Netherlands Scientific Council for Government Policy

W 68

Crop production potential of rural areas within the European Communities

IV: Potential, water-limited and actual crop production

G.H.J. de Koning

C.A. van Diepen

The Hague, Noven

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CONTENTS

PREFACE

The Netherlands Scientific Council for Government Policy has requested DLO The Winand Staring Centre in Wageningen to investigate the crop production potential of rural areas within the European Communities. The Council needed this information for a project on the possible future developments in rural areas of the EC as a result of ongoing growth in agricultural productivity. To get a clear view the Council explored the possible changes in 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 if a certain priority is given to the various objectives.
Information on the physical possibilities for land use was essential to carry out the explorations. A team from the Winand Staring Centre consisting of J.D. Bulens, A.K. Bregt, C.A. van Diepen, C.M.A. Hendriks, G.H.J. de Koning and G.J. Reinds led by 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 Communities". 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 fruit 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. Using this approach DLO The Winand Staring Centre opened up a new and promising line of research.

Prof. R. Rabbinge

ACKNOWLEDGEMENTS

At the request of the Netherlands Scientific Council for Government Policy (WRR), DLO The Winand Staring Centre (SC-DLO) in Wageningen conducted a study on the crop production potential of rural areas within the European Communities (EC). We gratefully acknowledge the grant provided by the Council. The SC-DLO study was supervised by a WRR team comprising Prof. R. Rabbinge (chairman), H. van Latesteijn (secretary), D. Scheele, H. Hengsdijk and 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 M. Cornaert and J. Maes is greatly appreciated.
Meteoconsult B.V. in Wageningen provided records of historical weather data for many meteorological stations within the EC.
Valuable data on crops were provided by colleagues at the DLO Centre for Agrobiological Research (CABO-DLO) in Wageningen.

Wageningen, October 1992,

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SUMMARY

Over the past 25 years, intensification of agriculture in the European Communities (EC) has resulted in surpluses of agricultural products. In some rural areas soil pollution and degradation have taken place, while unfavourable areas are being abandoned. To support policy re-orientation, the Netherlands Scientific Council for Government Policy (WRR) initiated a study to explore possible developments of land use within the EC. WRR applied a model for the General Optimal Allocation of Land use (GOAL). Data were needed on the regional production potential of the main agricultural crops.
At the request of WRR, DLO The Winand Staring Centre (SC-DLO) estimated the regional crop production potential of wheat, maize, oilseed rape, potato, sugar beet and grass as a function of soil and climate conditions within the EC. For this purpose a mixed qualitative/quantitative physical land evaluation procedure was followed using a geographical information system in combination with a crop growth simulation model.

In this report the results of the physical land evaluation are presented. The whole procedure was applied to 4200 different land evaluation units (LEU's), characterized by soil type, climate and administrative region. Soil data were derived from the digitized soil map of the EC (1 : 1000000), and weather data like sunshine duration, temperature, humidity, windspeed and rainfall were collected for 109 weather stations. In a first step a qualitative selection procedure was applied to all LEU's to exclude those soils unsuitable for mechanized crop production. It was estimated that 48% of the total EC-area can be used for grass cultivation, 44% for rotations with only cereals and oilcrops and 28% for rotations including root crops. For soils that were classified suitable, potential and water-limited yields were calculated with a crop growth simulation model. The potential yield is determined by the properties of the crop, solar radiation and temperature and can be seen as the production ceiling for crops growing under optimum soil moisture conditions. The water-limited yield applies to conditions without irrigation and/or drainage and therefore also includes effects of drought stress and excess water. Nutrient availability and crop protection are assumed to be optimal for both production levels.
After aggregation of the model results from LEU-level to NUTS-1 region-level, simulated and actual yields could be compared. In many cases the yield gap is still high. For example, at EC-level, the actual wheat yields are 60% of the calculated water-limited yields and 45% of the potential yields.

Reliability of the estimated regional crop production potential can still be improved, especially once more basic weather, soil and crop data become available. However, the results give good insight into the agricultural potential offered by the physical conditions prevailing within Europe. The results were implemented in the GOAL-model of the WRR, resulting in valuable instruments for the support of agricultural policy making.

GLOSSARY

AA	Used Agricultural Area
ACT. Y.	Actual yield
B	Belgium
CABO-DLO	DLO Centre for Agrobiological Research
CAP	Common Agricultural Policy
DK	Denmark
EC	European Communities
F	France
GE	West Germany
GIS	Geographical Information System
GOAL	General Optimal Allocation of Land use
GR	Greece
IRL	Ireland
IT	Italy
LEU	Land Evaluation Unit
LUX	Luxembourg
NUTS-1	Nomenclature des Unités Territoriales Statistiques, level 1
P	Portugal
POT. Y.	Potential yield
SC-DLO	DLO The Winand Staring Centre for integrated Land, Soil and Water Research
SP	Spain
UK	United Kingdom
W.L.Y.	Water-limited yield
WOFOST	Crop growth simulation model
WRR	Netherlands Scientific Council for Government Policy

1 INTRODUCTION

The Common Agricultural Policy (CAP) of the European Communities (EC) has stimulated agricultural production to the extent that surpluses of major commodities such as wheat, sugar, milk and wine have become structural. In areas favourable for agriculture, farm size has increased, narrow crop rotations have been introduced and large amounts of relatively cheap agro-chemicals and feeding-stuffs are being used. This intensification of agriculture has detrimentally affected environment, nature and landscape (Briggs and Wilson, 1987). In areas less favourable for agriculture, abandonment of land has taken place, with its associated social problems.
Regional and structural EC-funds are increasingly called upon to mitigate these undesirable socio-economic and environmental effects of the CAP. However, hardly any information is available on the cost-effectiveness of different forms of investments for agricultural development in the various EC-regions.
To support the development of a scientifically sound basis for policy re-orientation, the Netherlands Scientific Council for Government Policy (WRR) initiated a project to explore the possible developments of land use within the EC (WRR, 1992). The aim was to evaluate different land use scenarios with respect to their impact on rural development, taking into account agricultural, socio-economic, environmental and physical planning aspects. WRR has developed and applied a model for the General Optimal Allocation of Land use (GOAL model). This model uses a method known as Interactive Multiple Goal Linear Programming (Veeneklaas, 1990). For the purpose of this model the WRR required information about the production potentials of the major types of farming at different input levels.
At the request of the WRR, DLO The Winand Staring Centre (SC-DLO) carried out a study on the crop production potential within the EC countries. The study dealt with the agro-ecological characterization of the different regions within the EC by estimating crop yield potentials as a function of soil and climate conditions. For this purpose a geographical information system (GIS) was combined with physical land evaluation models. The SC-DLO study was called "Crop Production Potential of Rural Areas within the European Communities". Five separate reports, listed in Appendix 1, resulted from this study.
Based on the results of the SC-DLO study, input and output coefficients for various cropping systems within the EC were derived that could be implemented in the GOAL-model (De Koning *et al.*, 1992)

In the SC-DLO study, two groups of crops were distinguished: one group consisted of annual arable crops and grass, and the other of fruit crops and forestry. For these two groups different physical land evaluation procedures were followed. The land suitability within the EC for fruit crops and forestry was determined according to a totally qualitative land evaluation procedure. The methodological approach and results of this procedure are discussed by Van Lanen *et al.* (1992a) and will not be further treated here.
For grass and arable crops (wheat, maize, oilseed rape, potato, sugar beet and grass) a mixed qualitative/quantitative land evaluation was carried out. In this report the results of this mixed land evaluation are presented and discussed. The methods involved are extensively treated in other reports. These are referred to in Chapter 2 of this report, which gives a short summary of the mixed

land evaluation method.
The qualitative part of the approach comprises a selection of soils, suitable for mechanized crop cultivation. The results of this selection are given in Chapter 3. Crop yields were determined quantitatively by a crop growth simulation model. Two production situations were distinguished: the potential production level for which, through irrigation and drainage, optimum soil moisture conditions are assumed throughout, and the rainfed production level for which water supply can be sub-optimal.
In Chapter 4 the results of the crop growth model calculations are presented for all crops separately, together with the actual yields according to statistics.
For this study, data on for instance weather, soil and crops were used. These data were broadly defined on the scale of the EC and some were lacking. Several assumptions were made throughout the whole procedure. These and other aspects will be treated in the final discussion in Chapter 5.

2 SHORT DESCRIPTION OF THE LAND EVALUATION PROCEDURE

2.1 Introduction

Quantitative physical land evaluation methods yield suitability classifications expressed in quantitative terms, i.e. the production potential (e.g. kg dry matter per hectare per year) of land, for a particular land use, characterized by a crop cultivar with well-defined properties under specified management practices (Van Lanen *et al.*, 1992b). Land is characterized by its physical and/or chemical properties and the prevailing environmental conditions. Simulation models are essential parts of a quantitative land evaluation (Van Diepen *et al.*, 1991). A mixed qualitative/quantitative physical land evaluation procedure as proposed by Van Lanen *et al.* (1989), was developed for grass and a number of selected annual arable crops: wheat, maize, oilseed rape, potato and sugar beet. The qualitative procedure consisted of a selection of soils, suitable for the cultivation of a specific crop. The quantitative procedure consisted of the calculation of crop yields on the suitable soils, by means of a crop growth simulation model.
The land evaluation procedure will be further explained in this chapter according to the schematic representation in Figure 1.

2.2 Geographical Information System

The starting point of the land evaluation procedure was a Geographical Information System (GIS), in which three digitized maps were stored :

- the soil map of the EC, scale 1 : 1 million (see Map 1 for a representation of part of the EC soil map)
- an agro-climatic map, distinguishing 109 zones (see Map 2)
- a map of 61 administrative regions, according to the "Nomenclature des Unités Territoriales Statistiques", level 1 (NUTS-1 regions) (see Map 3)

More information on these maps and their attribute data is given by Reinds *et al.* (1992). An overlay of the three maps was carried out (Bulens and Bregt, 1992), which resulted in a map with about 4200 Land Evaluation Units (LEU's) each comprising a unique combination of soil unit, climatic region and NUTS-1 region. These LEU's made up more than 22000 polygons. The physical land evaluation methods were applied to each of the LEU's.

