-aside of arable land, which were not planned initially.

In the territory of the European Community, the role of the ground surveys should be reassessed to determine whether they should be continued. Their function of monitoring the quality of the photointerpretation work is no longer essential in the operational phase.

In the studies and discussions prior to the conception of the project, the importance of predicting foreign harvests was taken into consideration. However, for technical reasons, it seemed preferable to postpone this action to the second part of the ten-year programme.

For the application to foreign countries, which was an essential objective of action 4, it would be advisable to examine which information base could take the place of observations on the ground. A better balance should be established between the contribution of actions 2 and 3, which are less costly in operational use, and action 4, for which photointerpretation work will remain an essential, high-cost feature.

6. BACK-UP AND SYNTHESIS ACTIONS

Three back-up and synthesis actions were defined in the pilot project:
- action 5: advanced agricultural information system;
- action 6: area survey system;
- action 7: long-term studies.

Moreover, the large number of contacts and requests for information called for a huge effort in the area of information and communication.

6.1 Action 5: Advanced agricultural information system

The objective of this action was to integrate the various actions and also incorporate conventional surveys in order to create a complete information system including the new methods described above. It therefore lies downstream of the preceding actions.

Work mainly covered the link between area-type ground surveys and the analysis of high-resolution images from actions 1 and 4 (see paragraph 6.2: Area surveys).

Synthesis work, such as the Y.S.PRA Bulletin, was another way of taking advantage of the various individual actions in order to integrate the results (see copy of bulletin in annex). This makes use of the results of action 4 for acreage and actions 2 and 3 for yields. In contrast to the SOTEMS reports, the information supplied is aimed at national level.

6.2 Action 6: Area survey systems

The aim of this action was to design a type of survey to be used in conjunction with remote sensing and therefore suitable for the ground work required for the project. Another aim was to develop a comprehensive system of agricultural statistics on an area basis.

All the ground surveys conducted for the project were area-type surveys. In such surveys, the statistical survey units are not economic entities, such as agricultural holdings, but small geographical units called "segments". These segments, or small units of area are obtained by dividing up the territory. In the project the basic unit is a 50 ha square. After three years of studies, this shape and size proved on average to be fairly close to optimal in most of the regions studied. Non-square segments with physical boundaries might be easier for the enumerators on the ground; however, the creation of all these detailed boundaries would entail an extremely large investment. The Italian project, Agrit, made such an investment in Emilia-Romagna forts own purposes, and since 1990 we have used such segments with physical boundaries. The results do not appear to show any improvement with respect to square segments and therefore do not justify the cost. This was studied in Navarre, where the contractor reached the same conclusion.

Maintaining two survey systems - a list system and an area system - is expensive. In certain cases, e.g. countries in transition in eastern and central Europe, a list system is inoperable. This question was studied as part of the project to create a comprehensive area-based system.

In action 1, the yield component was obtained by identifying and questioning the farmers. These were not selected on the basis of agricultural censuses, but by identification on the basis of the area survey. The same method was used in action 4 for monitoring the results of photointerpretation. This method has been shown to be feasible and the response rates are generally very satisfactory. However, they depend greatly on the backing, or lack of it, of official bodies. Where official bodies were directly involved, the response rates were close to 100%.
The method was also used to obtain structural data, such as form of ownership or type of farming. In the example below of the Czech Republic, the following results were recorded in 1992, (figure 20). This survey will be repeated to monitor trends.Chart of the status of farmers in the Czech Republic
It is important to keep the technical lead that has been achieved with area surveys, which can be used not only for agricultural statistics but also for environmental or structural statistics. The link with remote sensing techniques means that they are susceptible to constant improvement. However, in the short term, the use of remote sensing is mainly confined to the stratification and allocation aspects of the surveys and does not extend to the automatic classifications which were the main subject initially studied.

