Netherlands Scientific Council for Government Policy

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Crop production potential of rural areas within the European Communities

III : Soils, Climate and Administrative Regions

G.J. Reinds

G.H.J. de Koning

J.D. Bulens

The Hague, March 1992

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PREFACE

The Netherlands Scientific Council for Government Policy has ~~asked the~~ Winand Staring Centre in Wageningen to investigate the crop production potential of the rural areas within the European Communities. The Council needed this information for a project on the possible future developments in the rural areas of the EC as a result of an ongoing growth in agricultural productivity. To get a clear view the Council explored the possible changes in the rural areas.
When exploring possible developments or options it is crucial to define the objectives at stake. Within agriculture not only production is of importance, but also (regional) employment, emissions of pesticides and nutrients to the environment, impact on the landscape, etc. Land use is taken as the key factor in the explorations by the Council. Through different types of land use different goals can be attained. The explorations show the differences in possible future land use when a certain priority is given to the various objectives.
Information on the physical possibilities for land use was absolutely necessary to carry out the explorations. A team from the Winand Staring Centre consisting of Ir. J.D. Bulens, Ir. A.K. Bregt, Ir. C.A. van Diepen, Ir. C.M.A. Hendriks, Ir. G.H. de Koning and Ir. G.J. Reinds led by Dr.ir. H.A.J. van Lanen compiled this information. A report of their research is given in a series of five separate documents under the common title 'Crop production potential of rural areas within the European Community'. The series consists of:

I	: GIS and datamodel (W65)
II	: A physical land evaluation procedure for annual crops and grass (W66)
III	: Soils, climate and administrative regions (W67)
IV	: Potential, water-limited and actual crop production (W68)
V	: Qualitative suitability assessment for forestry and perennial crops (W69)

The full report shows that a combination of Geographical Information Systems and simulation models can provide useful quantitative information on crop production potentials for different crops at different locations. With this approach the Winand Staring Centre opened up a new and promising line of research.

Prof.dr.ir. R.Rabbinge

ACKNOWLEDGEMENT

At the request of the Dutch Scientific Council for Government Policy (WRR) the Winand Staring Centre (SC) in Wageningen conducted a study on the crop production potential of the rural areas within the European Communities (EC). We gratefully acknowledge the grant provided by the Council. The SC study was supervised by a WRR team comprising Prof.dr.ir. R. Rabbinge (chairman), Drs. H.C. van Latesteijn (secretary), Drs. D. Scheele, Ir. H. Hengsdijk and Drs. E. Bolsius.
The digitized maps and some attribute data used in our study were supplied in a compatible form by the CORINE project team (DG XI, Commission of the European Communities, Brussels). The support of Mr. M.H. Cornaert and Ir. J. Maes is greatly appreciated.
Meteoconsult B.V. in Wageningen provided records of historical weather data for many meteorological stations within the EC.
Furthermore valuable data on crops were provided by colleagues at the Centre of Agrobiological Research (CABO) in Wageningen.

Ir. G.J. Reinds
Ir. G.H.J de Koning
Ir. J.D. Bulens

1 INTRODUCTION

The Common Agricultural Policy (CAP) of the European Communities (EC) has stimulated agricultural production to such a level that surpluses of some major commodities, such as wheat, sugar, milk, and wine has become structural. In areas favourable for agriculture, farm size has increased, narrow crop rotations have been introduced, and large amounts of relatively inexpensive agro-chemicals and feedstuffs are being used. The intensification of agriculture in these regions has detrimentally affected the environment, nature and landscape (Briggs and Wilson, 1987). In areas less favoured for agriculture, the abandonment of land and associated social hardship occurs.

EC funds are increasingly called upon to mitigate the undesirable socio-economic and environmental effects of the CAP. However, little or nothing is known about the cost-effectiveness of investments for agricultural development in the various EC regions in relation to the long term perspectives.

Therefore, the Netherlands Scientific Council for Government Policy (WRR) has started a project on the possible developments of the rural areas in the EC. Different land use scenarios will be evaluated in terms of their impact on rural development, taking into account agricultural, socio-economic, environmental, and physical planning aspects.
The WRR will develop and apply a model for the General Optimal Allocation of Land use (GOAL). This model uses a method known as Interactive Multiple Goal Linear Programming. For the purpose this model the WRR requires, among other input data, information about the regional production potentials of major crops at different input levels.

At the request of the WRR, the Winand Staring Centre has investigated the physical crop production potential of rural areas in the EC. The yield potential of some indicator crops, when grown on major land units suitable for agricultural use, was determined by a combined use of physical land evaluation methods and a Geographical Information System (GIS).

In this report the maps and data sets used in the land evaluation procedures will be discussed in detail. Consequently, when reading other working documents it can serve as background information.
The land evaluation map, showing the land evaluation units, was compiled by a digital overlay of three base-maps:

- the soil map of the EC on a scale 1 : 1.000.000
- an agro-climatic map of the EC, comprising 109 agro-climatic zones

- a map with 61 administrative regions, according to the 'Nomenclature des Unites Territoriales Statistiques', level 1 (NUTS-1 regions)

The land evaluation map comprises 4269 land evaluation units, each being an unique combination of soil type, climatic region and NUTS-1 region.
Each land evaluation unit is characterized by specific soil and meteorological data which formed the basis for the combined application of qualitative and quantitative land evaluation procedures. The principal components of these procedures are expert knowledge systems and crop growth simulation models respectively.

Chapter 2 describes the soil map of the European Communities on a scale 1:1.000.000. The classification system used to compose the map is outlined and the major soil units that occur are listed and briefly described. Furthermore, the general composition of the soil associations is discussed. Additionally, attention is paid to selected and representative soil profiles and the soil data derived from the map.
In chapter 3 the agro-climatical map and the corresponding meteorological data set used in the physical land evaluations, are characterized.
Chapter 4 discusses the map with administrative regions within the European communities. This map was used to aggregate the results of the physical land evaluations and to allow a comparison between simulated results and statistical data available for these so called Nuts-1 regions.
All maps and associated data where stored in a Geographical Information System. A detailed description of this GIS is provided by Bulens & Bregt (1991).

2 SOILS OF THE EUROPEAN COMMUNITIES

The most comprehensive and consistent soil map of the EC is the soil map of the European Communities on a scale 1:1.000.000.
This map was published by the Commission of the European Communities (CEC, 1985) and comprises six map sheets and an accompanying textbook. The map was compiled from twelve national soil maps of the same scale, supplied by each of the EC membership countries. A fragment of the EC soil map, illustrating the amount of detail on the 1:1.000.000 scale, is given on Map I.

2.1 Classification system.

The soils on the EC soil map are classified according to the FAO soil classification system (CEC, 1985). This classification system had been previously used to compile the soil map of the world on a scale 1:5.000.000 (FAO, 1974). It distinguishes 26 major soil groups or orders, 18 of which were included in the soil map of the EC. On this level of classification, soils are grouped according to general principles of soil formation.
The following is a broad description of the 18 soil orders that occur on the EC soil map. Most of these descriptions are based on those provided by Van Dam and Van Diepen (1982) in combination with the definitions of the soil orders listed in the legend of the soil map of the world (FAO, 1974).

Fluvisols
Soils developed in recent alluvial deposits, still showing fine stratification and often receiving fresh material at regular intervals from a river, a sea or by overland flow.

Gleysols
Soils that are strongly influenced by groundwater, showing groundwater influence within 50 cm of the surface and do not have any indication of strong soil development such as illuvial horizons.

Regosols
Soils consisting of loose materials that do not show soil development.

Lithosols
Soils whith coherent hard rock within 10 cm of the surface.

Arenosols
Strongly weathered sandy soils

Rendzinas
Soils with a topsoil with a high organic matter content and containing or directly overlying calcareous materials of a high calcium carbonate content.

Rankers
Shallow soils with a thin, acidic humic topsoil.

Andosols
Soils developed in volcanic materials.

Vertisols
Heavy clay soils, with deep cracks when dry that close in wet periods because of the presence of swelling clay minerals.

Solonchaks
Soils with a high content of soluble salts.

Xerosols
Soils developed under very dry and warm conditions; xerosols on the EC soil map always contain a calcic or a gypsic horizon indicating a high precipitation deficit.

Phaeozems
Soils with a very humic, brown topsoil. Similar to the well known chernozems.

Cambisols
Soils of medium to fine texture that are weakly weathered and have only minor alterations in parent material with respect to colour, consistency or structure.

Luvisols
Soils containing a subsoil horizon with a high base saturation showing illuvial accumulation of clay.

Podzols
Sandy soils developed under acid conditions, in which organic matter and aluminium with or without iron has accumulated at some depth.

Podzoluvisols
Soils showing both Luvisol and Podzol features.

Planosols
Soils with a leached horizon on top of a slowly permeable horizon causing water stagnation in at least some parts of the year.

Histosols
Soils formed under very wet conditions by prolonged accumulation of organic materials. Generally, the mean organic matter content should exceed 20 % over a depth of at least 40 cm.

The orders can be subdivided into great groups according to differentiating characteristics such as base saturation, gleyic features, humus content in the top soil and so on. On the EC soil map, for example, the order of Fluvisols is subdivided into three great groups according to differences in base saturation:

- Calcaric Fluvisols, Fluvisols containing free $CaCO_3$ and consequently have a base saturation of 100%.
- Eutric Fluvisols, Fluvisols with a base saturation of 50 to 100 %.
- Dystric Fluvisols, Fluvisols with a base saturation of less than 50 %.