2.3 Assessment of attribute data

The characteristics of LEU's in terms of soil attributes were derived from the EC soil map through an interpretation procedure (Reinds *et al.*, 1992; Reinds and Van Lanen, 1992). The legend of the EC

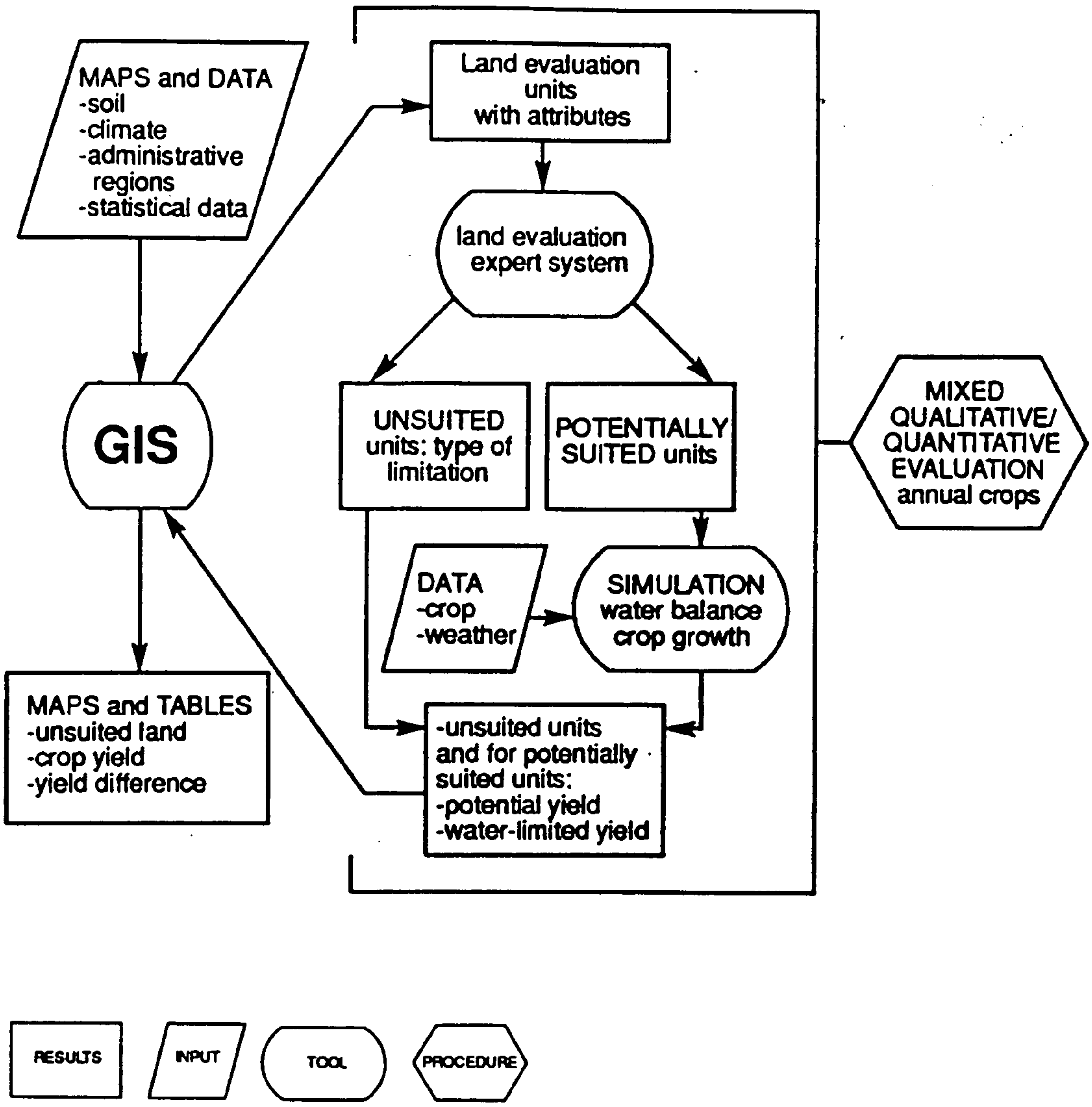

Figure 1. Outline of the land evaluation procedure

soil map consists of 312 units (CEC, 1985), designated as soil associations, each characterized by a dominant soil and by associated soils. For the purpose of this study, LEU's were characterized on the basis of the properties of the dominant soil unit only. The percentage of the area of the soil associations covered by the dominant soil unit is given in Appendix 2. Soil attribute data derived from the soil map were: texture, rooting depth, drainage condition, slope, salinity, alkalinity and soil phase.

For each of the 109 agro-climatic zones (adapted from Thran and Broekhuizen, 1965) a representative meteorological station was selected (Reinds *et al.*, 1992). For 81 stations historical records (usually 26 years) of monthly average data were available. For the other 28 stations long-term average monthly data were used (Map 2). The relevant weather data were maximum and minimum temperature, precipitation, number of rain days, sunshine duration, vapour pressure and wind speed. The monthly historical records were complete for temperature and precipitation, but for part of the years data on sunshine duration, vapour pressure or windspeed were missing. In such cases long-term monthly means were used as replacement values.

The NUTS-1 regions map was stored in the GIS to allow aggregation of results to that level. Statistical data were gathered for NUTS-1 regions (Eurostat, 1986, 1987), and this data can also be considered as attribute data. Actual crop yields and areas of the years 1982, 1983, 1984 and 1985 were used (when available).

2.4 Qualitative procedure : selection of suitable soils

A qualitative selection procedure was applied to all LEU's in order to exclude soils unsuitable for mechanized crop cultivation from further quantitative evaluation (Reinds and Van Lanen, 1992). In this procedure, three types of crops were distinguished: grass, cereals and root crops. For each type of crop a number of soil requirements were defined in terms of texture, slope, drainage, rooting depth, phase, salinity and alkalinity. Definition of the requirements was based on the workability of the soil with appropriate machinery (e.g. not too steep), and the minimum soil conditions allowing crop growth (e.g. not too shallow, no salinity). The criteria were increasingly severe for the three crop types (Appendix 3), according to the demands of the cropping system. Hence, the area suitable for cereals falls within that suitable for grass and the area suitable for root crops within that suitable for cereals. This phenomenon was called nesting. No climatic restrictions were taken into account in the qualitative selection, because the effects of climate on crop production were assessed in the quantitative evaluation.

A considerable number of soil mapping units have a compound texture class and/or a compound slope class. Consequently, a LEU can be partially suitable and partially unsuitable. To identify the suitable part, LEU's were partitioned into subunits, each comprising a single texture class and a single slope class. Since no data were available on the distribution of texture and slope classes within a compound unit, each subunit was assumed to cover an equal area within the compound unit. Thus if a LEU comprises four subunits, each subunit is assumed to cover 25% of the total area of the LEU.

From the qualitative selection procedure it follows that (part of) a LEU is either suitable or unsuitable for mechanized crop cultivation. In fact suitable means potentially suitable here, because the yield potential of the suitable land was later determined quantitatively using a crop growth simulation model. This is in contrast to a fully qualitative land evaluation, where suitability is expressed in classes, such as well suited land, moderately suited land etc. (Van Lanen *et al.*, 1992c).

2.5 Quantitative procedure : calculation of crop yields

After selecting LEU's (partially) suitable for the cultivation of a specific crop (Section 2.4), the production potential of these LEU's was calculated with the crop growth simulation model WOFOST. Production calculations were carried out for each crop separately.
The WOFOST model simulates growth, development and yield of a field crop, and the water balance of the soil, under defined weather and soil conditions (Van Diepen *et al.*, 1989). Calculations take place with time steps of one day. In the WOFOST model two production levels are distinguished: potential and water-limited. The potential yield is determined by crop genetic properties, solar radiation and temperature, and indicates the production ceiling for crops growing under optimum soil moisture conditions throughout. The water-limited yield also includes effects of drought stress and excess water. For both production levels, nutrient availability, pest, weed and disease control, and farm management are taken to be optimal.
From the prevailing level of incoming solar radiation, leaf area of the crop and photosynthetic characteristics of the individual leaves, WOFOST calculates, in dependence of ambient temperature, the daily potential gross photosynthesis of the canopy. Part of the daily production of assimilates is used for maintenance and growth respiration, the remainder being converted into structural dry matter, such as leaves, stems, roots and storage organs. The leaf area index of the crop is calculated by multiplying the live leaf weight by the specific leaf area. The phenological development rate is a function of temperature and, for some crops, daylength.
For the rooted zone, the water balance equation is solved every daily timestep. Water enters this zone through precipitation or, in the case of groundwater influence, capillary rise. If the rainfall intensity exceeds the infiltration rate of the soil, water runs off. Water leaves the rooted zone by soil evaporation and uptake by the crop. Uptake is equal to the potential transpiration rate unless the soil moisture content is below a critical level. Hampered water uptake directly causes a reduced photosynthesis rate, leading to reduced growth and, under severe stress, death of leaf tissue.
A number of data are needed in the model. Weather and soil data were derived from the attribute data of the LEU's. For example, global radiation figures were derived from the sunshine duration figures in the weather data sets (Reinds *et al.*, 1992) while temperature, vapour pressure and precipitation data could be used directly. Because the model needs weather data on a daily basis, monthly weather data (except rainfall) were linearly interpolated to obtain daily data. Monthly rainfall was randomly distributed to daily rainfall according to the number of rain days in each month. The water holding capacity of the soil (Reinds *et al.*, 1992), maximum rooting depth, maximum surface storage, runoff fraction and availability of groundwater for crop growth were derived from the soil attribute data (Reinds and Van Lanen, 1992).
Furthermore, several crop specific characteristics were needed in order to describe processes such as assimilation, respiration, phenology, leaf area development, drought stress and death of the crop. The basis for these crop data were the standard WOFOST crop parameter sets that are given for 22 crops in the WOFOST 4.1 documentation (Van Diepen *et al.*, 1988). The parameter values of these sets are based on data collected from the literature by Van Heemst (1988). For the arable crops wheat, maize, potato, sugar beet, and oilseed rape, the parameters were updated with data from the crop growth model SUCROS, (Spitters *et al.*, 1989) as well as data from field trials across Europe. Information was also gathered on regional crop calendars, such as sowing dates for use as model

input, and dates of flowering, emergence and maturity for adjusting the development rate of the crops (Broekhuizen, 1969; Bignon, 1990, Hough, 1990; FAO, 1978; unpublished data). For grass, that is frequently mown, the model was modified and parameters collected from the literature.