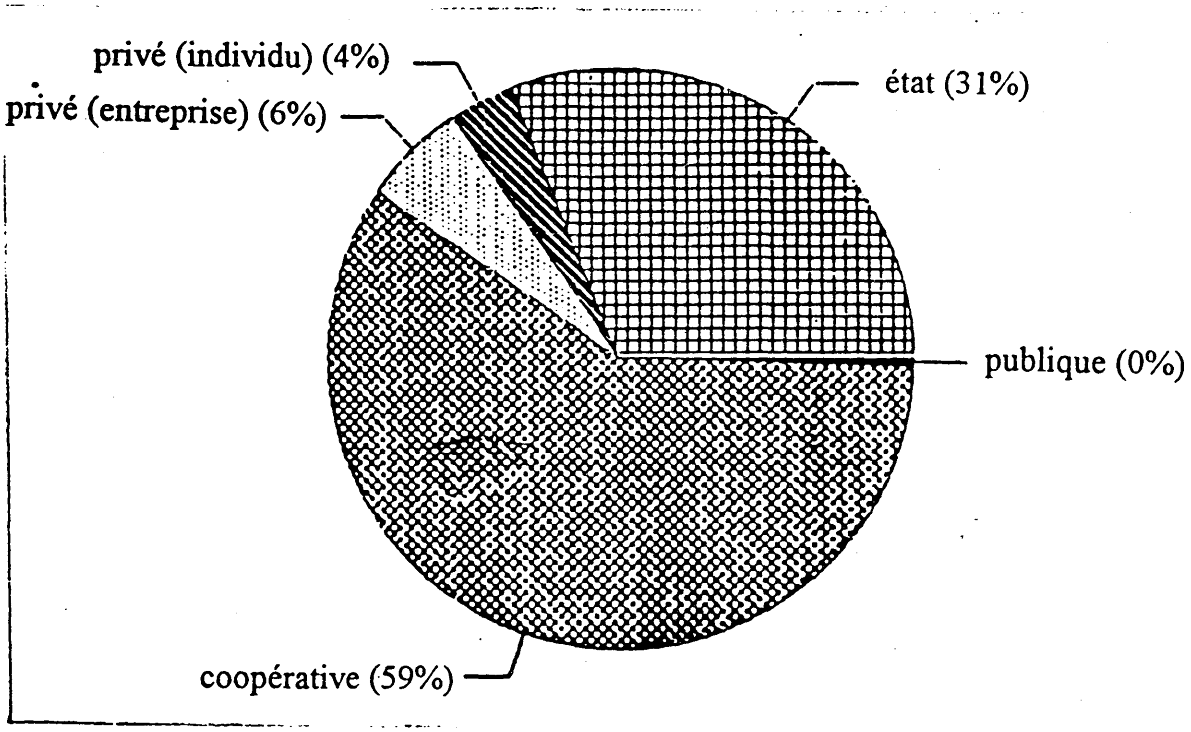


Figure 20: Diagramme related to the agricultural farms in the Czech Republic

6.3 Action 7: Long-term studies

The objective was to allocate part of the resources of the project to work that would probably not generate operational applications during the life of the project, but would deal with prospective uses in the medium and long term.

In 1989 and 1990, this work focused mainly on basic research into radar techniques. Following the launching of the ERS 1 satellite in 1991, work continued using real data for which there is expected to be continuity of service. By mid-1993, it was apparent that radar images are of potential use to the project, for both action 1 and 4. However, this technique has yet to be tested on larger areas and, above all, the actual image acquisition capacity will have to be ascertained, as ERS 1 is a multi-mission satellite mainly intended for marine applications (see radar image in annex).

Work also went into developing the Space software on parallel computers in support of action 2. The operational processing of a database of 10 years of satellite images for the whole of Europe, particularly in real time, is extremely burdensome. The use of parallel computers could lighten the load, as the time savings achieved with such computers have demonstrated.
However, more work is needed to ascertain whether these savings are not partly or fully cancelled out by the handling, inputting and outputting time for the data storage media.

6.4 Information and Communication

The large number of participants in the project meant that one person had to be assigned exclusively to information and communication activities. Four activities were involved:
- editing the Teleagrinews bulletins;
- organizing conferences, meetings and visits;
- organizing training courses;
- setting up scientific working parties.