Some great groups are further subdivided into subgroups according to other differentiating characteristics (CEC, 1985). On the EC soil map, for example, Calcaric Fluvisols are subdivided into two subgroups:

- Fluvi-Calcaric Fluvisols, Calcaric Fluvisols that are formed in river deposits.
- Gleyic-Calcaric Fluvisols, Calcaric Fluvisols that show groundwater influence within 100 cm of the surface.

2.2 Soil associations and their characteristics.

The EC soil map consists of 312 different soil associations. Each of these soil associations contains a dominant soil unit, one or more associated soils which cover less than 50 % but more than 10 % of the area of the association, and one or more inclusions. Inclusions always cover less than 10 % of the area of the soil association.
On the map 78 different dominant soil units have been distinguished; two are specified at order level, 49 at great group level and 27 at subgroup level.

The soil texture of the uppermost 30 cm of the soil profile of dominant soil unit and the most common slope of each association are known and listed in the map legend. The soil texture of the associated soils and inclusions is not specified.
The topsoil texture of the dominant soil unit is divided into five classes (CEC, 1985):

1 coarse: more than 65 % sand and less than 18 % clay.
2 medium: more than 15 % sand and less than 35 % clay; more than 18 % clay if the sand content exceeds 65 %.
3 medium fine: less than 15 % sand and less than 35 % clay.
4 fine: more than 35 % clay but less than 60% clay.
5 very fine: more than 60 % clay.

If it was not possible to allocate the texture of the top soil to a single texture class, a compound texture class was indicated comprising two or more texture classes.
Peat soils (Histosols) also occur on the map. Two types of peat soils have been distinguished, namely Dystric and Eutric Histosols, for which, of course, no texture class was specified.

The slope dominating the terrain where the soil association is situated, is divided into four classes (CEC, 1985):

a level: major slopes between 0 and 8 %.
b sloping: major slopes between 8 and 15 %.
c moderately steep: major slopes between 15 and 25 %.
d steep: major slopes exceed 25 %.

The map often shows compound slope classes, comprising two or more of these slope classes.

The polygons on the soil map each have a number referring to a symbol. These symbols are listed on the map legend and solely refer to the dominant soil within the soil associations.
An example of such a symbol is Je-1/2ab. This code contains:

- the characterization of the dominant soil unit: Je, in which J is the character for Fluvisol and e for Eutric. The number of characters indicating the name of the dominant soil unit is one for soils specified at order level, two for soils specified at group level and three for soils specified at sub-group level.
- the texture of the dominant soil, indicated by the next two characters: 1/2 which means that the texture of the topsoil is in class 1 or 2. Single value texture classes are indicated by one character.

- the slope of the site on which the soil association is situated, given in the last two characters: ab. These characters refer to the slope classes a and b so the slope of the unit is between 0 and 15 %. Single value slope classes are indicated by one character.

On the soil map some soil associations are marked with rasters indicating so-called soil phases. These soil phases are used to indicate adverse soil conditions that can negatively affect the characteristics of the soil in connection with soil management for instance. Seven different phases were distinguished (CEC, 1985):

- stony phase: areas in which the number of stones (>7.5 cm), boulders or rock outcrops in the topsoil prohibit the use of mechanized agricultural equipment.

- gravelly phase: areas in which the topsoil contains more than 35 % gravel (<7.5 cm) often only allowing the use of simple agricultural tools.

- concretionary phase: areas in which the topsoil contains more than 35 % pedogenetic concretions, limiting the use of mechanized agricultural equipment.

- petrocalcic phase: areas having a cemented or indurated calcic horizon within 100 cm of the soil surface.

- lithic phase: areas with coherent and hard rock within 50 cm of the soil surface.

- saline phase: areas with a saline horizon within 100 cm of the surface.

- sodic phase: areas with a sodic horizon within 100 cm of the surface.

In addition to these seven single soil phases, there are seven combinations of two phases each. Since soil phases may significantly influence some important soil characteristics, the soil phase was taken as a diagnostic characteristic. This means that, in this study, a dominant soil unit with a particular soil phase is considered to be different from the same soil unit with either no soil phase or another soil phase. In this way the number of different soil associations increased from 312 to 546.

2.3 Selected and representative profiles

To characterize the soils on the EC soil map, a selected profile was described for each dominant soil unit; some profile descriptions are listed in the legend of the EC soil map (EC, 1985) others in the legend of the FAO soil map of the world (FAO, 1974). Soil units however, can differ in various soil characteristics even when classified in the same great group or sub-group, due to several factors such as climate, parent material and land use. For example, the chemical and physical soil characteristics of an Orthic Luvisol formed in a subtropical Mediterranean climate used as arable land will probably be different than those of an Orthic Luvisol in Ireland, developed in a temperate climate and used as permanent pasture. The selected profile described in the legend of the EC soil map, "representing" Orthic Luvisols, is located in Denmark and has a beech vegetation. To use the data given in this profile description to characterize all Orthic Luvisols in the EC would be incorrect as this Danish soil is developed under environmental conditions and in a parent material other than that of many Orthic Luvisols in other European regions. In other words, the data presented for the selected profiles are site-specific and cannot be used for all of Europe. This problem has been recognized by authors who used the EC soil map for broad physical land evaluations (Van Lanen et al., 1988, Proctor et al., 1988, Madsen et al. 1987). For these evaluations, the soil data used often needed to be retrieved from national data bases.

Madsen (1988), proposed a soil analytical data base for the entire European Communities that should be established within the frame of the CORINE project. CORINE is an acronym for gathering and coordinating information on the state of the environment and natural resources in the European Communities (Wiggins et al., 1987). In the first development stage this data base should contain profile descriptions and analytical data for all dominant soil units within each EC country. Soil analysis and profile descriptions in each country should be made according to generally accepted standard methods.
In the second stage, associated soils and inclusions should be described and analyzed as well. In the third stage, the profile descriptions and analytical data should be gathered for different regions within each country. Finally, descriptions should be made dependent on land use.
One of the first attempts to establish a soil data base for the EC soil map was made in 1987 by Gardiner (1987). Gardiner collected 252 representative soil profile descriptions and accompanying analytical data from seven EC-countries. Unfortunately 220 of these soil profiles were located in England, Scotland and Ireland, so the number of profiles in other countries was very limited. No profiles were obtained from Germany, The Netherlands, Belgium, Greece and Portugal. Furthermore, no standardization was made in the data base: profile descriptions were given in the national language and the number and type of analytical data was dependent on the soil survey organization that supplied the

data. This collection of profile descriptions and accompanying soil analytical data, therefore cannot serve as a data set for a physical land evaluation for the entire EC, as the information is too fragmentary, partly difficult to access and only covers a small part of the EC map area.

From the foregoing it follows that at present representative soil data for the soil units on the EC soil map are lacking. For the dominant soil units only topsoil texture and slope are explicitly described, for associated soils and inclusions even texture data are lacking. The texture of the associated soils is in particular of major importance as these soils cover a relatively large area on the EC soil map. Figure 2.2 shows the frequency distribution of the percentage of the area of a soil association covered by the dominant soil unit. For instance, figure 2.2 shows that about 25 % percent of the soil associations contain a dominant soil unit which covers 75 % of the area of the soil association. Estimations of these relative areas were obtained from the information in the map legend of the EC soil map. It cannot be computed exactly, as the percentage of the soil association covered by the dominant soil unit is sometimes given as a range (eg. 40-60%) sometimes as more than a certain percentage (e.g. > 70%) and sometimes as less than a certain percentage (e.g. < 60 %). If a range is specified, the mean percentage of the range was used. If only a minimum or maximum relative area was indicated in the legend, the area covered by the dominant soil unit was approximated taking into account the number of associated soils and inclusions within that specific association.

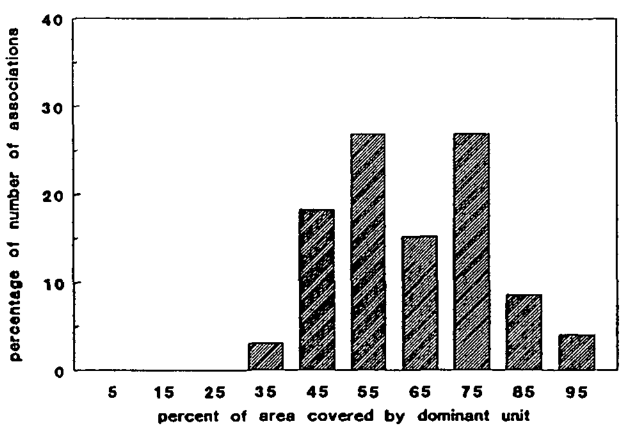

Figure 2.2 Frequency distribution of the percentage of the area of the soil associations covered by the dominant soil unit.

Figure 2.2 shows that most dominant soils cover only 40 to 80 % of the area of the soil association. The percentage of the total area on the EC map occupied by dominant soils computed as 60 % was obtained by multiplying the area of each soil association and the percentage of the association occupied by the dominant soil. This means that for about 40

% of the map area soil texture data are lacking.

For broad land evaluation studies at EC level, such as conducted in this study, the first two soil data base stages described by Madsen are important if evaluation results need to be improved. Besides, additional information on for instance rooting depth, soil water retention and drainage status for all mapping units on the EC soil map would be very useful.