The simulations were carried out at LEU-level for all (mostly 26) years of weather data. For each LEU, the long-term mean of the calculated yields is considered to be an indicator of the agricultural potential. The results were stored in the GIS and could be aggregated to the level of, for example, agro-climatic zones or NUTS-1 regions.

3 RESULTS OF THE QUALITATIVE SELECTION OF SUITABLE SOILS

3.1 Introduction

The land and soil characteristics that can be derived from the soil map of the EC, are listed in Table 1. The soil area having a specific characteristic is given in Table 1 as percentage of the total area of the EC. On the soil map of the EC, some parts are indicated as non-soil areas, for example major cities, lakes, glaciers and snowcaps. The non-soil areas are regarded as being unsuitable for every agricultural land use type.
The selection criteria that have been used to determine the suitability of soils for the three types of crops (Reinds and Van Lanen, 1992) are shown in Appendix 3.
In the qualitative land evaluation procedure, soils were classified as either suitable or unsuitable for the mechanized cultivation of a certain type of crop, based on only soil characteristics (Appendix 3). Unsuitable soils were excluded from further evaluation. The climatic conditions of a location may also be restrictive for crop growth. For the suitable soils this was afterwards evaluated quantitatively using the crop growth simulation model (Chapter 4). The combination of soils and climate is often called land. Thus, the overall suitability of land within the EC, could only be determined after both evaluations had been performed.
The NUTS-1 regions mentioned in this chapter can be localized using Map 3.

3.2 Grass

The land use requirements for the mechanized cultivation of grass are shown in Appendix 3. From the total area of the EC, 48% consists of soils suitable for the production of grass. Combining Table 1 and Appendix 3 indicates that the main reasons for unsuitability are slope (37%) and phase (25%), expressed as a percentage of the total EC-area.
Table 2 shows that the area of suitable soils within the EC-countries varies from 98% of the total country area in Denmark, to 13% in Greece. The countries with a relatively small percentage of suitable soils are mainly located in southern Europe. In terms of absolute area, large extents of suitable soils occur in France, the former West Germany, the United Kingdom and Spain.
For the whole of the EC, texture is only a minor cause of unsuitability. A relatively large area of soils with a very fine texture is only found in the German region of Baden-Wurttemberg (14% of the soil area).
Peat soils (histosols) are the only soils with a very poor drainage. The drainage condition of all other soils is suitable for mechanized grass cultivation (Appendix 3). Regions with a relatively large proportion of peat are Scotland (41% of the soil area), Northern Ireland (10%), Ireland (9%), Noord-Nederland (29%), West-Nederland (16%) and in Germany the regions Schleswig-Holstein (10%), Niedersachsen (14%) and Bremen (10%).
Lithosols (with a maximum rooting depth of 10 cm) occur widely in Portugal (21% of the soil area) and Greece (34%).

Table1. Percentage of the total area of the European Communities having a specific land or soil characteristic.

land and soil characteristics:		% total area EC
Texture:	1 = coarse	16.3
	2 = medium	31.7
	3 = medium fine	29.3
	4 = fine	18.0
	5 = very fine	0.7
	(peat)	2.8
Maximum rooting depth:	1 = 10 cm	5.0
	2 = 40 cm	26.9
	3 = 60 cm	7.3
	4 = 80 cm	28.2
	5 = 120 cm	31.4
Drainage condition:	1 = very poor (peat)	2.8
	2 = poor	1.4
	3 = temporary poor	4.2
	4 = imperfect	8.9
	5 = moderately well	3.5
	6 = well	72.8
	7 = excessive	5.2
Slope:	1 = 0-8 %	29.5
	2 = 8-15 %	32.2
	3 = 15-25 %	22.2
	4 = >25 %	14.9
Salinity:	1 = absent	98.3
	2 = saline	0.5
Alkalinity:	1 = absent	98.6
	2 = present	0.2
Phase:	0 = no phase	59.1
	1 = gravelly	13.7
	2 = stony	9.3
	3 = lithic	8.1
	4 = concretionary	0.7
	5 = petrocalcic	1.4
	6 = saline	0.8
	7 = alkaline	0.4
	8 = lithic/stony	3.5
	9 = petrocalcic/gravelly	0.0
	10 = concretionary/stony	0.0
	11 = lithic/gravelly	1.1
	12 = petrocalcic/stony	0.0
	13 = petrocalcic/concr.	0.0
	14 = stony/gravelly	0.7
Non-soil area:		1.2

Table 2. Estimated area suitable for mechanized grass cultivation for NUTS-1 regions and countries within the EC. The suitable area is expressed as a percentage of the total area.

Region/country	% suitable	Region/country	% suitable
Schleswig-Holstein	89	Vlaams gewest	99
Hamburg	78	Region Wallonne	36
Niedersachsen	75	Brussel	48
Bremen	81	Belgium	64
Nordrhein-Westfalen	65		
Hessen	37	Luxembourg (G.D.)	31
Rheinland-Pfalz	31		
Baden-Wurttemberg	39	North	66
Bayern	43	Yorkshire & Humber.	78
Saarland	42	East Midlands	87
West Germany	53	East Anglia	94
		South East	87
Ile de France	56	South West	70
Bassin Parisien	72	West Midlands	84
Nord-Pas-de-Calais	83	North West	73
Est	62	Wales	49
Ouest	62	Scotland	31
Sud-Ouest	61	Northern Ireland	66
Centre-Est	32	United Kingdom	61
Mediterranee	29		
France	57	Ireland	73
Nord-Ovest	24	Denmark	98
Lombardia	58		
Nord-Est	40	Ellas (North)	14
Emilia-Romagna	44	Ellas (Central)	11
Centro	24	Ellas (East, S. Isl)	10
Lazio	13	Greece	13
Campania	12		
Abruzzi-Molise	15	Noroeste	18
Sud	24	Noreste	42
Sicilia	31	Madrid	59
Sardegna	10	Centro	44
Italy	28	Este	40
		Sur	49
Noord-Nederland	70	Spain	42
Oost-Nederland	93		
Zuid-Nederland	97	Norte do continente	25
West-Nederland	80	Sud do Continente	42
Netherlands	85	Portugal	33

Steep slopes are the reason for the unsuitability of major areas of the EC. In all regions of Portugal, Greece and Italy (except for Lombardia and Emilia-Romagna) more than 50% of the soil area is too steep for mechanized grass cultivation. Due to steep slopes, the unsuitable area in Spain amounts to 45% of the national soil area, with a maximum of 81% in region Noroeste. Regions in the other EC-countries which have a large area (more than 30% of the soil area) of land that is too steep are: Mediterranee, Est and Centre-Est (all in France), Luxembourg, Region Wallonne (Belgium), Bayern, Rheinland Pfalz, Baden-Wurttemberg (all in West Germany) and Wales.
Finally, soils can be unsuitable due to a phase. In Denmark, Ireland, the United Kingdom and the Netherlands these are relatively small areas. In Germany, Belgium and Luxembourg, stoniness is the most common phase. This phase covers more than 20% of the soil area in all regions of these three countries, except for Vlaams gewest and Germany's most northerly regions. In France, the regions Mediterranee, Ile de France and Est have the highest coverage of unsuitable phases, while the average of the country amounts to 20% of the soil area. In Portugal this percentage is 14%, in Spain 29% and in Greece 47%. Italy is the most unfavourable country in this respect: 55% of its soil area has a phase that prevents mechanized grass cultivation. In the regions Campania, Sardegna and Lazio this area is more than 75%.
Salinity occurs mainly in Spain. In the region Noreste about 9% of the soil area is saline. For the rest of the EC, saline and alkaline soils are of only minor importance.
Regions with a high percentage of non-soil area, are Hamburg (13%), Ile de France (14%), Brussel (52%) and North West (UK)(14%). This is due to urban zones.

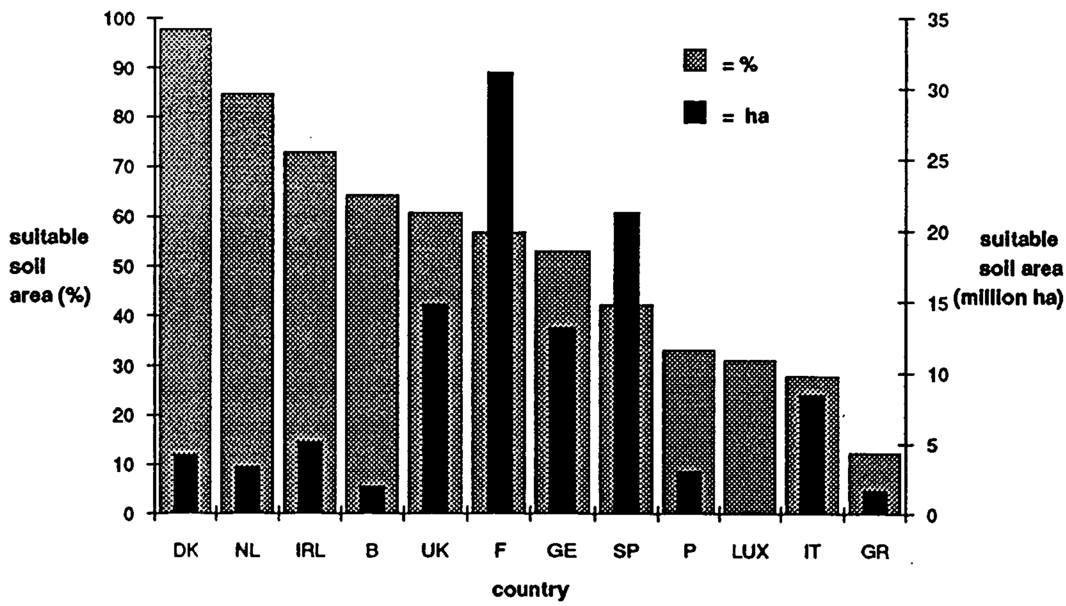

Figure 2. Estimated soil area suitable for mechanized grass cultivation per EC country, expressed as a percentage of total country area (%) and as the total number of hectares (ha). Abbreviations of countries are explained in the glossary.