Five Teleagrinews bulletins were produced, providing information on the main results achieved by the project and the scientific choices made. The frequency and regularity of the bulletins left something to be desired, but this constituted only one means of communication.

A conference was organized every two years. The first was held in Varese, Italy, on 10 and 11 October 1989 and the second at Belgirate, Italy, on 26 and 27 November 1991. A third one is planned for 17 and 18 November 1993, again in Belgirate. They provided an opportunity for a detailed presentation of the project's progress and comparison with other methods. They also allowed national agricultural statisticians to communicate with scientists working in the field of remote sensing.

Several training courses in connection with action 1 on regional inventories were held in Ispra, Lisbon and Athens. Some regional and national agricultural statisticians took part, but the content of the courses was aimed at a fairly wide public.

Several scientific working parties were set up to provide back-up for the project. A short-lived technical group studied problems of classification and the processing of satellite data for Mediterranean regions. The soils and geographical information systems support group was set up to validate the work on soil cartography done as part of the project. The agrometeorology support group monitored certain aspects of the yield prediction model.

The Agricultural project is also represented in several international organisations and working groups such as, PASSAGER VEGETATION, GISIG (Geopgraphical Information Systems International Group), International Society for Photogrammetry and Remote Sensing, etc..

The project has established close contact with groups such as the European Space Agency, F.A.O., the World Meteorological Organisation, the European Environment Agency (task force), United Nations Programme for the Environment, United States Department of Agriculture, United States Department for Agricultural Research, etc..

7. INTERNAL STUDIES RELATING TO THE PROJECT

Most of the scientific work for the project consisted in assessing the various alternative methods, choosing one or more and having the corresponding studies carried out under contract. The monitoring and evaluation of the contracts led in turn to the preparation of the next stage.

Apart from this, studies were carried out by the project's own teams, particularly in the area of computers.

A complete computer system called MARS-PED was set up for processing high-resolution data for action 1. This was derived from and adopted all the formats of an application called PEDITOR used by the US Department of Agriculture. The version currently available was developed on VAX microprocessors. We were able to take advantage of earlier development work by the JRC, which was all done on VAX, system VMS. A system for digitalizing the ground surveys using video camera was developed to shorten data inputting times for these surveys. For one region and some 400 observations, processing which originally took about one and a half months was completed in a week. This method is now used by about ten services companies in their work.

The aim of these actions is to assist the companies that produce the inventories and to harmonize computer systems. They enable the project team to master the techniques in order to be able to assist regional and national organizations that decide to equip themselves with similar systems. The emphasis was placed on action 1, because, for the other actions, processing is to be done centrally and the problems of coordination are less acute and on the production of maps based on satellite images to support activities in the field (Action 6).

The centralized developments for action 2 and 3 were done on SUN hardware using UNIX operating software.Equipment suitable for processing NOAA-AVHRR data in near real time has been installed, it is copied from the ESA's equipment in this field, i.e. SUN 3 plus optical disks.The geographical information system and the agrometeorological models for yield prediction have also been installed on SUN. The installation of this equipment was done gradually and this has allowed the work done externally to be progressively integrated.

8. BUDGETARY MATTERS

The table in Annex 2 giving the cost of the project action by action shows very different trends in the various actions.

The cost of action 1 - regional inventories - was very high at the beginning of the project. This is because it started earlier. Five regions were monitored, instead of the three or four originally planned. The passage to the operational stage was accelerated by the higher outlay, which led to savings at the end of the programme.

Similarly, the cost of action 4 appears very high. This is because of a much greater than expected increase in the cost of high-resolution satellite images. It is also because part of the work planned for action 5 was carried out for monitoring purposes as part of action 4 and is therefore included in this action.

The cost of actions 2 and 3 was much lower than expected. This is partly because they were delayed by about one year; indeed, they could not be started right at the beginning owing to staff shortages. The lost time was made up without extra cost owing to the low cost of NOAA images. Moreover, processing is done internally, which led to savings. It is difficult to separate the cost of these two actions because the same equipment and maintenance is used for both.