Soil maps, however, contain valuable information, as soil units with regard to some general soil characteristics are unique.
Common soil characteristics such as drainage status and soil depth are used as diagnostic characteristics in the classification of soils. Lithosols, for example , are defined as soils with as soil depth of less than 10 cm, Gleysols are defined as soils with groundwater influence within 50 cm of the surface. Using these classification criteria, some important, general soil characteristics can be estimated from the symbol of the soil unit solely (CEC, 1985, Ameryckx & Verheye, 1986). This process of data retrieval from the EC soil map is discussed in the next section.

2.4 Estimation of some general soil characteristics from the EC soil map.

2.4.1 Assessment of some general characteristics from the soil unit symbol.

To assess some important soil characteristics needed for the physical land evaluations, all symbols of dominant soil units were interpreted. Soil and land characteristics were derived for each dominant soil unit by a straightforward interpretation of the symbol of the soil unit. This interpretation was based on a pilot study by Ameryckx and Verheye (1986) who derived soil characteristics for the dominant soils of the soil associations in France, indicated on the EC soil map.
Each of the 546 symbols representing a soil unit in combination with a soil phase, was analyzed automatically. Decision rules were developed to split up each symbol into three parts, one with one to three characters representing the pedogenetic name of the soil unit according to the FAO classification system, a second part indicating the texture of the topsoil and a third part indicating the slope of the site at which the soil unit was situated (see also section 2.1). This information yielded 11 soil and land characteristics as follows:

- texture, subdivided into five single-value classes and eight compound classes.
- cation exchange capacity, subdivided into five single-value classes and eight compound classes.
- maximum rooting depth, subdivided into five single-value classes.
- drainage condition, subdivided into seven single value classes.
- slope, subdivided into four single-value classes and six compound classes.
- presence of alkalinity, subdivided into two classes.
- presence of salinity, subdivided into two classes.
- presence of free $CaCo_3$, subdivided into two classes.
- presence of free $CaSo_4$, subdivided into two classes.
- base saturation, subdivided into three classes.
- organic matter content of the topsoil, subdivided into three classes.
- presence and type of soil phase.

A description of these characteristics and their subdivision into classes, is given in ANNEX III.
An example of how a particular soil characteristic was estimated from the symbol of the soil unit, is provided in Figure 2.3. This figure illustrates the assessment of a base saturation class for each soil unit. Firstly the soil order to which the soil unit belongs was determined by identifying the first character of the pedogenetic name. All Andosols, Rankers, Podzols and Podzoluvisols were assumed to have a base saturation lower than

50 %. All Solonchaks, Rendzinas and Xerosols were assumed to have a base saturation of 100 %. For all other soils, the great group to which this soil unit belongs was determined by identifying the second character of the pedogenetic name. All dystric, humic, and ferric soils, not included in the previously mentioned soils, were assumed to have a base saturation of less than 50 %. All calcic soils were assigned to the group of soils which have a base saturation of 100 %. All other soils are assumed to have a base saturation between 50 and 100 %.
Other properties were derived in a similar way. It is beyond the scope of this report to fully list all decision rules. Only a brief indication of how the other characteristics were derived, is given below.

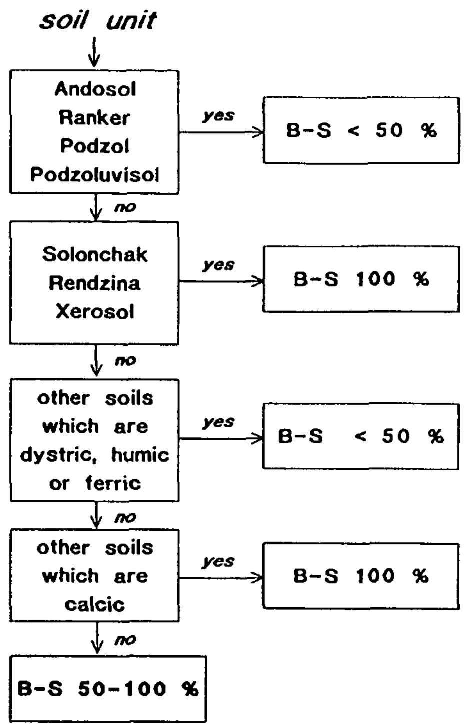

Figure 2.3 Assessment of a base saturation class.

Texture and slope were defined in the soil unit symbol, so they could be instantly derived. Cation Exchange Capacity was directly and solely related to the texture of the topsoil as organic matter content data are too broad to improve the assessment. The drainage condition was derived from the name of the soil unit and its texture.
The maximum rooting depth was derived from the pedogenetic name of the soil unit, combined with its texture, phase and drainage conditions. The presence of alkalinity, free $CaCO_3$, free $CaSO_4$ in the topsoil and the organic matter content of the topsoil were derived from the name of the soil unit. The presence of salinity was expressed by the name of the soil unit as well as by its phase.

As stated earlier, many soil units have compound texture and/or slope classes. Unfortunately, the relative area of each of the single texture- and slope classes within a compound unit is not given for the soil units on the EC soil map. Since no composition data were available, each single value class was assumed to cover an equal area within the compound unit. For instance, a soil unit with moderate to steep slopes (slope class ab) and a coarse to medium texture (texture class 1/2) was subdivided into four sub-units. One sub-unit with slope class a and texture class 1, one with slope class a and texture class 2, one with slope class b and texture class 1 and one with slope class b and texture class 2. Each of these sub-units was assumed to cover an equal area, namely 25 % of the area of the soil unit. Each sub unit was separately evaluated by the physical qualitative and quantitative land evaluation methods.

2.4.2 Water retention data

The crop growth simulation model WOFOST (Van Diepen et al. 1988) was used in the quantitative land evaluations.
This model calculates the yield reduction caused by water stress on basis of a simple soil water balance. To simulate the water balance of the soil, some soil hydraulic properties must be specified for each land evaluation unit. For free draining soils, a specification of the water holding properties by three points on the water retention curve is sufficient to run the water balance routine. However, for groundwater influenced soils, that cover only a minor part of the EC, a full water retention curve and a hydraulic conductivity curve must be specified. Drought stress occurs if the amount of available water within the root zone is insufficient to allow optimal transpiration of the crop. In the root zone, the water content below which drought stress occurs is dependent on crop characteristics and the evaporative demand. The water content of the soil is determined by rainfall, simulated evapotranspiration, runoff and percolation, and on the amount of available water. In the WOFOST model, available water content is therefore the most important soil physical property influencing water-limited crop growth. It is defined as the water content at pF 2.0 or pF 2.3, depending on the drainage status of the soil, minus the water content at pF 4.2. These two points on the water retention curve are often referred to as field capacity and permanent wilting point respectively.
Unfortunately, only a small number of such soil physical data are readily available. Moreover, they represent only a limited number of EC countries. Data on available water as determined in some EC countries are listed in table 2.4.

This table shows that the available water contents given by the various authors are within close ranges. An exception are the coarse textured soils where data cover a broad range. This is probably due to differences in organic matter content of the analyzed samples as organic matter content can substantially influence the water holding capacity of coarse textured soils. As there was insufficient water retention data to allow a regional differentiation of the water holding properties of the five texture classes, it was decided to

Table 2.4 Water content between pF2.0 and pF 4.2 in cm/m as determined in various EC countries.

Coarse	Medium	Medium-Fine	Fine	Very fine	Source	Country
8	15	19	18	17	1	France
11	21	24	20	19	1 *	United Kingdom
15	21	24	19		2	Belgium
16	22	17	17	14	3 **	Germany
17	23	22	23	21	4	Netherlands
16	20				5	Denmark

sources:
1 King & Daroussin, 1988.
2 Vereecken, 1988
3 Mc Keague et al., 1984
4 Wosten et al., 1987
5 Madsen & Platou, 1983

* water content between pF1.8 and pF4.2
** water content between pF1.7 and pF4.2

use only one set of water retention data for each texture class in the EC. This simple allocation of water retention data to texture classes irrespective of the region where the soil is situated, is of course a drastic simplification.
The soil water retention curves from Vereecken (1988) were used in our study to represent the texture classes on the EC soil map. Firstly, these data are close to the mean available water contents for the countries as listed in table 2.4. Secondly, the division of texture into texture classes as practiced by Vereecken is very similar to the texture division on the EC soil map, enabeling texture classes to be compared very well. Vereecken (1988) described the water retention curves by means of a parameter equation developed by Van Genuchten (1980). The parameter values needed to compute the relationship between water content and pressure head, however, were only given for the texture classes comparable to the EC texture classes coarse, medium, medium fine and fine. There is no data for texture class very fine. These parameter values were assessed by a relation also given by Vereecken (1988) where an estimation of the parameters was achieved using easily measurable soil characteristics. For texture class very fine, bulk density, clay content, sand content and organic matter content were estimated and these values were used to calculate the parameter values required to describe the water retention curve. Note that this rather speculative pF curve for texture class five only applies to about 0.5% of the total soil map area. Moreover, in the land evaluation procedures, land evaluation units with texture class very fine were assumed to be unsuitable for far most types of land use (Reinds & Van Lanen 1991).