Only soils suitable for mechanized grass cultivation have been discussed. For these soils the crop growth simulation model was applied. However, it should be kept in mind that many different types of grassland occur in the EC. Large areas of grassland are extensively managed. These grasslands are mainly located in the less favourable areas. If it is assumed that the only restriction for extensively managed grassland is the unsuitability of soils on slopes steeper than 25%, the resulting regional suitable areas for extensively managed grassland are substantially greater than for intensively managed grassland. This is shown in Appendix 26. The grass growth model could however not be used for these extra soil areas, because it is not adapted to such extensive production situations.

3.3 Cereals

Soil criteria for the mechanized cultivation of cereals are shown in Appendix 3. From the total area of the EC, 44% consists of soils suitable for the production of cereals. The only difference with the land use requirements for grass cultivation is the additional unsuitability of soils with drainage classes poor or temporary poor. These classes are associated with gleysols and stagnogleyic soils. This reduces the percentage of suitable soil area, compared with grass, particularly in Ireland (from 73% to 47%) and the United Kingdom (from 61% to 34%). The absolute number of suitable hectares in the United Kingdom is about the same as in Italy. The regional figures are given in Table 3.
In the southern part of the EC, the drainage classes poor and temporary poor are of no significance (except for Lombardia in Italy, where they cover 10% of the soil area). In the United Kingdom however, 35% of the soil area has poor or temporary poor drainage, with large areas in the regions North (70%), Yorkshire & Humberside (63%) and North West (64%). Other EC-regions which should be mentioned are Ireland (33%), West-Nederland (11%), Baden-Wurttemberg (14%) and Luxembourg (25%).

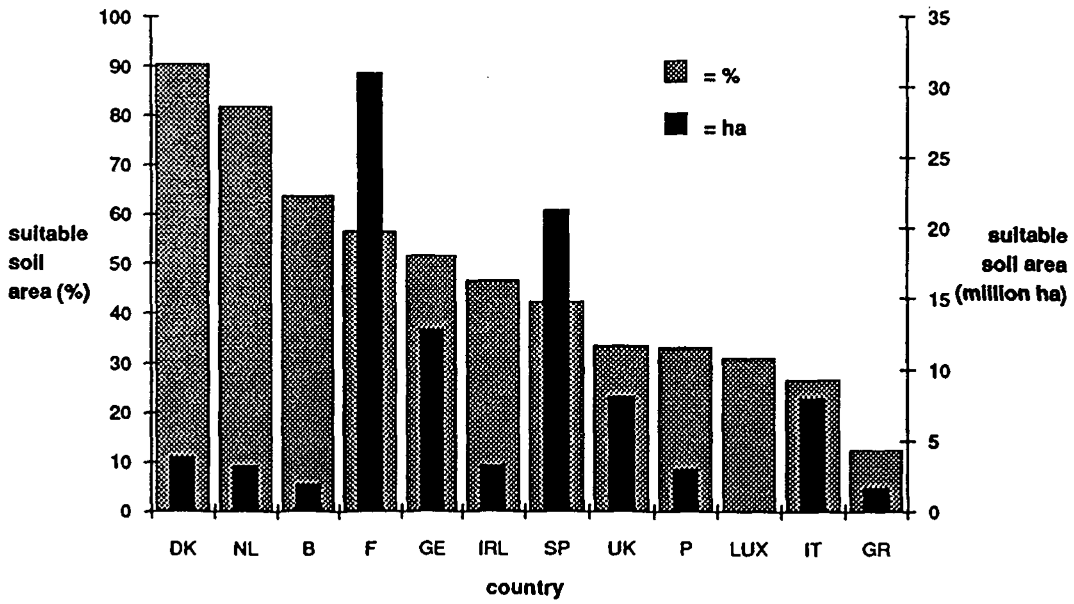

Figure 3. Estimated soil area suitable for mechanized cereal cultivation per EC country, expressed as a percentage of total country area (%) and as the total number of hectares (ha). Abbreviations of countries are explained in the glossary.

Table 3. Estimated area suitable for mechanized cereal cultivation for NUTS-1 regions and countries within the EC. The suitable area is expressed as a percentage of the total area.

Region/country	% suitable	Region/country	% suitable
Schleswig-Holstein	87	Vlaams gewest	99
Hamburg	70	Region Wallonne	36
Niedersachsen	74	Brussel	48
Bremen	81	Belgium	64
Nordrhein-Westfalen	60		
Hessen	34	Luxembourg (G.D.)	31
Rheinland-Pfalz	28		
Baden-Wurttemberg	38	North	9
Bayern	43	Yorkshire & Humber.	23
Saarland	42	East Midlands	48
West Germany	52	East Anglia	63
		South East	55
Ile de France	56	South West	54
Bassin Parisien	72	West Midlands	53
Nord-Pas-de-Calais	83	North West	15
Est	62	Wales	32
Ouest	62	Scotland	19
Sud-Ouest	60	Northern Ireland	29
Centre-Est	32	United Kingdom	34
Mediterranee	29		
France	57	Ireland	47
Nord-Ovest	20	Denmark	90
Lombardia	47		
Nord-Est	40	Ellas (North)	14
Emilia-Romagna	44	Ellas (Central)	11
Centro	23	Ellas (East, S. isl)	10
Lazio	13	Greece	13
Campania	12		
Abruzzi-Molise	15	Noroeste	17
Sud	24	Noreste	42
Sicilia	31	Madrid	59
Sardegna	10	Centro	44
Italy	27	Este	40
		Sur	49
Noord-Nederland	70	Spain	42
Oost-Nederland	93		
Zuid-Nederland	97	Norte do continente	25
West-Nederland	68	Sud do Continente	42
Netherlands	82	Portugal	33

Table 4. Estimated area suitable for mechanized root crop cultivation for NUTS-1 regions and countries within the EC. The suitable area is expressed as a percentage of the total area.

Region/country	% suitable	Region/country	% suitable
Schleswig-Holstein	74	Vlaams gewest	88
Hamburg	37	Region Wallonne	35
Niedersachsen	66	Brussel	47
Bremen	30	Belgium	58
Nordrhein-Westfalen	56		
Hessen	27	Luxembourg (G.D.)	15
Rheinland-Pfalz	16		
Baden-Wurttemberg	26	North	9
Bayern	37	Yorkshire & Humber.	22
Saarland	1	East Midlands	28
West Germany	43	East Anglia	41
		South East	42
Ile de France	43	South West	46
Bassin Parisien	43	West Midlands	47
Nord-Pas-de-Calais	70	North West	15
Est	13	Wales	31
Ouest	55	Scotland	19
Sud-Ouest	49	Northern Ireland	29
Centre-Est	25	United Kingdom	28
Mediterranee	24		
France	39	Ireland	47
Nord-Ovest	2	Denmark	89
Lombardia	9		
Nord-Est	16	Ellas (North)	10
Emilia-Romagna	26	Ellas (Central)	7
Centro	16	Ellas (East, S. Isl)	6
Lazio	7	Greece	8
Campania	8		
Abruzzi-Molise	9	Noroeste	2
Sud	8	Noreste	12
Sicilia	18	Madrid	32
Sardegna	6	Centro	12
Italy	12	Este	12
		Sur	13
Noord-Nederland	51	Spain	12
Oost-Nederland	76		
Zuid-Nederland	86	Norte do continente	6
West-Nederland	39	Sud do Continente	25
Netherlands	62	Portugal	16

3.4 Root crops

Of the total area of the EC, 28% consists of soils suitable for the production of root crops. The difference with cereals is the additional unsuitability of soils with texture class fine, or with the phases gravelly or concretionary. Suitability at country level, expressed as a percentage of the total country area, ranges from 89% in Denmark to only 8% in Greece (Table 4). In France the absolute number of suitable hectares is still the highest. The regional figures are also given in Table 4.
Texture class fine occurs widely within the EC. While the area of fine soils is only 1% of the soil area in Denmark, this area is 55% in Greece. Other regions with a large relative area of fine soils are eastern and southern England, West-Nederland, Luxembourg, north-eastern France, south western Germany and in Italy the regions Lombardia, Emilia-Romagna and the southern regions.
Gravelly soils are mainly found in France (13%), Portugal (35%), Spain (37%) and northern Italy. Most of the concretionary soils are located in Italy, especially in the north: Nord-Est (13%), Lombardia (11%) and Emilia-Romagna (6%).