For the three fairly centralized actions, 2, 3 and 4, the operating costs are in the region of ECU 500 000, ECU 500 000 and ECU 2 500 000 respectively. One-third of the cost of each project is attributable to the purchase of input data, meteorological data or satellite images. However, the cost of analysts is not included in these amounts for actions 2 and 3, whereas it is included in the cost of action 4. Analysis is necessarily decentralized at each level for actions 2 and 3.

9. RELATIONS WITH REPRESENTATIVES OF THE MEMBER STATES

The representatives of the Member States were kept informed of the progress of the project via the Standing Committee on Agricultural Statistics (see Articles 2 and 4 of Council Decision 88/503/EEC) and the working parties on crop production statistics, chaired by the Statistical Office. One of the working parties met at Ispra on 26, 27 and 28 March 1991 and has taken a particular interest in remote sensing.

The national statistical services will play an active part in putting the methods developed by the pilot project into operational use. This is already the case with action 1 on regional inventories. In this connection, attention should be drawn to the implementation of the plan for restructuring the agricultural survey system in Greece following Council Decision 90/386/EEC of 16 July 1990.

Other operations aimed at introducing remote sensing methods into national systems have also been carried out in Portugal and Spain.

An informal working party has been proposed to monitor these operations and give advice on the process of putting the methods into operational use. It will be coordinated by Eurostat.

10. CONCLUSIONS

During the first phase 1989-1993, the progress on the pilot project on remote sensing applied to agricultural statistics was in line with the programme established and approved by Council Decision 88/503/EEC.

Action 1 on regional inventories was put into operational use as early as 1991, even though this was originally planned to take three to five years. Programmes for this have been developed with the countries concerned.

For actions 2 and 3 on the monitoring of plant growth and agrometeorological yield prediction, a georeferenced database has been established. It is complementary to the Corine database and could have many applications in the fields of both agriculture and the environment.

Cartographical products and trend indicators concerning the state of crops were generated from these models and are already being used for action 4. However, action 4 is entering the validation stage, which will probably lead to certain changes. These products must be adapted to suit national and especially regional needs. Links have not been established between the models of action 3 and remote sensing data, either to provide input data for the model or for monitoring purposes at certain stages.

Action 4 on European rapid estimates of acreage and potential yields led to the production, as early as 1992, of forecasts that have proved fairly accurate at an early date. It is ready to be put into operation at the end of the first phase without major changes, with the possible exception of ground monitoring.

Some work involving non-Community countries was done following the recommendations of the 1991 report to the Council . This was confined to limited technical cooperation.

At the end of the first five-year period, all the basic tools planned have more or less been developed. The potential of remote sensing as a new source of information for agricultural statistics has been fully explored. Certain activities, such as action 4, have produced results fully in line with initial expectations. In other cases, such as action 1, remote sensing has proved to be more effective in the area of stratification than in automatic classification, though the project had placed the emphasis on the latter.

For the qualitative and quantitative crop yield prediction models, results were expected first from action 2 and only in the second phase of the project from action 3. The basic products were obtained as early as the fourth and fifth years. However, they have not been validated and are not yet in a form that can be put into operational use. Nevertheless, they can begin to be used, even though the final development of stable products will take another two or three years.

The bulk of future work will involve the integration of the various components, which are mutually reinforcing. The products of actions 2 and 3 must be better integrated. By allowing for close observation of certain sites, action 4 should provide an opportunity to improve these models. Conversely, the models will provide opportunities to improve the yield component of action 4.

The interaction and complementarity of the various actions should also be essential in the development of prediction methods for foreign harvests, which was one of the initial priorities but was postponed until the second phase for technical reasons.

As and when the actions come into operational use, it is important to maintain effective coordination between large numbers of users. The continuation of action 1 depends on Eurostat making efforts in this field, as does the employment by the Member States of methods developed in actions 2 and 3.

While the JRC has an important role to play in the actions that are still being developed, i.e. actions 2 and 3 and the prediction of foreign harvests, for the actions that are being put into operational use its role should be confined to providing technical support, the details of which remain to be defined. Here, it is the user and the coordinator who play the essential role and direct this technical support.