2.4.2 Data for associated soils

Estimates of soil characteristics derived from the pedogenetic name of the soil unit could also have been made for the associated soils of each soil association.
However, soil texture is only known for the dominant unit within each association. As the texture of the uppermost 30 cm of the soil is a prerequisite for the evaluation of its crop growth potential, the estimation other soil characteristics for associated soils or inclusions was of no use. This implies that the physical land evaluation referred to the dominant soil unit of each soil association. Consequently, the crop growth potentials of a soil association were only represented by those of the dominant soil unit. This is of minor importance if the dominant soil unit covers a large part of the area of the association. In the previous section, however, it was shown that dominant soils cover only about 60% of the total map area.
A relatively high proportion of EC land occupied by associated soils and inclusions does not necessarily mean that the results obtained for the dominant soil unit do not apply to the soil association. If a soil association is composed of a dominant soil, associated soils and inclusions with very different soil physical properties such as texture and rooting depth, the estimated production potential for this association will not be completely accurate as the dominant soil cannot represent the entire association. If, on the other hand, the association consists of soils with almost identical physical properties, the production potential of the soil association can be reasonably assessed.

3 AGRO-CLIMATIC ZONES

For each land evaluation unit, a representative set of meteorological data was needed to allow evaluation of the crop growth potential with the physical land evaluation models.
To this end a map was constructed on which 109 agro-climatic zones were distinguished. For each of these zones a representative meteorological station was selected. A historical record of monthly average weather data was available for 81 stations. For the other 28 stations long-term average monthly weather data were used.
The crop growth simulation model WOFOST, which is a vital part of the quantitative land evaluation procedure, can only be utilized with a complete set of weather data; i.e. a set without any missing data. Data on either a daily or a monthly basis can be used. Weather input data needed for WOFOST are global radiation, minimum temperature, maximum temperature, vapour pressure, wind speed, precipitation and, in case of monthly data, number of days with precipitation. Within the model, monthly data are translated to daily data by means of stochastic distribution procedures for precipitation and by linear interpolation for other weather variables (van Diepen et al., 1988). For the qualitative land evaluation procedure less detailed weather data were required.
A number of data was missing in both the historical and the long-term records of weather so substitutes had to be found. Some of the weather variables had to be converted to meet the input requirements of WOFOST, e.g all sunshine duration data had to be converted to global radiation. The replacement of missing values and conversion of weather data in both the historical and long-term average data records will be discussed separately in this chapter.

3.1 The agro-climatic map

A digitized agro-climatic map for the EC was constructed based on the Agro-climatic Atlas by Thran and Broekhuizen (1965). The Agro-climatic Atlas was developed to characterize the ecological conditions for cereal growing in Europe. This original map was adapted somewhat. The most important modification concerned a more accurate localization of mountainous areas. Furthermore a geographical map projection had to be found by trial and error, due to the lack of specifications on the source map. This projection was needed to perform a map overlay with the soil map and the map with administrative regions. On the agro-climatic map, 109 zones were distinguished.
Weather data from meteorological stations were available as long-term mean data or as historical records. For most stations a historical record of monthly data was available, for others only the monthly long term average weather data were known. One representative

meteorological station was allocated to each of the agro-climatic zones. Priority was given to a station with a historical record of data. A valley station was selected in mountainous zones, because it was assumed that most agricultural activities take place under lowland conditions.
The agro-climatic zones and their corresponding meteorological stations are shown on Map II.

3.2 Historical records of weather data

A historical record of monthly average weather data for 81 stations was obtained from "Meteoconsult", a specialised meteorological company in Wageningen, the Netherlands. This historical record covered 26 years: 1961 to 1986 inclusive. For 8 of the stations the historical record only covered a number of years between 15 and 26. A list of the 81 stations is given in ANNEX I, together with some specifications. The data set with monthly data contained the following weather variables:

- average temperature (degrees Celsius)
- sunshine duration (hours/month)
- average vapour pressure (mbar)
- precipitation (mm/month)
- number of days with more than 1 mm rainfall (days/month)

3.2.1 Missing data

A number of data in the historical records was lacking. Wind speed figures were not available at all and for the years 1961 to 1968 inclusive the records contained no sunshine duration figures. Furthermore a small number of values concerning all weather variables was missing throughout the data set in a non-systematic way.
To substitute these missing data, another source of weather data was also consulted. In Muller (1987) long term average monthly data of 1178 meteorological stations throughout the world are provided. In this book figures of 16 weather variables are given with a varying completeness depending on the station.

In the process of updating the historical records, 2 types of stations were distinguished:

a: Stations that are not listed by Muller (1987).
This applied to 15 of the 81 stations with a historical record. The long-term average monthly value of each weather variable for each station was calculated from the available data in the historical record of that station as obtained from Meteoconsult. These averages were used to replace missing values. When there were less than 10 figures available to calculate a long-term average, a long term average was used from the most adjacent station listed by Muller (1987). Values from adjacent stations had to be used for the sunshine duration of 8 stations and the number of rainy days of 3 stations. Because no wind speed data were available in the historical records, long term wind speed data of 9 stations were derived from 4 nearby stations provided by Müller (1987), from 2 stations by Wallén (1970 and 1977) and from 3 stations by Bendelow and Hartnup (1980). The wind speed figures of the remaining 6 stations were estimated from data available on other locations and general wind gradients (e.g. coastal effects).

b: Stations for which data are provided by Muller (1987).
This applied to 66 of the 81 stations. When figures were missing for the variables temperature, sunshine duration, precipitation or number of rainy days, the long-term average figures for the same station according to Müller (1987) were used to substitute the missing values.
Müller (1987) does not provide vapour pressure values. Missing vapour pressure values were therefore replaced by long-term averages from the historical records as described for the stations listed under "a". The historical record of the station Braganca contained only 9 complete years of vapour pressure data. For all other stations at least 10 years of monthly vapour pressure figures were available.
Wind speed figures are given by Müller for only 26 of the 66 stations. Wind speed figures for 6 of the other stations were retrieved from Wallen (1970; 1977). For 3 stations in the United Kingdom wind speed was taken from Bendelow and Hartnup (1980). For the remaining 31 stations wind speed was estimated from available data on other locations and general wind gradients (e.g. coastal effects).

3.2.2 Conversion of data

Much meteorological data in the historical records had to be converted to appropriate input data for the crop growth model WOFOST. In the dataset from Meteoconsult, temperature was given only as the average day temperature in a specific month. WOFOST, however, requires minimum and maximum temperature. For each station, the long-term monthly range between maximum and minimum temperature was retrieved from Müller (1987).

When the specific station was not listed, an adjacent station was used. This long-term temperature range was used to convert the monthly average temperatures in the historical records to maximum and minimum temperatures.
The sunshine duration was converted to global radiation ($J\ m^{-2}\ d^{-1}$) according to a standard procedure as described by Berkhout (1986). In this procedure an algorithm is used for the calculation of the Angot value developed by De Bruin (1977). The Angot value is the amount of solar radiation that theoretically reaches the edge of the atmosphere. The conversion of hours sunshine to global radiation is based on the general relation

$$Ri = Ra\ (A + B \cdot n/N)$$ where,

Ri = the radiation actually received ($J\ m^{-2}\ d^{-1}$)
Ra = Angot value ($J\ m^{-2}\ d^{-1}$)
n/N = ratio of actual duration of bright sunshine and the maximum possible sunshine duration on a cloudless day
A,B = empirical constants, that were set at 0.18 and 0.55 respectively, as proposed by the FAO (Frere and Popov, 1979)

3.3 Long-term average weather data

There was no historical record of weather data available for 28 agro-climatic zones. For all of these zones, a meteorological station was selected from the ones listed by Müller (1987) with long-term monthly average weather data. A list of these 28 stations is given in ANNEX II, together with some specifications.
The wind speed was available for 3 of these stations. For the other stations wind speed had to be estimated from available data on other locations and from broad wind gradients. Sunshine duration was converted to global radiation as described in section 3.2.
The relative humidity figures listed by Muller (1987) were converted to vapour pressure using a standard equation (Feddes et al., 1978):

$$VP = RH/100 * 1.333*\exp((1.089*T-276.488)/(0.0583*T-2.194))$$

where,
VP = vapour pressure (mbar)
RH = relative humidity (%)
T = temperature (Kelvin)

In this equation, T is the temperature at which the relative humidity is measured. As this temperature was unknown, the average temperature was used.

3.4 Derived meteorological data

Meteorological data derived from the updated records were used as input for the qualitative land evaluation procedure. Moreover data were derived for a further characterization of the agro-climatic zones which proved to be very useful for the interpretation of the simulated crop growth potentials.

The annual global radiation was obtained by adding the monthly global radiation for each station. Results are shown on Map III. The highest radiation levels were found in the south of the Iberian Peninsula and Greece. The annual global radiation in the west of Ireland and the north of the United Kingdom is about 50% of the highest levels in the EC.

Mohrmann and Kessler (1959) calculated the annual precipitation deficit for 287 stations in Europe. The results were summarized on maps showing iso-lines of annual precipitation deficits in Europe. For each month the potential evapotranspiration, calculated according to Turc's formula, was substracted from the precipitation. The annual precipitation deficit was obtained by adding all the values of the months in which the potential evapotranspiration was higher than the precipitation.
This methodology was applied for the 109 EC-stations used in this study but in a slightly modified way. Instead of Turc's formula for the potential evapotranspiration, the Penman formula was applied. For this purpose the WOFOST crop growth model was used, which contains a module to perform the Penman calculation (Van Diepen et al., 1988). The potential evapotranspiration was calculated assuming a closed canopy all year round. The resulting annual precipitation deficits are shown on map IV. Deficits higher than 600 mm are mainly found in Portugal, Spain and Greece, together with a few zones along the Mediterranean coast of France and Italy. France makes up the transition zone from the dry climates in the south to the humid climates in the north of the EC. Noteworthy are the very humid zones along the Bascian coast.