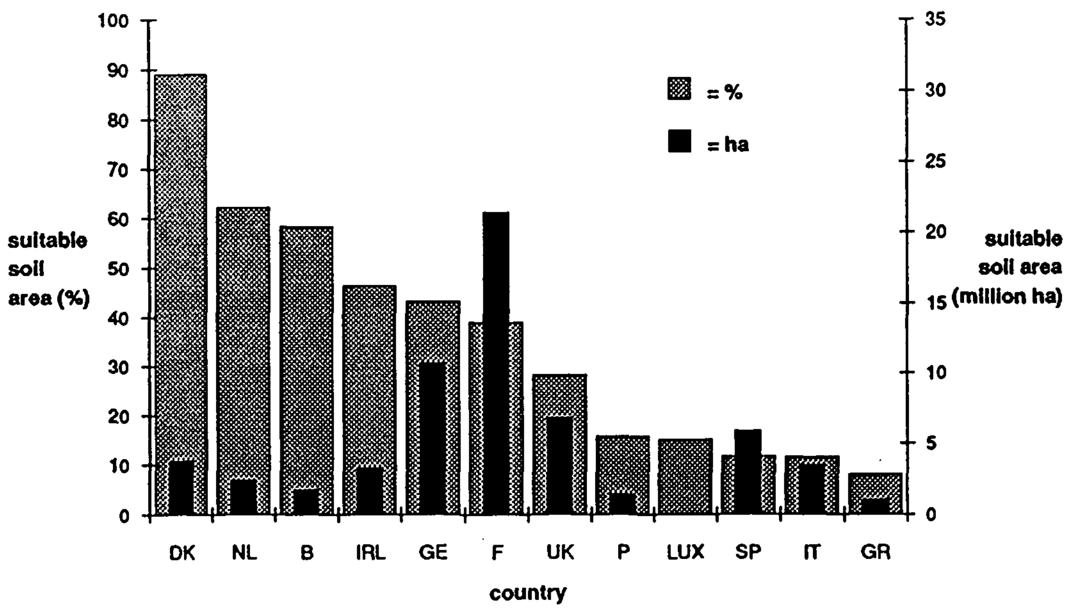

Figure 4. Estimated soil area suitable for mechanized root crop cultivation per EC country, expressed as a percentage of total country area (%) and as the total number of hectares (ha). Abbreviations of countries are explained in the glossary.

3.4 Discussion

The qualitative selection procedure leads to the exclusion of considerable areas of the soil map from further quantitative evaluation. Within the EC the Mediterranean regions have a relatively high percentage of soils unsuitable for crop production. The main soil characteristics causing exclusion are related to slope and phase.

It was assumed that the suitability criteria for cereals also apply to oilcrops (oilseed rape, sunflower). From the qualitative selection of suitable soils, it was estimated that 48% of the total EC-area can be used for mechanized grass cultivation, 44% for rotations with only cereals and oilcrops and 28% for rotations including root crops. The area for root crop rotations falls within that for cereals and oilcrops, and the area for cereals and oilcrops falls within that for grass.

Actual land use figures are given in Appendix 18. About 56% of the total EC-area is agricultural area. The agricultural area consists of arable land covering 30% of the total EC-area, grassland covering 21% of the total EC-area and permanent crops (fruit trees, vineyards and olive trees) covering 5% of the total EC-area. Relatively large areas of permanent crops are grown in Italy, Spain and, Greece. In most countries about half of the total area is used as agricultural area, with the United Kingdom, Ireland and Denmark having relatively more AA, and Belgium and Greece somewhat less. The high proportions of AA in the United Kingdom and Ireland are due to the inclusion of rough grazing land in this land use category. In a number of countries, about 30% of the total area consists of arable land (Appendix 18). A much higher proportion of arable land is found in Denmark and a lower one in Ireland, Luxembourg, Belgium and the Netherlands.

The actual land use figures cannot be directly compared with the results of the qualitative selection of suitable soils because at present no accurate land use map of Europe is available, making it impossible to verify whether the areas classified as suitable for a specific crop correspond with the actual land use. Furthermore, either grass, arable crops or fruit trees may be grown on land suitable for all these crops. Also, potential agricultural land can be used for non-agricultural purposes. Finally, no climatic constraints have been evaluated in the qualitative selection. However, when comparing Table 3 and Appendix 18, it can be concluded that in most regions the actual area of arable land is below the area that was classified as suitable for cereal cultivation. In 15 regions, the actual area is larger: 9 regions in Italy, 5 regions in the UK and Greece. When comparing the total actual agricultural area (including intensively and extensively managed grassland farming and permanent crops) with the area that was classified as suitable for mechanized grass cultivation (Table 2), the actual area is larger in 31 regions: 3 regions in West Germany, 4 in France, 10 in Italy, 1 in Belgium, Luxembourg, 5 in the UK, Ireland, Greece, 5 in Spain and Portugal. In all regions, except for Greece, the total actual agricultural area is below the area that was classified as suitable for extensively managed grass cultivation (Appendix 26).

4 POTENTIAL, WATER-LIMITED AND ACTUAL CROP YIELDS

4.1 Introduction

Results of the crop growth simulations will be given in this chapter. Two production levels were calculated: potential yields and water-limited yields (Section 2.5). These are compared with actual production figures of recent years for NUTS-1 regions, according to statistics (Eurostat, 1986, 1987). The different crops for which the model calculations were carried out, will be treated separately. Some general remarks, however, concern all crops and will therefore be discussed first.

4.1.1 Potential crop production

Potential crop yields are determined by radiation, temperature, sowing date and (related to temperature and sowing date) the length of the growing season. Generally, long and sunny summers with mild temperatures are ideal for maximum biomass production.
Under suitable temperature conditions, the photosynthesis rate of a green crop is strongly related to the amount of received radiation. Map 4 indicates the amount of incoming annual global radiation in each agro-climatic zone (Reinds *et al.*, 1992). The highest levels of radiation are received in the southwest of the Iberian Peninsula and in parts of Greece, while the west of Ireland and the northern part of the United Kingdom receive the least radiation within the EC. The greatest regional differences in radiation regime are related to cloudcover. If cloudcover was equal all over Europe, there would be hardly any north-south difference in received radiation during a four month period around the summer solstice. The lower radiation intensity in the north is compensated for by longer days. Outside that period the incoming radiation with constant cloudcover is highest in the south. Moreover, the less frequent occurrence of clouds in the southern regions leads to a generally higher level of incoming radiation.
If radiation is sufficient, crops realize the highest growth rates when the average daily temperatures are moderate. If it is too hot, respiration losses increase and the photosynthesis rate may be hampered. If temperatures become too low, physiological processes proceed more slowly and the photosynthesis rate also decreases. Crops respond differently to temperature. While maize can resist high temperatures, the potato crop prefers cool weather. Summer temperatures in the EC generally increase from north to south, but conditions are milder near the coasts. Furthermore temperatures decrease at higher elevations.
The potential length of the growing season, is the uninterrupted period when temperatures do not prevent crop growth. In the EC, growth of the crops under consideration is only prevented by low temperatures, because even in the hottest regions (limited) crop growth is still possible in summer. Therefore, the potential growing season decreases from south to north and with increasing altitudes. However, although long potential growing seasons may have a high biomass potential, this potential can only be fully exploited by a green crop. Most crops have a much shorter growing season than the potential growing season, and under warm conditions the growing season of a crop is further

shortened due to rapid development, thus reducing final yield. Generally, in southern Europe the actual growing season is shorter than in northern Europe, due to the higher temperatures. Again, the effects of coasts and mountains play a role.
The start of the growing season of arable crops is determined first of all by the sowing date. In southern regions, the date of sowing is mainly determined by the temperature regime. The sowing date in these regions was for each crop chosen according to crop calendars. In the humid regions in the northern part of the EC and along the Bay of Biscay, the sowing date may be delayed due to excessive wetness of the soil. In the crop growth model WOFOST this was accounted for by a subroutine that determines for a given soil and for a period prior to the growing season which days are workable and which are not, depending on precipitation and soil type. The sowing date is calculated by the model as the first day on which the soil is workable after a certain critical date. This critical date was chosen according to local crop calendars. The time from sowing to emergence, needed for germination, was calculated in WOFOST with a crop specific temperature sum, using average daily temperatures.
Two winter crops were simulated: winter wheat and oilseed rape. Because the model is not suitable for simulating vernalization processes, simulation for these crops was started on the first of January, assuming a certain initial biomass on this date.
Some temperature regimes allow double cropping in one growing season, for example a green manure crop or silage maize as a second crop, but in the present study the production potential obtainable under two successive crops was not investigated.

4.1.2 Water-limited crop production

As well as the factors that determine potential yields, water-limited yields are also affected by the water supply, which is determined by the combination of climate and soil characteristics. Yield reductions due to drought stress occur only if there is a soil moisture deficit during the growing period. Yield reductions may also be the result of excess water, but their occurrence is less widespread and their effects less severe, so that they barely influence the yield pattern on a regional scale.
The difference between precipitation and potential evapotranspiration, i.e. the precipitation deficit, may serve as a climatic parameter for moisture availability or drought. The annual precipitation deficit in the agro-climatic zones is shown on Map 5 (Reinds *et al.*, 1992). 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. The very humid zones along the Bay of Biscay are notable. Even in regions with a very low mean precipitation deficit, there are usually years with large deficits in some months, leading to lower than potential mean water-limited yields. The influence of a climatic moisture deficit on yield depends on the time of its occurrence in the growth cycle, and on the soil type.
If there is a drought in the period before filling of the storage organs (e.g. in cereals before flowering) the growth of leaves and stems is reduced. This leads to a lower leaf area index (LAI) of the canopy. When the LAI decreases to below a critical level, light interception, and therefore photosynthesis

rate, are reduced. Under severe stress this is aggravated by death of leaf tissue. A lower than optimal LAI leads to less than potential growth rates during the period of filling of the storage organs, even when water is sufficiently available. This leads to lower final yields. When the storage organs are present, the majority of the assimilates are partitioned to these organs. Drought stress during this period therefore directly causes lower yields as a result of the reduced assimilation rate.

Crop calendars influence the impact of drought stress. Early maturing winter crops such as wheat and oilseed rape are more likely to avoid the summer drought than crops with a long growth cycle such as sugar beet and late-sown crops such as maize.

The water-supplying capacity of the soils is related to soil texture, soil depth and groundwater influence. On slopes, some of the precipitation is lost due to runoff. The fraction of runoff depends on the steepness of the slope and amount of daily rainfall. Runoff was set at zero for land with slopes of 0 to 8%, while for land with slopes of 8 to 15% runoff was set at 25% of heavy showers over arable land and 15% of heavy showers over grassland. Runoff decreases with diminishing rainfall intensities.