ANNEXES

Annex 1: Main project contractors in 1990 and 1991

Annex 2: Cost of the pilot project

Annex 3: Project publications

Annex 1: Main Contractants of the Project

		Contractant	Sub-contractant
Action 1: Regional Inventories			
	Germany	GAF (F.R.G.)	
	Spain	Hunting (U.K.)	Aurenza (E)
	France	Sodeteg/Sysame (F)	Aquater (I)
	Greece	BDPA/Sysame (F)	ADK (G), BRGM (F)
	Italy	Aquater (I)	Sodeteg/Sysame (F)
Informatics:		R.S.D.E. (I)	
Action 2: Vegetation monitoring			
	Thematic studies	DHV (NL)	
		Hunting (U.K.)	
		I.N.M.G. (P)	
		INRA (F)	LERTS, CEMAGREF (F)
		Logica (U.K.)	Reading Univ (U.K.)
		Silsoe College (U.K.)	
		Telespazio (I)	
	Informatics		
	1990-1991	Tecnodata (I)	
	1992-1993	E.O.S. (R.U.)	
Action3: Agrometeorological models			
	Model developement and statistical validation	Staring Centre (NL)	CABO (NL)
		Fac.Sciences Agron. de Gembloux (B)	
	Informatics	Hunting TS (U.K.)	
		Q-RAY (NL)	
		Metea Consult (NL)	
	Potential evapotranspiration	Univ. East Anglia (U.K.)	
		SGS-Qualitest (F)	Météo-France (F)
			INRA (F)

Agrometeorological crop inventories	Fac. Sciences Agron. Gembloux (B) INRA (F) Scottish Crop Research Institute (U.K.) Univ. Edinburgh (U.K.) Meteorological Office (U.K.) A.G.P.M. (F) Aquater (I)	
Processing and interpolation of meteorological data	Meteo Consult (NL) Staring Centre (NL)	
Global solar radiation	The Meteorological Office (U.K.) World Meteorological Organization	
Grapevine production prediction - pollen	CEMAGREF (F)	C.N.R.S (F)
Statistical model, yield prediction of fruits and grapevine	Fac. Sciences Agron. Gembloux (B)	

Action 4: Rapid Euroepen Estimates

Image analysis		
1988-1991	SCOT Conseil (F)	SCEES/SGS/GEOSYS (F)
1992-1993	SCOT Conseil (F)	SOTEMA, CISI (F) Telespazio (I) GAF (F.R.G.) NRSC (U.K.)
Field documents	IGN-Espace (F) Hunting TS (U.K.)	
Field observations	ERA (I) Bureau of Land Data (DK) AGRAR (F.R.G.) DGPA (P) Organotechnica (G) K.U.L. (B) Ibersat (E) SCEES (F) R.S.D.E. (I) Hunting TS (U.K.)	

Action 5: Advanced Agricultural Information System

N.L.R. (NL)

Annex 2: Project costs (KEcus)

Credits and Staff

P: planned
R: realized

		1989	1990	1991	1992	1993
Specific Credits	P	4825	5425	5725	6025	6000
	R	4825	5425	4600	5370 (1)	4840 (2)
Staff number	P	12	12	12	12	12
	R	9	9	8	12	12

(1) 4670 KEcus were planned in the beginning of the year, and a supplementary 700 KEcus were obained later on;
(2) 3540 KEcus were planned in the beginning of the year, and a supplementary 1300 KEcus were available at the end of 1992.

Costs per Action

	1989	1990	1991	1992	1993	Total
Action 1	1300	1400	600	550	250	4100
Action 2 & 3	825	1225	1100	1370	1590	6110
Action 4	1400	1500	2100	2600	2300	9900
Research	600	600	200	300	200	1900
Others	700	700	600	550	500	3050
TOTAL	**4825**	**5425**	**4600**	**5370**	**4840**	**25060**

Annex 3: A selection from the main publications of the J.R.C. Scientists within the Project or JRC Publications

1. General

The 10-Year Research and Development Plan for the Application of Remote Sensing in Agricultural Statistics - JRC, Report SP.I.88.35/EN.