Within the EC, administrative regions are distinguished at four NUTS levels. NUTS stands for Nomenclature des Unites Territoriales Statistiques. At the highest level (NUTS-0), the EC is divided into the twelve member states. At the second level each country is subdivided into a number of NUTS-1 regions. A further subdivision of these NUTS-1 regions results in the NUTS-2 and NUTS-3 units (Table 4.1).

Table 4.1 Subdivision of the EC at different NUTS-levels.

NUTS 0		NUTS I		NUTS II		NUTS III
Belgium	3	Regions	9	Provinces	-	Arrondissements
Denmark	1		3	Grupper af Amter *	15	Amter
France	8	Zeat	22	Regions	96	Departements
Germany	11	Lander	31	Regierungs bezirke	-	Kreise
Greece	3	Groups of Development Regions	9	Development regions	51	Nomoi
Ireland	1		1		9	Planning regions
Italy	11	Gruppi di regioni *	20	Regioni	95	Provincie
Luxembourg	1		1		1	
Netherlands	4	Lansdelen	12	Provincies	-	C.O.R.O.P. gebieden
Portugal	1	Grupos de CCR *	5	CCR & regiones autonomos	27	Concelhos *
Spain	7	Agrupacio de comunidades autonomas *	18	Comunidades autonomas & Mellila y Ceuta	52	Provincias
Un. Kingdom	11	Standard regions	35	Groups of counties *	65	Counties

notes * groups of smaller regions
- regions not included in the CORINE data base

For these territorial units statistical data are gathered by the statistical office of the EC, Eurostat. Most statistical data are available at country level. The availability of statistical data decreases towards NUTS-3 level.
To evaluate the possible developments of rural areas in the EC, the Dutch Scientific Council for Government Policy has developed a model for global optimal allocation of land use requiring input on NUTS-1 level. To provide appropriate crop production data for this model, all results of the physical land evaluations had to be aggregated to NUTS-1 level. These aggregations were performed by the GIS, using the digitized delineations on the NUTS-1 map. Furthermore this aggregation allows for comparisons to be made with statistical crop production data and land use statistics. Therefore, statistical data on crop yield and land use at NUTS-1 level were also stored in the GIS (Bulens & Bregt, 1991). The digitized administrative map needed for the aggregation procedure was provided by

the EC-CORINE project team. The regional boundaries are shown on Map V. Originally the NUTS-1 map contained 64 regions. For this study however only 61 regions were evaluated because the three other regions were either of minor importance for agricultural production or important data were lacking. These regions excluded were West-Berlin, the Canarian Islands and the Portugüese islands. In table 4.2 the 61 NUTS-1 regions are listed together with their areas, the NUTS-1 regions are also shown on map V. Table 4.2 and map V show that the size of the NUTS-1 regions varies considerably.

Table 4.2 Acreages of the NUTS-1 regions.

NUTS1 CODE	NUTS1 DESCRIPTION	TOTAL AREA SQUARE KM
11	Schleswig-Holstein	15740
12	Hamburg	648
13	Niedersachsen	47672
14	Bremen	371
15	Nordrhein-Westfalen	33955
16	Hessen	21352
17	Rheinland-Pfalz	19840
18	Baden-Wurttemberg	36148
19	Bayern	70602
1A	Saarland	2285
	FR Germany	248612
21	Ile de France	12000
22	Bassin Parisien	146096
23	Nord-Pas-de-Calais	12084
24	Est	48386
25	Ouest	86600
26	Sud-Ouest	105928
27	Centre-Est	72034
28	Mediterranee	70672
	France	553801
31	Nord-Ovest	34045
32	Lombardia	24624
33	Nord-Est	39967
34	Emilia-Romagna	22474
35	Centro	41987
36	Lazio	17619
37	Campania	14214
38	Abruzzi-Molise	15919
39	Sud	46859
3A	Sicilia	27441
3B	Sardegna	24781
	Italy	309929
41	Noord-Nederland	8582
42	Oost-Nederland	10063
45	Zuid-Nederland	7032
47	West-Nederland	8992
	Netherlands	34669

NUTS1 CODE	NUTS1 DESCRIPTION	TOTAL AREA SQUARE KM
51	Vlaams gewest	13493
52	Region Wallonne	16906
53	Brussel	163
	Belgium	30562
60	Luxembourg (G.D.)	2650
71	North	16204
72	Yorkshire & Humbers	15328
73	East Midlands	15706
74	East-Anglia	12521
75	South East	27993
76	South-West	23992
77	West Midlands	12984
78	North-West	7267
79	Wales	20545
7A	Scotland	78962
7B	Northern Ireland	14020
	United Kingdom	245523
80	Ireland	69653
90	Danmark	43323
A1	Ellas (North)	59740
A2	Ellas (Central)	62783
A3	Ellas (East and S.	16096
	Greece	138619
B1	Noroeste	47065
B2	Noreste	73580
B3	Madrid	8353
B4	Centro	224106
B5	Este	63633
B6	Sur	101858
	Spain	518595
C1	Norte do continente	46706
C2	Sud do Continente	46595
	Portugal	93302

5 DISCUSSION

The soil map of the EC on a scale 1:1.000.000 proved to be a proper basis for the land evaluations preformed in this study. As final results were aggregated for Nuts-1 regions, the detailing of a 1:1.000.000 map can be considered to be sufficient.
The major shortcoming of the EC soil map is the very limited amount of soil data representative for the soil associations on the map. At present only the texture of the topsoil of the dominant soil unit and the most common slope of the association are provided for each soil association. Dominant soils, however, cover only about 60 % of the map area.
Furthermore, for a dominant unit with a compound texture and/or slope class, the fraction of the unit area occupied by each specific texture and slope class should be made available. As the texture of the topsoil and the slope of the site where the soil unit is situated strongly determine the suitability of the soil for various crop types, such data would contribute to a more accurate assessment of land suitability.
The selected soil profiles that accompany the map are not always representative for the soils on the map. Often, profiles selected demonstrate very site specific features which cannot be regarded as common characteristics for these soils.
A database for the soils on the EC soil map as proposed by e.g. Madsen (1989) would greatly improve the usefulness of the map for global qualitative and quantitative land evaluations. Data on the rooting depth of the soil, subsoil texture, groundwater depth's and fluctuations for groundwater affected soils and on soil physical properties such as water-retention and hydraulic conductivity would especially improve the accurateness of the crop growth simulations. For the assessment of environmental features, other soil characteristics such as cation exchange capacity and mineralogical composition might be needed.

The adapted agro-climatic atlas (Thran en Broekhuizen, 1965) provided a useful agro-climatic zoning for this study. The agro-climatic zones are far more realistic than zones created by mathematical methods, such as Thiessen polygons (Bulens and Bregt, 1991). For most agro-climatic zones it was possible to use a representative meteorological station. Sometimes, however, a meteorological station is located near the shore where the conditions are different than inland. Such coastal stations are for example Plymouth, Brest and La Coruna. In other cases meteorological observations were obtained from an airport, where weather characteristics can differ from those in agricultural fields. Some examples of airport stations are Dublin, Paris and Milano.
Unfortunately, a historical record of weather data was not available for all meteo stations. This is mainly caused by the very high costs of historical records of meteo data.
Some inaccuracy in the data records was introduced because of the conversion from

sunshine duration to global radiation. The values of the parameters A and B in the conversion equation which were assumed to be constant in our study, for example, depend on location (Doorenbos and Pruitt, 1977).
It would be more accurate to use measured radiation figures instead of converted sunshine duration data, but such data are hardly available.
In mountainous areas additional problems arise because of the the high variability in weather conditions. These areas usually have pronounced horizontal and vertical gradients. When performing this study, no detailed, digitized altitude map was available. Such a map would have been very helpful to delineate agro-climatic zones more precisely and to adjust weather data such as temperature in dependence of altitude.

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ANNEX I. Weather stations with a historical record of data.
Lat. = Latitude (degrees North),
Long. = Longitude (degrees West),
Alt. = Altitude (m)

No.	Station	Lat.	Long.	Alt.
1	LERWICK	60.1	1.2	82
2	STORNOWAY	58.2	6.3	3
3	ABERDEEN/DYCE	57.2	2.1	59
4	TIREE	56.5	6.9	9
5	EDINBURGH/ROYAL OBS.	56.0	3.4	35
6	ESKDALEMUIR UK	55.3	3.2	239
7	VALLEY	53.3	4.5	10
8	MANCHESTER AIRPORT	53.4	2.3	77
9	WADDINGTON	53.2	0.5	68
10	BIRMINGHAM AP	52.5	1.7	96
11	GLAMORGAN/RHOUSE AP	51.4	3.4	67
12	LONDON/GATWICK AIRPORT	51.2	0.2	59
13	PLYMOUTH/MOUNT BATTEN	50.4	4.1	27
14	DURNEMOUTH/HURN AP	50.8	1.8	10
15	BELFAST/ALDERGROVE AP	54.7	6.2	73
16	VALENTIA OBSERVATORY	51.9	10.3	14
17	CORK AIRPORT	51.9	8.2	162
18	SHANNON AIRPORT	52.7	8.9	7
19	DUBLIN AIRPORT	53.4	6.3	81
20	ALBORG	57.1	-9.9	3
21	KOBENHAVN/LANDBOHOJSKOLEN	55.4	-12.6	22
22	DE BILT	52.1	-5.2	0
23	UCCLE	50.8	-4.4	104
24	BREST/GUIPAVAS	48.5	4.4	103
25	TRAPPES	48.8	-2.0	168
26	PARIS/LE BOURGET	48.8	-2.5	50
27	NANCY/ESSEY	48.7	-6.2	217
28	STRASBOURG/ENTZHEIM	48.6	-7.6	154
29	NANTES	47.3	1.6	27
30	BOURGES	47.1	-2.4	162
31	DIJON	47.3	-5.1	227
32	LIMOGES/BELLEGARDE	45.9	-1.2	403
33	LYON/BRON	45.7	-4.8	201
34	BORDEAUX/MERIGNAC	44.8	0.7	51
35	TOULOUSE/BLAGNAC	43.6	-1.4	152
36	NIMES/COURBESSAC	43.9	-4.4	60
37	MARSEILLE/MARIGNANE	43.3	-5.4	8
38	NICE/COTE DAZUR	43.7	-7.2	10