The water-holding capacity of a soil in relation to its texture was estimated by Reinds *et al.*, (1992). For a given rainfall deficit the largest yield reductions were calculated for shallow, coarse-textured soils under sloping topography, without groundwater influence, and the highest yields for deep, medium-textured soils with groundwater influence, under level topography. Coarse-textured shallow soils include podzols, sandy regosols and arenosols. Soils with a water-supplying capacity hardly better than that of podzols are the rendzinas, characterized as shallow medium-textured soils. A third category of soils that may lead to appreciable yield reductions are deep (80 or 120 cm) coarse-textured soils without groundwater influence, of which the sandy cambisols are the most widespread. Concentrations of coarse soils are located in Ireland, the southern part of the United Kingdom, Denmark, northern Belgium, south and east Netherlands, Niedersachsen, Schleswig-Holstein, south-west France, Portugal and western Spain.

An estimation of areas where groundwater at shallow depth is available for crop growth has been made by Reinds and Van Lanen (1992). It was assumed that histosols, gleysols, fluvisols, and soils with a gleyic or stagnogleyic phase have a groundwater influence in the root zone during the growing period. Under these assumptions, groundwater influence is mainly present in Ireland, the United Kingdom, the Netherlands, and further south in the river valleys (Map 6).

Within a climatic zone, represented by one station, the variation in water-limited yield levels between land evaluation units can be related exclusively to differences in soil depth, soil texture, topography and groundwater influence. These yield differences are consistent and become larger for regions with more frequent and more severe precipitation deficits. The aggregated regional water-limited yield figure is influenced by the mix of soil types occurring in each climatic region. In this regional yield figure the internal variation in yields between land evaluation units is obscured and the extremes are levelled off.

The range in yields within a NUTS-1 region, comprising land evaluation units from more than one climatic zone, is more complicated because of the accumulation of the effects of climate and soil type.

The regional distribution of water-limited crop yields will be discussed for each crop in more detail for the temperate and Mediterranean zones separately. For this purpose the temperate zone is broadly considered to be all those agro-climatic zones where the annual precipitation deficit is less than 300 mm (Map 5).

4.1.3 Actual crop production

Actual production figures for NUTS-1 regions were obtained from the Statistical Office of the EC, Eurostat. In the Eurostat statistics, cultivated areas and production volumes (fresh weight) are given for a number of crops. When this study was being done, figures were available for 1982, 1983, 1984 and 1985 (Eurostat 1986, 1987). Crop production in these statistics is expressed as fresh weight. For comparison with simulated yields, fresh weights were converted into dry weights using fixed crop-dependent dry matter contents. Average crop yields per hectare for a NUTS-1 region were obtained by dividing the production volume of a crop by the total number of hectares used for its production. For Portugal and Greece only figures at country level were available. Therefore, yields for all NUTS-1 regions within these countries were considered to be equal to the national average

4.2 Wheat

4.2.1 Potential production of wheat

The mean long-term potential grain yields of wheat within the EC at LEU-level, are shown on Map 7. Average yields per agro-climatic zone are given in Appendix 4. The highest grain yields, more than 10 tonnes dry matter per hectare, are found for a series of Atlantic coastal zones from Porto (Portugal) to Plymouth (UK). Yields of slightly below 10 tonnes are found for some more northern Atlantic zones in the United Kingdom and Ireland, and for zones at higher elevations of about 700 metres on the northern Castilian plateau in Spain, the Massif Central in France, and the Black Forest in southern Germany. For most other zones the simulated potential yields fall within the range of 7.5 to 9 tonnes per hectare. Major exceptions are the Po Valley with 7.1 tonnes and Greece with even lower yields, due to the hot weather. Lower yields are also found as a result of cold weather, for example at altitudes above 1000 metres in central Europe or above 300 metres in Scotland.
Potential wheat yields are determined by radiation, temperature and (related to temperature) the growing season (Section 4.1.1). Under very hot conditions, the photosynthesis rate of wheat is hampered, thus reducing yields. However, more important for wheat yields within Europe are the effects of temperature on the development of the crop. For winter wheat, effects concerning vernalization were not taken into account. The crop growth model was initiated on the first of January, assuming that vernalization requirements are always met. The accumulated temperature sum after this date, determines the moment of maturity in the model. The earliest maturity dates are calculated for the most southern Mediterranean coastal zones: the end of May. Going north along the coasts the calculated date of maturity shifts gradually to the end of June for the coastal regions of the northern Mediterranean and the Bay of Biscay. In non-coastal lowlands such as the valleys of the Ebro and the Po, wheat matures about two weeks later than in coastal areas, because of the lower winter temperatures. At higher elevations on the Spanish plateau and in the Apennine chain, wheat matures about one month later than along the coast. More northerly, the simulated maturity dates are the end of July for northern France, mid-August for the Netherlands and from the end of

August to early September for Denmark and lowland stations in Scotland.
The length of the grain-filling period varies from six to ten weeks. It depends on the temperature during that period which in turn can be related to latitude, altitude, and marine influence. The shortest length is found for hot continental summer types such as in northeastern Greece and the Po valley. It is about seven weeks in the Mediterranean zone and in the interior of France, but about one week longer along the Atlantic coast. It is also eight weeks in the Benelux countries and in northern Germany, a few days longer in England, and nine to ten weeks in Scotland.
The simulated harvest index relates the final grain yield to the total production of above-ground biomass. These simulated indices differ from experimental data because the total biomass from field measurements does not include the stubble and plant parts that have already decayed at the moment of the harvest.The simulated harvest index averages 0.38, and varies from 0.33 to 0.44. This small range indicates a rather stable growth pattern of the defined cultivar, which is efficient in terms of yield formation.

4.2.2 Water-limited production of wheat

The mean long-term water-limited grain yields of wheat at LEU-level, are shown on Map 8. The average grain yields per agro-climatic zone range from 2.2 tonnes dry matter per hectare in Penhas Douradas (Portugal) to a maximum of almost 10 tonnes in Brest (France) (Appendix 4). The water-limited yield in Lisboa (Portugal) is only 23% of the potential yield, while in some West German zones (Munchen, Hof) the water supply hardly reduces the potential grain yields at all. Low water-limited grain yields (between 2.5 and 4.5 tonnes) are found on the Iberian Peninsula, in southern Italy and Greece and along the Mediterranean coast of France. In the central part of the EC and along the Atlantic coast yields are generally high.
Differences between potential and water-limited yields are caused by the water supply, which is determined by the combination of climate and soil characteristics (Section 4.1.2). The crop growth model was for wheat applied to all soils that were not excluded for cereal production in the qualitative selection procedure (Section 3.3). In a number of these suitable soils, the maximum root growth of wheat (set at 125 cm) is hampered in the model. Primarily these are the podzols, arenosols, regosols, rankers and rendzinas (rooting depth 40 cm). Planosols have a rooting depth of 60 cm. Furthermore, some soils with groundwater influence limit the root growth of wheat. These are the gleyic soils (with the exception of cambisols) and fluvisols, which have a rooting depth of only 60 cm if their texture is coarse and 80 cm for the other texture classes. Finally, rooting is hampered on soils with a gravelly or concretionary phase.

- The temperate zone

The highest yield reductions are calculated for soils with low moisture-supplying capacities: coarse-textured shallow soils without groundwater. For podzols, arenosols and regosols it was assumed that the maximum rooting depth is only 40 cm. In zones with a precipitation deficit of less than 100 mm, such as De Bilt (Map 5), water-limited yields calculated by the model are on these coarse shallow soils 35% to 45% lower than the potential yields, depending on slope. If the soils have

groundwater influence (Map 6), calculated yield reductions are limited to 25%. On deep sandy soils yields are always clearly higher. Large podzol areas occur for example in Denmark and Les Landes, south of Bordeaux. However, the major part of Les Landes is located in the climatic region of Biaritz, a station with a lower precipitation deficit than De Bilt and an early maturity date, resulting in an average yield reduction, calculated by the model, of only 25% on these unfavourable soils. Rendzinas occur as dominant soil units in southern England in the climatic regions Plymouth and Durnemouth and in the eastern part of the Paris Basin, where they constitute up to 25% of the area classified as suitable for the cultivation of cereals. Together with sandy soils they are responsible for the relatively large yield reductions in these regions.
On soils with an average moisture-supplying capacity (deep medium-textured soils without groundwater influence) the calculated reductions in wheat vary from 0 to 10% throughout the whole temperate zone, except for part of France. Yields for similar soils with groundwater influence are usually only a fraction higher, and sometimes even lower as a result of oxygen deficiency, especially for fine-textured soils on flat terrain where stagnating water may occur. The yield-depressing effect of the increasing summer moisture deficit in southerly regions is partly counterbalanced by the earlier date of maturity, because the crop evades the driest period. It is mainly in regions in France and Italy with precipitation deficits of up to 300 mm that calculated water-limited wheat yields on deep medium-textured soils decline to 80% of the potential yield as a result of the occurrence of more serious droughts. On the most unfavourable soils in these regions, yields are only 25% of potential.

- The Mediterranean zone

Under the relatively humid climate of the coastal zone of Porto, reductions in wheat yields due to water limitation are less than 10% on soils with good water-holding capacity. But because a large proportion of the suitable soils are classified as deep sandy cambisols on slopes where, according to the model, yield reductions can amount to 50%, the mean water-limited wheat yield in this agro-climatic zone is almost 40% below the potential yield of this zone.
Further south along the Atlantic coast in Portugal the simulated yield reductions increase sharply. On deep medium-textured soils the reduction is 20% for Lisboa and over 50% in the extreme south, but reductions of 70% to 85% are calculated for coarse-textured soils in these regions. From the soils classified as suitable a high proportion are sandy, varying from 75% in northern parts to 40% in the south. The sandy soils include podzols which are concentrated in the western central part of Portugal, and moderately deep cambisols in the other parts. The widespread occurrence of these sandy soils leads to a low mean water-limited yield level.
On the Spanish plateau, climatic conditions are unfavourable due to the combination of rather cold winters, followed by hot and dry summers. The proportion of sandy soils is usually limited to about 10% of the suitable soils, except for the Badajoz region where about 40% of the area consists of moderately deep gravelly sandy cambisols. The greatest simulated yield reductions are found for the northern Castilian plateau, because of the later start of the grain-filling period. The range in water-limited yields expressed as a percentage of potential yields is from less than 10% on the sandy cambisols, 30% on deep medium-textured soils, to 60% on medium-textured alluvial soils with groundwater influence.
On the southern plateau, grain-filling starts one month earlier, when the soil moisture reserve is less

depleted, so that yield reductions are less. The mean calculated yields are 15% of the potential yields on the sandy cambisols, 60% on deep medium-textured soils and 85% on alluvial soils. Similar yield levels are found for the agro-climatic zone of Granada. The average yields along the south coast are favourably influenced by the earliness of the crop and the absence of coarse-textured soils, but the rainfall is too low for high yields. The water-limited yield on deep medium-textured soils is less than half the potential yield in Murcia, and 75% in Malaga. High yields are found for the agro-climatic zone of Cordoba, because of a higher rainfall in the spring. Water-limited yields are above 90%, and the occurrence of serious yield reductions is confined to 15% of the suitable soils including cambisols and planosols with a sandy texture. The southwestern coastal plain of Cadiz is drier and therefore has lower yields.