Proceedings of the Conference on the Application of Remote Sensing to Agricultural Statistics - Varese (Italy) 10-11 October 1989 - June 1990 - JRC, Report EUR 12581/EN.

Proceedings of the Conference on the Application of Remote Sensing to Agricultural Statistics - Belgirate, Italy, 26-27 November 1991 - 1992 - JRC, Report 14262 EN.

J. Meyer-Roux, C. King, 1992. Agriculture and Forestry. International Journal of Remote Sensing, Special Issue: European Achevements in Remote Sensing, Vol. 13, No. 6 and 7, pp. 1329-1342, April/May 1992.

J. Meyer-Roux, 1992. Remote Sensing Applied to Agriculture: State of the Art and New Trends. Space in the Service of the Changing Earth. In Proc. of the Central Symposium of the "International Space Year" Conference, ESA SP-341, p. 647-649 Munich (Germany), 30 March-4 April 1992.

J. Meyer-Roux, M. Cornaert, 1991. Stato dell'Arte, Esempi dei Progetti MARS e CORINE. Atti del Convegno Europeo sui Sistemi Informativi per la Difesa del Suolo e la Tutela del Territorio, Roma 14-15 Maggio 1991.

TeleAgriNews no. 1-5.

J. Meyer-Roux, 1991. La Télédétection Appliquée aux Statistiques Agricoles, Commission Economique pour l'Europe, 8-11 Juillet 1991, Document FAO/ECE:ESS(91)-7.

A. Burrill, 1992. GIS Applications at the European Communities' Institute for Remote Sensing Applications. EUROCARTO X: Pan-European Environmental Policy: some relevant GIS applications, Oxford (GB) 16-18 Sept., 1992.

2. Action 1

J. Delincé, 1993. La Prévision et l'Estimation des Productions Végétales en Europe: Les Applications de la Télédétection dans le Projet MARS. In Proceedings of International Symposium MARISY 92, Rabat (Maroc), Oct.7-9, 1992
Géo Observateur MARISY 92, Numéro Spécial, pp. 37-42, 1993.

J. Gallego 1992. Applications of Remote Sensing to Agricultural Statistics in the MARS Project of the EC. 2° Convegno Nazionale "Informatica e Agricoltura" Firenze, 17-18 Dicembre 1992.

J.P. Le Gorgeu, J. Meyer-Roux, J.M. Terres1992. Area Frame Sampling Surveys in Romania and Czechoslovakia. 12th EARSeL Symposium, Eger (Hungary), 8-11 September 1992.

J. Gallego, C. Rueda,1991. Area Estimates with Sampling Units Shared by Different Strata. 19th European Meeting of Statisticians, Barcelona (Spain), Sept. 2-6, 1991.

F.J. Gallego 1992. Flächenschätzungen für einjährige Feldfrüchte mit Hilfe Fernerkundung: Neue Wege raumbezogener Statistik. Forum der Bundesstatstik No. 20, pp. 109-120, Wiesbaden: Statistisches Bundesampt.

V. Perdigao, 1992. Stratification of Tras-os-Montes using integrated GIS and Landsat TM data, JRC EUR 14638 EN.

D. Avenier, V. Perdigao, J.M. Terres, 1992. Méthodologies de stratification sur images satellitaires et urilisation d'un système d'information géographique. Mise en place du plan d'échantillonage, JRC EUR 14855 FR.

V. Perdigao, 1992. Guide pratique à l'interprétation des images satellitaires pour la stratification, Eurocourses Télédét.. App.. Stat. Agr, Lisboa 1992.

3. Action 2

M. Sharman, I. Barnes, Ph. Bierlaire, A. Le Lerre, 1991. Software for Processing AVHRR Data for the European Communities: Algorithms, Benchmarks and Standards. 5th AVHRR Data Users Meeting, Tromso (Norway), 25th-28th June 1991.