39	PERPIGNAN	42.7	-2.9	48
40	AJACCIO/CAMPO DEL ORO	41.9	-8.8	5
41	LA CORUNA	43.4	8.4	67
42	VALLADOLID	41.7	4.7	715
43	BARCELONA	41.4	-2.2	95
44	MADRID/RETIRO	40.4	3.7	657
45	PALMA DE MALLORCA	39.6	-2.7	45
46	MAHON, MENORCA/SAN LUIS	39.9	-4.3	59
47	BADAJOZ	38.9	6.8	192
48	LISBOA/PORTELA	38.7	9.1	95
49	PORTO/PEDRAS RUBAS	41.2	8.7	70
50	FARO	37.0	8.0	8
51	BEJA	38.0	7.9	246
52	PENHAS DOURADAS	40.4	7.6	1380
53	BRAGANCA	41.8	6.8	691
54	SCHLESWIG	54.5	-9.6	48
55	HAMBURG/FUHLSBUTTEL	53.6	-10.0	16
56	EMDEN-NESSERLAND	53.3	-7.2	1
57	HANNOVER	52.5	-9.7	55
58	ESSEN	51.4	-7.0	161
59	KASSEL	51.3	-9.5	163
60	GEISENHEIM	50.0	-8.0	108
61	STUTTGART/CANNSTADT	48.8	-9.2	315
62	NURNBERG	49.5	-11.1	319
63	MUNCHEN/RIEM	48.1	-11.7	529
64	MILANO/LINATE	45.5	-9.2	103
65	VERONA/VILLAFRANCA	45.4	-10.9	67
66	VENEZIA/TESSERA	45.4	-12.4	17
67	PISA/S. GIUSTO	43.7	-10.4	2
68	PESCARA	42.4	-14.2	9
69	ROMA/FIUMICINO	41.9	-12.5	131
70	NAPOLI/CAPODICHINO	40.9	-14.3	88
71	BRINDISI	40.7	-18.0	15
72	MESSINA	38.2	-15.6	51
73	TRAPANI/BIRGI	37.9	-12.5	79
74	CATANIA/FONTANAROSSA	37.5	-15.1	65
75	ALGHERO	40.6	-8.3	23
76	CAGLIARI/ELMAS	39.3	-9.1	18
77	THESSALONIKI/MIKRA	40.5	-23.0	61
78	KERKYRA	39.6	-19.9	2
79	ATHINAI /NAT. OBS./	38.0	-23.7	107
80	KALAMATH	37.0	-22.1	5
81	HIRAKLION/CRETE	35.3	-25.2	48

ANNEX II. Weather stations with long term average data.
Lat. = Latitude (degrees North),
Long. = Longitude (degrees West),
Alt. = Altitude (m)

No.	Station	Lat.	Long.	Alt.
82	DALWHINNIE	56.6	4.1	359
83	CLERVEAUX	50.0	-6.0	454
84	TOURS	47.3	-0.5	98
85	LE PUY EN VELAY	45.0	-3.5	714
86	BIARITZ	43.3	1.3	69
87	LES ESCALDES *	42.3	-1.3	1080
88	SANTANDER	43.5	3.5	7
89	LEON	42.4	5.4	913
90	SORIA	41.5	2.6	1080
91	ZARAGOZA	41.4	0.5	237
92	CIUDAD REAL	38.6	3.6	628
93	MURCIA **	37.6	1.1	44
94	CORDOBA	37.5	4.5	91
95	GRANADA	37.1	3.4	689
96	MALAGA	36.4	4.3	34
97	L'AGUILA ***	42.2	-13.2	735
98	FOGGIA	41.3	-15.3	74
99	POTENZA	40.4	-15.5	826
100	KAWALA #	40.6	-24.3	27
101	TRICALA	39.3	-21.5	149
102	LARISA	39.4	-22.2	76
103	TYNEMOUTH	55.0	1.3	33
104	HOF	50.2	-11.5	567
105	FREUDENSTADT	48.5	-8.3	797
106	GRENOBLE	45.1	-5.4	223
107	GENEVA	46.1	-6.1	405
108	DOMODOSSOLA ##	46.1	-8.2	300
109	NURBURG ###	50.2	-6.6	626

*   Sunshine duration and relative humidity of Pic du Midi
** Relative humidity of Almeria
*** Sunshine duration of Perugia
#   Sunshine duration of Tarent
Temperature range and relative humidity of Lugano
Sunshine duration of Kahler Asten

ANNEX III. Subdivision of soil parameters

texture:
- 1 = coarse
- 2 = medium
- 3 = medium fine
- 4 = fine
- 5 = very fine

maximum rooting depth
- 1 = 10 cm
- 2 = 40 cm
- 3 = 60 cm
- 4 = 80 cm
- 5 = 120 cm

drainage condition
- 1 = very poor
- 2 = poor
- 3 = temporary poor
- 4 = moderately well
- 5 = well
- 6 = excessive

slope
- 1 = 0-8 %
- 2 = 8-15 %
- 3 = 15-25 %
- 4 = >25 %

salinity
- 1 = absent
- 2 = saline (ec > 4 mmho/cm)

alkalinity
- 1 = absent
- 2 = present (sar > 15)

phase
- 11 ( ) = no phase
- 12 (1) = gravelly
- 13 (2) = stony
- 14 (3) = lithic
- 15 (4) = concretionary
- 16 (5) = petrocalcic
- 17 (6) = saline
- 18 (7) = alkaline
- 22 (8) = lithic/stony
- 23 (9) = petrocalcic/gravelly
- 24 (10) = concretionary/stony
- 25 (11) = lithic/gravelly
- 26 (12) = petrocalcic/stony
- 27 (13) = petrocalcic/ concretionary
- 28 (14) = stony/gravelly