Northeastern Spain includes the distinct agro-climatic zones of the Ebro basin and the Mediterranean coast. Some 20% of the suitable soils are medium-textured alluvial soils, and sandy soils are rare. In the Ebro valley shallow medium-textured xerosols occupy 10% of the suitable area. Here the wheat crop matures one month earlier than on the high plateau, but the rainfall is not sufficient to take advantage of this, and the yield is only 20% of potential on deep medium-textured soils, but much better, 75%, on alluvial soils. In the coastal region the calculated yields are higher as a result of earliness and higher rainfall, and is 60% for deep medium-textured soils without groundwater, and close to potential yields if groundwater is present.

The small French Mediterranean zone has sharp climatic gradients. The coast from Perpignan to Marseille is dry. Water-limited yields on deep medium-textured soils vary from 20% in Perpignan to 50% in Nimes and 75% in Nice. For alluvial soils these percentages are 55, 70, and 90 respectively.

In Italy, there are no shallow soils of less than 60 cm deep among the suitable soils, and few soils have groundwater influence. Throughout Italy the medium and fine-textured deep soils make up at least 75% of the suitable soils. The lowest yields are found for deep (80 or 120 cm) sandy cambisols on sloping terrain, but these soils do not occur frequently. The second lowest yields are found for flat cambisols that cover large areas in floodplains. It was assumed that such soils do not have groundwater influence, but a favourable condition is the absence of runoff losses.

On the Italian peninsula yield reductions depend very much on the earliness of anthesis and on the rainfall in spring. The earliest crops are found in the most southern coastal stations such as Messina, where wheat is a true winter crop with some rainfall in spring during grain-filling. Maturity is reached before the heat and drought stress would become severe. Yield reductions on medium to fine-textured soils vary from 5% for Messina to 20% for Brindisi. Over the full length of the country, conditions for rainfed wheat are more favourable along the Tyrrhenian Sea than along the Adriatic Sea due to differences in earliness of the crop and the spring rainfall. On the Tyrrhenian side, average regional yield reductions do not exceed 15%. The greatest yield reductions are found for the Foggia region: almost 50% on deep medium-textured soils on gentle slopes. In the Apennines grain-filling takes place later and under drier conditions, leading to greater yield reductions than in the lowlands.

Still warmer and drier weather conditions than in southeastern Italy are found in Greece. Reductions in water-limited yield, however, are moderate because none of the number of suitable soils are either coarse-textured or shallow, and many have groundwater influence. In the warm Mediterranean climate of the western and southern coastal regions, the wheat crop matures very early taking maximum advantage of the favourable weather in spring, and calculated yield reductions are less than 10%. In the continental Mediterranean climate of the northeastern regions the crop matures later, and under drier conditions. The relative yield on soils with groundwater influence is 80%, against about 50% without groundwater influence. Groundwater is present in relatively small areas in the Mediterranean zone and mainly confined to river valleys (Map 6). In some zones however, only a small fraction of the soil surface was considered suitable for wheat cultivation (Section 3.3), but most of this suitable area consists of soils with groundwater influence, which can result in relatively high average water-limited yields in the suitable area. This is illustrated by the agro-climatic zone of Tricala in Greece, where 97% of the suitable soil area has groundwater influence.

4.2.3 Actual production of wheat

Appendix 20 shows the distribution of the wheat area within the EC as a percentage of the total area per NUTS-1 region. The highest concentrations of wheat are found in eastern England, the Paris Basin, the Italian peninsula and Sicily. In Italy 60% of the wheat area is under durum wheat.
In the context of the present study wheat has been used as an indicator crop for cereals, except for maize and rice, and as such serves as a stand-in for small grains including common and durum wheat, barley, oats and rye, and for both summer and winter cultivars. Cereals are the major group of annual crops, occupying slightly more than 50% of the arable land in the EC. In the Netherlands and Ireland cereals are less prominent (Appendix 19). Wheat is the most important single cereal, accounting for 42% of the total EC area under cereals. Next in importance are barley and grain maize. In the major cereal-growing countries the dominance of wheat is largest in Italy with over 60% of the cereal area under wheat, followed by France and the United Kingdom with 50%. Wheat is the second cereal after barley in West Germany, Spain, Ireland and Denmark. Furthermore, wheat is second after grain maize in a number of regions in northern Italy, southwestern France and northwestern Spain.
Actual wheat yields are given in fresh weight by Eurostat. The average yield of common spring wheat, common winter wheat and durum wheat was used and converted into dry matter yield using a dry matter content of 84%. Appendix 11 shows that the highest wheat dry matter yields are found in the northwestern part of the EC. Here, wheat yields of between 5 and 6.5 tonnes dry matter per hectare are common. Further south in the EC, yields are considerably lower. In large parts of Germany dry matter yields are between 4 and 5 tonnes and in a number of regions along the Mediterranean yields are between 2 and 3 tonnes. In central Spain, Portugal and the most southern part of Italy, yields decrease to under 2 tonnes. Simulated potential and water-limited yields have been aggregated to NUTS-1 level and are also listed in Appendix 11 to allow a comparison between actual and simulated yields.
The total actual production volume of wheat within the EC equals 70.4 million tonnes fresh weight or 59.1 million tonnes dry weight. When multiplying the simulated NUTS-1 yields by the actual wheat areas in these regions, the water-limited production volume amounts to 97.8 million tonnes dry weight and the potential production to 130.1 million tonnes dry weight for the whole of the EC. In other words, on average the actual production is 60% of the water-limited production and 45% of the potential production. The same relative production figures were calculated for separate countries and are given in Table 5. The figures in Table 5 are an indication of the management level. In general, the northern member states have the highest relative actual wheat yields. Of these countries, Ireland

and Germany seem to do less well. In the southern countries the relative actual yield is especially low compared with the potential yields, indicating high irrigation requirements. It must be kept in mind that the actual production is the average production of common spring wheat, common winter wheat and durum wheat.

Table 5. Actual wheat production of the EC-countries, expressed as a percentage of the calculated potential and water-limited production. Source of actual production: Eurostat (1986, 1987).

	actual production as percentage of:	
	potential	water-limited
Ireland	62	69
United Kingdom	62	77
Denmark	67	95
Netherlands	74	85
Belgium	62	72
Luxembourg	40	53
West Germany	60	67
France	54	67
Portugal	12	24
Spain	26	60
Italy	29	37
Greece	31	38

The proportion of actual wheat production for each country within the EC is listed in Table 6. The United Kingdom, West Germany, Italy and especially France are at present the main wheat-producing countries, together accounting for more than 80% of the total production.

Table 6. The distribution of wheat production within the EC. Averages over 1982, 1983, 1984 and 1985. Source : Eurostat (1986, 1987).

	production volume (% of EC-total)
Ireland	0.7
United Kingdom	16.9
Denmark	2.6
Netherlands	1.4
Belgium	1.6
Luxembourg	0
West Germany	13.4
France	39.8
Portugal	0.5
Spain	7.6
Italy	12.5
Greece	3.0

4.3 Maize

In this study two types of maize production were distinguished: green (silage) maize and grain maize. In all regions of the EC where maize is grown, it can be used as green maize by harvesting the total above-ground crop. For grain maize however, the grains are the final product. To be able to harvest a valuable grain maize crop, climatological conditions must allow the ripening of the grains. These conditions are not met in the northern part of the EC and therefore only total above-ground dry matter production was considered for this area (green maize). In the southern part of the EC the maize crop is able to reach maturity and for this area the total above-ground dry matter (green maize) as well as the grain yield (grain maize) were considered.
In the crop growth model a green maize variety for the northern part of the EC and a grain maize variety (that can also be harvested as green maize) for the southern part of the EC were distinguished by means of two crop parameter sets, differing mainly in development rate. For the northern climatological zones the fast-developing early variety was used and for the southern zones the late variety. This is according to the practice in the EC, where varietal distribution is related to the temperature sum during the growing season (Bignon, 1990; Derieux and Bonhomme, 1982a, 1982b). In the northern regions early varieties are grown in order to allow the crop to proceed in development as much as possible. Going south the grown varieties increase in lateness.