M. Sharman, I. Barnes, Ph. Bierlaire 1991 Automatic Extraction from AVHRR of Data on Vegetation Condition for the European Communities. 5th AVHRR Data Users Meeting, Tromso (Norway), 25th-28th June 1991.

4. Action 3

P. Vossen, 1992. Forecasting of National Crop Production: the Methodologies Developed in the Joint Research Centre in Support to the Commission of European Communities. EARSeL Workshop on Agrometeorology, Florence (Italy)13-14 April 1992.

P. Vossen, 1992. La Prévision du Potentiel de Production Viti- et Oléicole à l'Aide de la Méthode Aéropalynologique: Evaluation Primaire de la Méthode et des Investissements Faits par le Centre Commun de Recherche de la C.E. In: Résumé de la Conférence Méthodes Aéropalynologiques, Phénologie de la Floraison et Prévision de Rendements, Bordeaux (France) 10-11 Mars 1992.

P. Vossen, 1992. Timely forecasting of national sugar beet production in Europe: the CEC methodology and planned improvements using satellites. In: Proceedings of the 55th Winter Congress of the International Institute for Sugar Beet Research, Brussels, Belgium, February 1992, pp. 261-281.

J. Vogt, P. Vossen, 1993. Suivi des ressources hydriques de la zone méditerrannéenne par l'intégration des modèles agrométéorologiques et de données satellitaires: premiers résultats du projet hydre. In: Proceedings of the Conference Télédétection des Ressources en Eau, Tunis, Tunisie, Sept. 21-24, 1993.

A. Burrill, . P. Vossen, 1992. Development of an operational agrometeorological monitoring system. Proceedings of the Conference Application of Remote Sensing to Agricultural Statistics, Belgirate, Italy, 26th - 27th November 1991, pp. 357-360.

A. Burrill, P. Vossen, 1993. Agro-climatic zonation of grape sugar content in the E.C., Proceedings of the 4th European Conference on Geographical Information System (EGIS '93), 29 March - 1April, 1993, Genova.

J.Meyer-Roux and A.Burrill, 1993. Remote Sensing and Geographic Information Systems Within the MARS Project, Geodetical Info Magazine, Vol. 7, no. 1, pp. 65-69.

A.Burrill, 1992. An AML-Driven Crop State Monitoring System, Proceedings of the Twelfth Annual ESRI User Conference. 8-12 June, 1992, Palm Springs.

Ph. Bierlaire, A.Burrill and P.Vossen, 1992. Outline of an Operational Crop State Monitoring System. Paper presented at the Third European Conference on Geographical Information Systems (EGIS '92), April, 1992, Munich.

5. Collection

Un système d'Information Agronomique pour la Communauté Européenne / An Agricultural Information System for the European Community:

G. Russell, 1990. Barley Knowledge Base. JRC, EUR 13040 EN.

E. Choisnel, O. de Villele, F. Lacroze, 1992. Une Approche Uniformisée du Calcul de l'Evapotranspiration Potentielle pour l'Ensemble des Pays de la Communauté Européenne. JRC, EUR 14223 FR.

A. Carbonneau, R. Riou, D. Guyon, J. Riom, C. Schneider, 1992. Agrométéorologie de la Vigne en France. JRC, EUR 13911 FR.

A. Falisse, 1992. Aspects Agrométéorologiques du Développement des Cultures dans le Benelux et les Régions Voisines. JRC, EUR 13910 FR.

G. Narciso, P. Ragni, A. Venturi, 1992. Agrometeorological Aspects of Crops in Italy, Spain and Greece. JRC, EUR 14124 EN.

R. Palm, P. Dagnelie:, 1993. Tendance Générale et Effet du Climat dans la Prévision des Rendements Agricoles des Différents Pays des C.E. JRC, EUR 15106.

J. Bignon, 1990. Agrométéorologie et Physiologie du Maïs Grain dans la Communauté EuropéenneJ. RC, EUR 13041.

M.N. Hough, 1990, Agrometeorological Apsects of Crops in the United Kingdom and Ireland. A Review of Sugar Beet, Oliseed Rape, Peas, Wheat, Barley, Oats, Potatoes, Apples and Pears. JRC, EUR 13039.