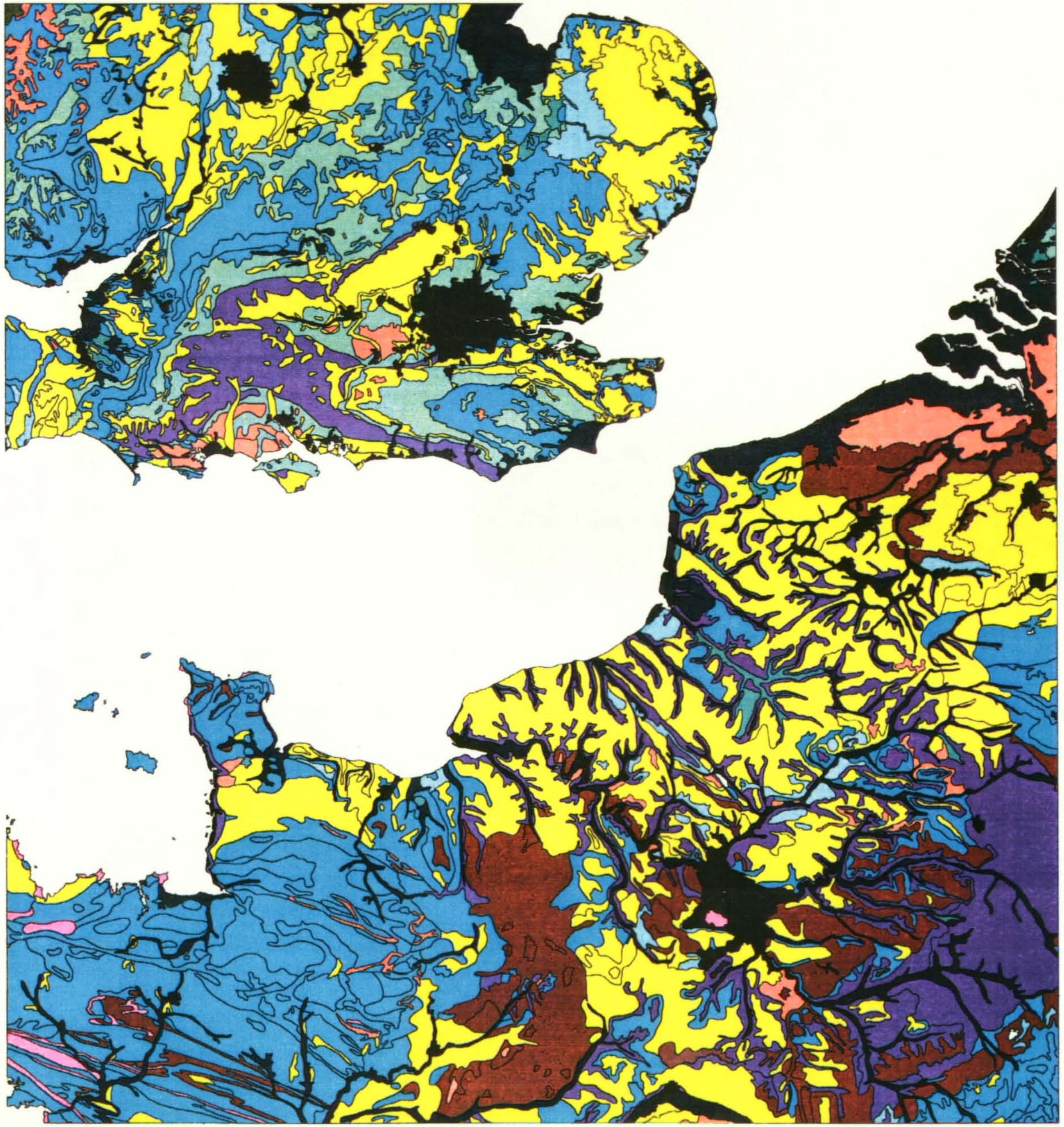
MAP I

PART OF THE SOIL MAP OF THE EC

SCALE 1 : 2500000

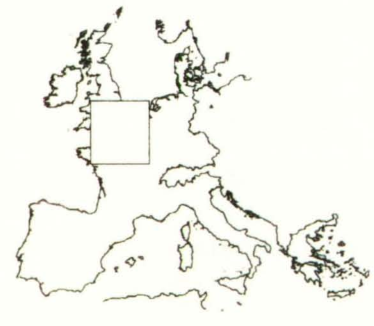
kilometers

0 150



LEGEND

ARENOSOLS	PODZOLUVISOLS
CAMBISOLS	RANKERS
ANDOSOLS	PHAEOZEMS
FLUVISOLS	PLANOSOLS
GLEYSOLS	REGOSOLS
HISTOSOLS	RENDZINAS
LITHOSOLS	SOLONCHAKS
LUVISOLS	VERTISOLS
PODZOLS	XEROSOLS



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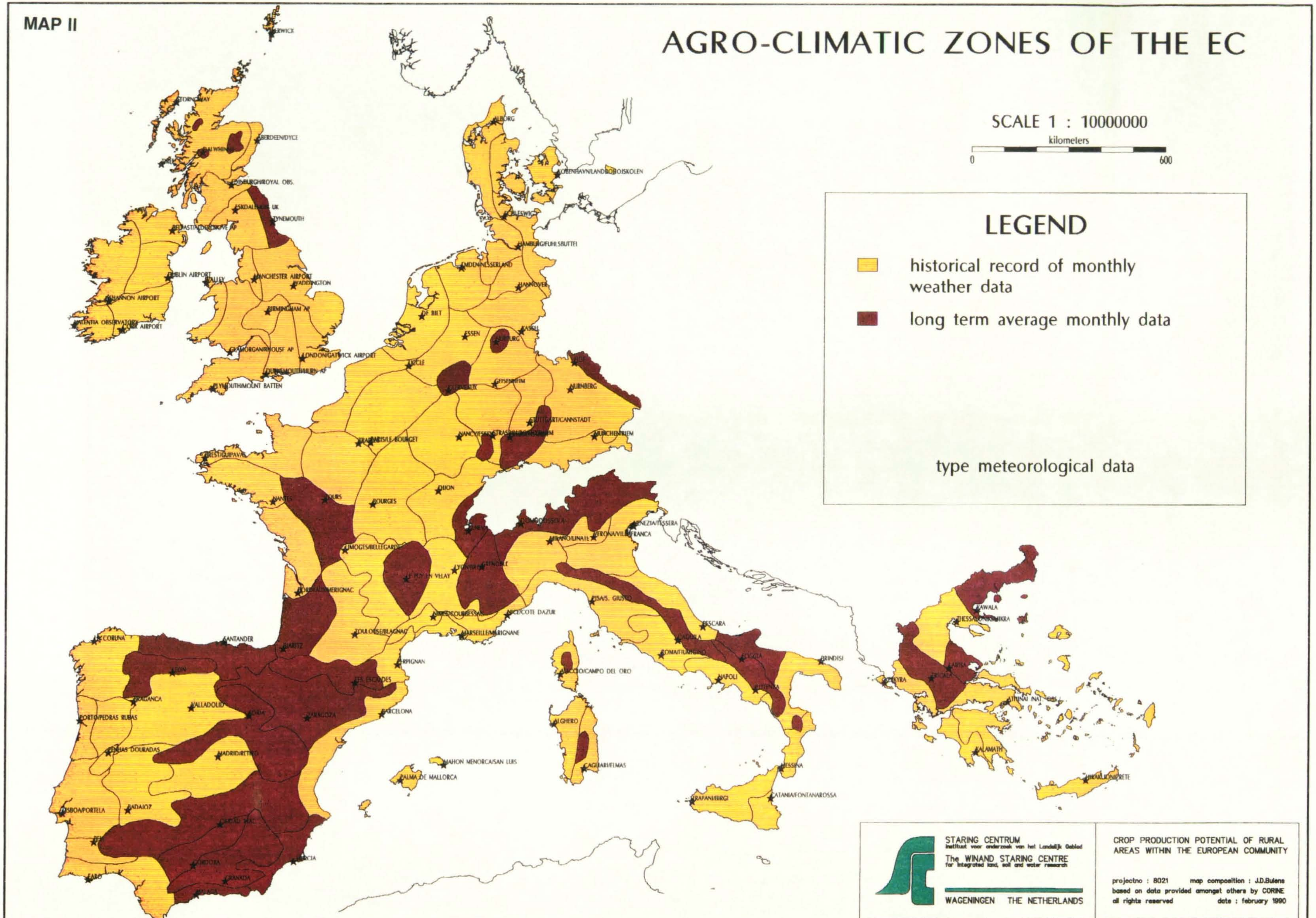
WAGENINGEN THE NETHERLANDS

CROP PRODUCTION POTENTIAL OF RURAL AREAS WITHIN THE EUROPEAN COMMUNITY

projectno : 8021 map composition : J.D.Bulens
based on data provided amongst others by CORINE
 date : february 1990