E.G. Beek, 1991.Spatial Interpolation of Daily Meteorological Data. The Winand Staring Centre for Integrated Land, Soil and Water Research, 2 Volumes.

M.N. Hough and J. Parker, 1992. The Estimation, for the EC, of Global Solar Radiation and Sunshine Hours from Cloud Cover for 1-Day and 10-Day Periods. Meteorological Office.

G.H.J. de Koning, M.J.W. Jansen, E.R. Boons-Prins, C.A. van Diepen, F.W.T. Penning de Vries, 1993. Crop Growth Simulation and Statistical Validation for Regional Yield Forecasting Across the European Community. Simulation Reports CABO-TT, no. 31. JRC-CABO-DLO.

E.R. Boons-Prins, G.H.J. de Koning, A. van Diepen, Penning de Vries, 1993 Crop-specific Simulation Parameters for Yield Forecasting Across the European Community. Simulation Reports CABO-TT, no. 32. JRC-CABO-DLO, 250 pp.

R. Palm, P. Dagnelie, 1993. Tendance Générale et Effects du Climat dans la Prévision des Rendements Agricoles des Différents Pays des C.E. JRC, EUR 15106.

I. Supit, 1993. Optimizing the Uses of European Solar Radiation Network. JRC-EUR report.

6. Action 4

M. Sharman, 1990. Visual Image Interpretation of High Resolution Imagery for Real Time Agricultural Monitoring in Europe. ISPRS Symposium, Victoria B.C., Sept. 17-21, 1990.

M. Sharman, H. de Boissezon, 1992. Action 4 - From image statistics: operational review after two years of rapid estimates of acreages and potential yields of major annual crops throughout the European Community. Proceedings of the European International Space Year Conference, Munich, 30th March - 4th April, 1992 ESA Publication ISY1.

M. Sharman, J. Meyer-Roux, 1991. The Use of High Resolution Imagery in an Advanced Agriculture Information System. 5ème Colloque International Masures Physiques et Signatures en Télédétection, Courchevel (France) 14-18/01/1991.

SOTEMA, 1992. Estimation Rapides au Niveau Européenne des Superficies et des Rendements Potentiels. Rapport final Phase 2. Centre Common de Recherche et SOTEMA, Toulouse, 130 pp.

SOTEMA, 1933. Estimations Rapides au Niveau Européenne des Superficies et des Rendements Potentiels. Rapport final Phase 3. Centre Commun de Recherche et SOTEMA, Toulouse, 146 pp.

SOTEMA, 1933. Rapid Estimates of Crop Acreages and Potential yields at European Scale. Document de Synthèse. Centre Commun de Recherche et SOTEMA, Toulouse, 11 pp.

7. Action 6

V. Perdigao, J. Delincé, J.P. Cantou, V. Rodriguez, 1990. Utilisation des Images Numériques pour l'Organisation des Enquêtes Agricoles - Production d'un Nouveau Type de Documents. In: Proc. of Symposium International de Cartographie Thématique Dérivée des Images Satellitaires, Saint-Mandé (France), 1990, Comité Français de Cartographe Bull. 127-128.

V. Perdigao, et al., 1991. Synthetic Cartographic Documents Based on High Resolution Satellite Imagery. In: Proc. 11th EARSeL Symposium, Graz, 1991, pp. 406-417.

V. Perdigao, 1991. Ground Survey Documents Based on High Resolution Satellite Imagery - 1990 Campaign. JRC, S.P.I. 91.29.

8. Support to DG XI EEA-FF

V. Perdigao, A. Annoni, 1993. Integration of Remote Sensing and G.I.S. to Update a Multisources Land Cover Database. In: Proc. of Int. Symp. Operationalization of Remote Sensing, Vol. 6, pp. 53-60, Enschede.

ISSN 0254-1475

COM(94) 332 final

DOCUMENTS

EN

15 03

Catalogue number : CB-CO-94-406-EN-C

ISBN 92-77-80558-7

Office for Official Publications of the European Communities
L-2985 Luxembourg