MAP II
AGRO-CLIMATIC ZONES OF THE EC
SCALE 1 : 10000000
kilometers
0
600
LEGEND
historical record of monthly weather data
long term average monthly data
type meteorological data
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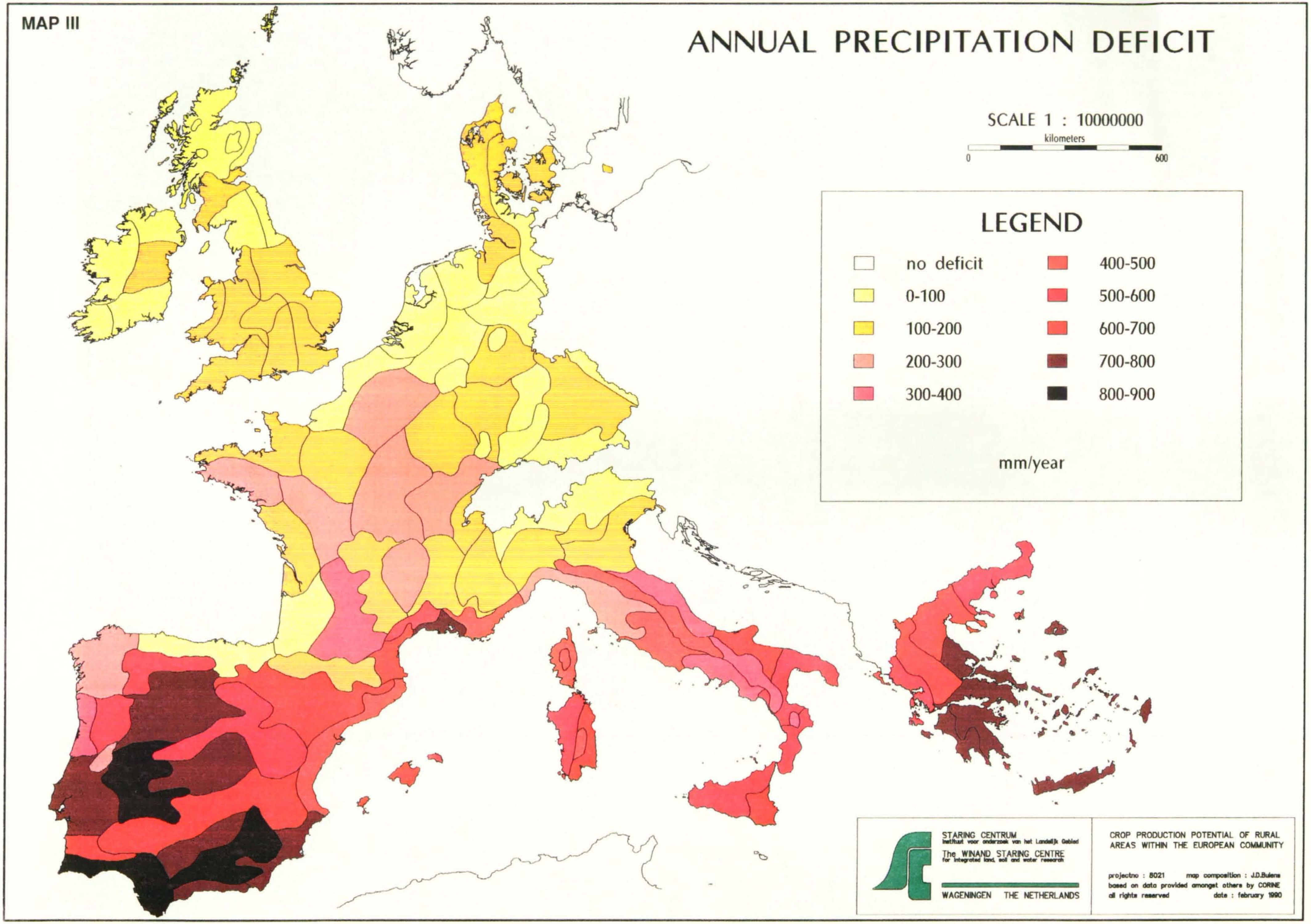
MAP III
ANNUAL PRECIPITATION DEFICIT
SCALE 1 : 10000000
kilometers
0
600
LEGEND
no deficit
0-100
100-200
200-300
300-400
400-500
500-600
600-700
700-800
800-900
mm/year
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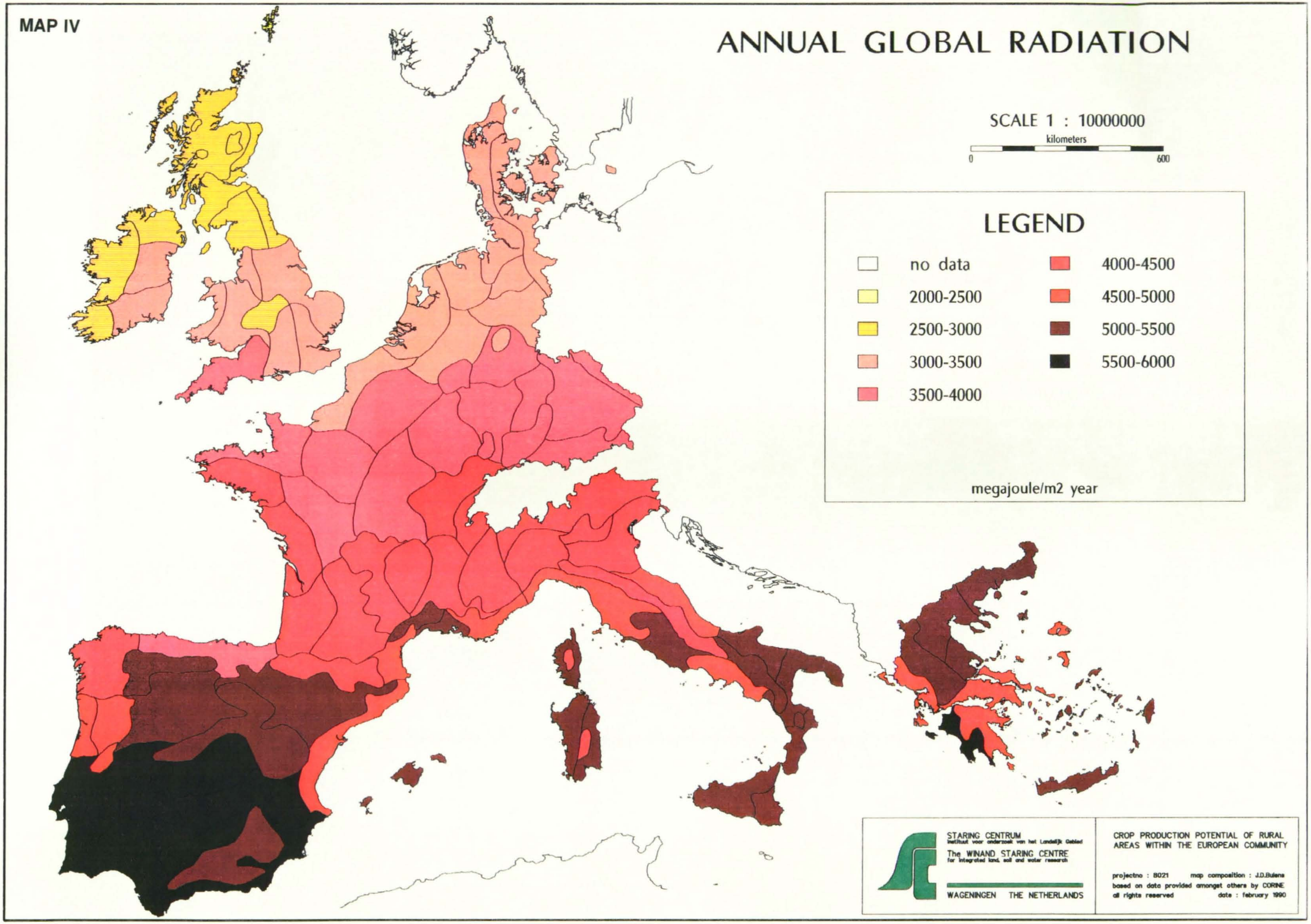
MAP IV
ANNUAL GLOBAL RADIATION
SCALE 1 : 10000000
kilometers
0
600
LEGEND
no data
2000-2500
2500-3000
3000-3500
3500-4000
4000-4500
4500-5000
5000-5500
5500-6000
megajoule/m2 year
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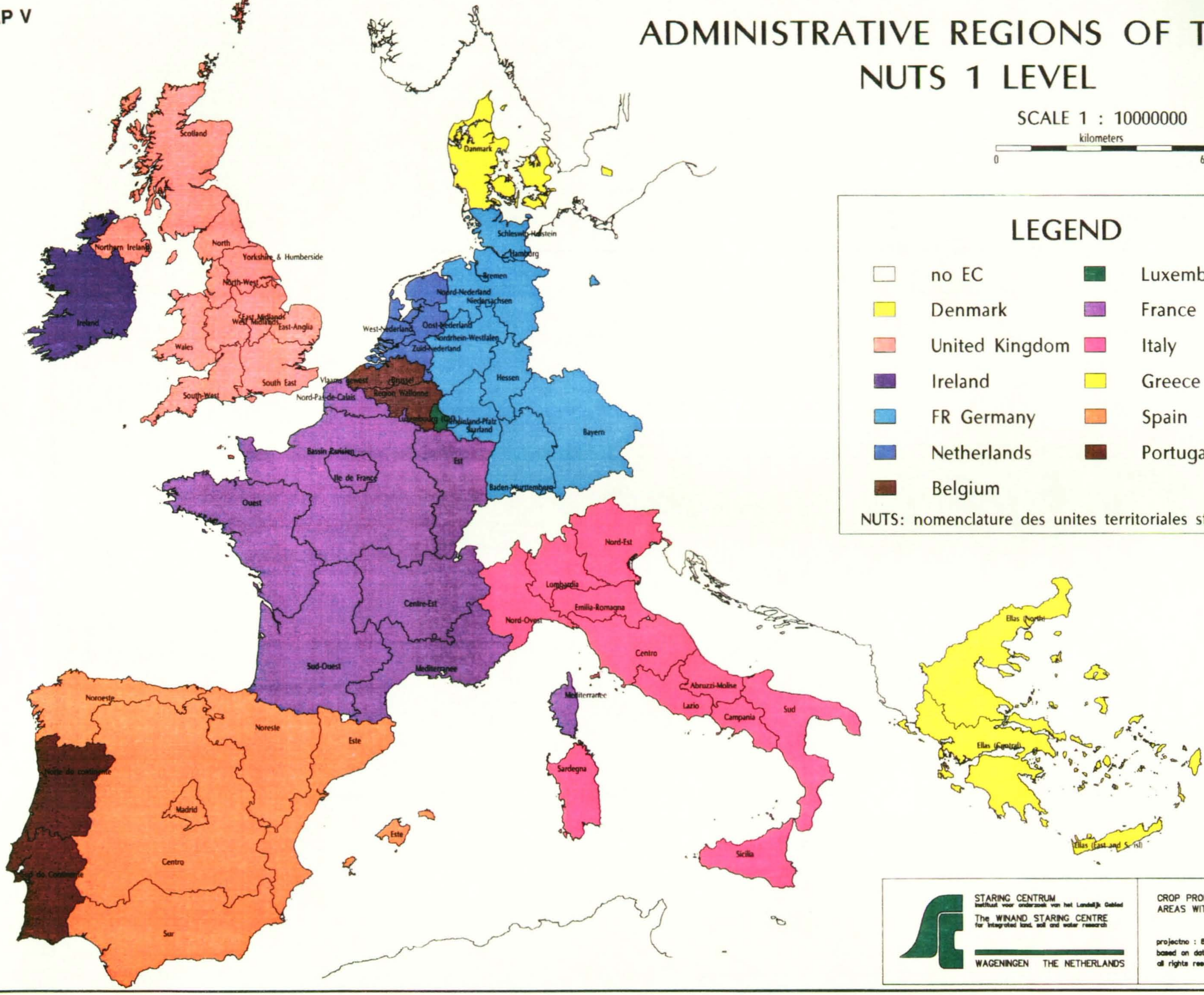
MAP V

ADMINISTRATIVE REGIONS OF THE EC
NUTS 1 LEVEL

SCALE 1 : 10000000

kilometers

0 600



LEGEND

no EC	Luxembourg
Denmark	France
United Kingdom	Italy
Ireland	Greece
FR Germany	Spain
Netherlands	Portugal
Belgium	

NUTS: nomenclature des unites territoriales statistiques

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