4.3.1 Potential production of maize

The mean long-term potential above-ground (green) maize yields at LEU-level, are shown on Map 9. Average above-ground yields per agro-climatic zone range from less than one tonne dry matter per hectare in Lerwick (Scotland) to a maximum of 28 tonnes in Porto (Portugal) (Appendix 5). Potential above-ground yields of 23 tonnes or more can mainly be achieved in agro-climatic zones in France, the southwest of Germany, the north and west of the Iberian peninsula and western Italy. In the north of the EC, the yield potential is lower. In the Netherlands, northern Germany and southern England, potential above-ground yields range from 17 to 21 tonnes, while still further north in England and most of Ireland above-ground yields of between 11 and 17 tonnes can be reached. Above-ground yields decrease to less than 9 tonnes in some parts of Scotland. Within the Mediterranean countries, above-ground yields are lowest in Greece, where they amount to less than 21 tonnes in most regions.
The mean long-term potential grain yields at LEU-level in areas where the maize crop reaches maturity are shown on Map 10. Average grain yields per agro-climatic zone range from about 9 tonnes dry matter per hectare in Larisa (Greece) to 16 tonnes in Leon (Spain) (Appendix 6). There is a good agreement between the distribution of grain yields and the above-ground yields.
Potential maize yields are determined by radiation, temperature, sowing date and (related to temperature and sowing date) the length of the growing season (Section 4.1.1).
In the crop growth model, the photosynthesis rate of maize is hardly affected by high temperatures. During very hot summers in Mediterranean zones only minor reductions in growth rate occur. However, temperatures can be too low for optimal growth rates. This causes yield reductions in the

northern part of the EC, especially at higher altitudes.
The start of the growing season is first of all determined by the sowing date. In general, the variation in the sowing date of maize within Europe is small compared with that of potato and sugar beet. In the southern regions the date of maize sowing is mainly determined by the temperature regime and moisture conditions of the soil. The sowing date used in the model, was for these regions chosen according to crop calendars. These dates range from the first week of April in Greece, southern Italy and the south of the Iberian peninsula, to the 15th of April in the transition zone to the more temperate regions (e.g. Toulouse).
In the humid regions in the northern part of the EC and along the Bay of Biscay, the sowing date may be delayed due to excessive wetness of the soil. The sowing date is calculated by the model as the first day on which the soil is workable after a certain critical date (Section 4.1.1.). Soils with texture classes coarse, medium, medium-fine and fine were assumed to be suitable for maize growing (Section 3.2). The earliest sowing dates can be realized on the coarse-textured soils while the longest delay of sowing occurs on the fine-textured soils. On the coarse soils of the humid regions, the earliest average sowing dates were calculated for the regions along the Bay of Biscay: 15th of April. In the more northerly located regions the sowing date is maximally six days later. Wetness causes hardly any delays on coarse soils. On soils with a medium texture, the average sowing date for most agro-climatic zones is only one or two days later than on the coarse-textured soils. This delay can amount to four days in the wettest regions (e.g. Dalwhinnie). On the medium-fine and fine-textured soils additional delays occur, which lead to sowing in the last week of April in many zones. Only in two zones sowing is postponed until May (Freudenstadt and Eskdalemuir).
For maize the required temperature sum between sowing and emergence was set in the model at 110 degree-days, with a base temperature of four degrees centigrade and a maximum germination rate at temperatures of 30 degrees centigrade or higher. The temperatures used are average day temperatures. In the south of the EC the average calculated germination time is only nine days in the zones with the warmest conditions after sowing (e.g. Murcia, Faro, Heraklion) and can increase to almost three weeks in mountainous zones (e.g. Soria, Le Puy en Velay). In the humid northern regions, the calculated germination time on coarse soils amounts to about 3 weeks in most zones. On fine soils germination time is about one to two days shorter than on the coarse soils due to later sowing dates and thus higher temperatures during germination.
Emergence date and development rate determine the length of the growing season. At high temperatures the crop develops more rapidly than at low temperatures. Only in the southern part of the EC does the maize crop reach physiological maturity. Within these grain maize regions the shortest growing seasons were calculated for the lowlands of Greece and southern Spain, amounting to about 105 days. In these regions this results in maturity around the first of August. In northern Spain, Italy and southern France, the growth duration amounts to about 120 days and the crop is mature at the end of August. In central France, with a growing season of 145 days, maturity is reached at the end of September.
In the northern part of the EC maturity is not reached. For these green maize regions the day on which the crop is harvested was set in the model at the first day of October. This results in a growing season of about 145 days.

4.3.2 Water-limited production of maize

The mean long-term water-limited above-ground yields of maize at LEU-level are shown on Map 11. The above-ground yields per agro-climatic zone range from less than one tonne dry matter per hectare in Lerwick (Scotland) to a maximum of 24 tonnes in Grenoble (France) (Appendix 5). The water-limited yield in Lisboa (Portugal) is only 23% of the potential yield, while in some Scottish zones the water supply hardly reduces the above-ground potential yields at all. Low water-limited above-ground yields (between 6 and 9 tonnes) are found in agro-climatic zones at the Iberian Peninsula, in southern Italy and Greece and along the Mediterranean coast of France. In the north of the United Kingdom yields are also low due to low potential yields. Yields are highest in the central part of the EC.

The mean long-term water-limited grain maize yields at LEU-level are shown on Map 12. The grain maize yield distribution pattem is very similar to that of the above-ground yields. In many Mediterranean agro-climatic zones the average grain yields are less than one tonne dry matter per hectare. Further north grain yields are considerably higher with a maximum of 12 tonnes in the agro-climatic zone of Grenoble (Appendix 6).

Differences between water-limited and potential yields are caused by the water supply, which is determined by the combination of climate and soil characteristics (Section 4.1.2). The crop growth model was for maize applied to the same soils as for wheat (Section 3.3). However, the maximum rooting depth of the crop was set at 80 cm for maize and at 125 cm for wheat in the simulation model. This means that variations in soil depth deeper than 80 cm can still influence the soil water reserves available for wheat, but not for maize. The potential root growth of maize is hampered in a number of suitable soils. These are primarily the podzols, arenosols, regosols, rankers and rendzinas (rooting depth 40 cm). Planosols have a rooting depth of 60 cm. Furthermore, some soils with groundwater influence limit the root growth of maize. These are the gleyic soils (with the exception of cambisols) and fluvisols, which have a rooting depth of only 60 cm if their texture is coarse. Finally, rooting is hampered on soils with a gravelly or concretionary phase.

- The temperate zone.

The highest reductions in potential yields are calculated for the least favourable soils: coarse-textured soils without groundwater influence. Some of these coarse soils (podzols, arenosols and regosols) allow a rooting depth of only 40 cm. In regions with a precipitation deficit of less than 100 mm (Map 5), the reduction of the potential above-ground yield on 40 cm deep coarse soils can amount to 25% on level terrain and up to about 30% on sloping terrain. With groundwater influence the reductions on 40 cm deep level coarse soils are only about 10%. In these humid regions, reductions in the above-ground yield on medium, medium-fine and fine-textured deep soils without groundwater influence are less than 5%. If groundwater is present, above-ground yields hardly increase on these soils and can even be slightly lower due to oxygen deficiency. Medium-fine-textured soils are most sensitive to oxygen deficiency.

Further south in the temperate zone precipitation deficits increase to almost 300 mm, for example in Pisa (Italy) and La Coruna (Spain). On shallow (40 cm) coarse soils without groundwater and on sloping terrain, the water-limited above-ground yield in these regions is only 30% of the potential production and the grain maize yield less than 20%. The grain yield is relatively more affected than the above-ground yield because drought mainly occurs at the end of the growing period when the grains are being filled. With groundwater on level coarse soils the above-ground yields increase to at least 60% and the grain yield to at least 30% of the potential production. Without groundwater, water-limited above-ground yields on medium-fine-textured soils amount to about 70% and grain yields to about 40% of the potential yields. On fine-textured soils these figures are 60% and 30%, respectively, while intermediate yields are achieved on the medium-textured soils. If groundwater is present the water-limited yields are considerably higher. The above-ground yield is for example at least 85% of potential for medium and medium-fine soils. On slopes yields are maximally 10% lower than on level terrain due to runoff.

- The Mediterranean zone.

Due to the drier climate, differences in soil properties result in a more pronounced variation in maize yields than in the temperate zone. Again the lowest yields are reached on the coarse soils. In regions with annual precipitation deficits of less than 400 mm the water-limited yields on deep level coarse soils are about 30% of the potential above-ground yield and 10% of the potential grain yield. On shallow sloping coarse soils these figures are 15% and 4% respectively. In Faro (precipitation deficit 896 mm) the water-limited yields on the most unfavourable soils, the sloping coarse shallow soils, are negligible: less than 5% of the potential above-ground yield and less than 1% of the potential grain yield. The water-limited maize yields on deep level soils with medium to fine textures are considerably higher. The above-ground yields on these soils ranges from about 50 to 60% of potential in the northern part of the Mediterranean zone to 30 to 40% in the zones with the highest precipitation deficit. On medium-fine soils grain yields range from 30% to less than 5% of potential, depending on the precipitation deficit. Yields are further reduced on slopes.
If groundwater is present, yields are always higher. In Napoli the grain yield on a level medium-textured soil increases from 2500 without groundwater influence to 6000 kg dry matter in the presence of groundwater while in Badajoz the grain yield increases from 260 kg to 1130 kg under the influence of groundwater. Groundwater is present in relatively small areas in the Mediterranean zone, and mainly confined to river valleys (Map 6) but, as shown in section 4.2.2, in some agro-climatic zones the majority of the soils evaluated as suitable for the cultivation of cereals, were classified as soils with groundwater influence.

4.3.3 Actual production of maize

-Green maize.

Appendix 21 shows the distribution of the green maize area in the EC as a percentage of the total area per NUTS-1 region. The highest concentrations of green maize are associated with the Netherlands, Belgium, western France, Germany and northern Italy. In these regions, the proportion of green maize within the area of arable land is often higher than 10%. The high proportion of green maize in northwestern Spain is also notable.

The actual green maize yields are given in fresh weight by Eurostat. Actual yields have been converted into dry matter yields using a dry matter content of 27%. Actual regional green maize yields over 13 tonnes dry matter per hectare are realized in regions in Belgium, Germany, France, Spain and Italy (Appendix 12), with a maximum of 17.6 tonnes in Sardegna (Italy). Yields of between 9 and 13 tonnes dry matter occur in all other regions except for Greece, where the green maize yield is only 3.3 tonnes. Simulated potential and water-limited yields have been aggregated to NUTS-1 level and also listed in Appendix 12 for comparison between actual and simulated yields.
The actual production volume of green maize in the EC is 130.9 million tonnes fresh weight, or 35.3 million tonnes dry weight. When multiplying the simulated NUTS-1 yields by the actual green maize areas in these regions, the water-limited production volume amounts to 54.2 million tonnes dry weight and the potential production to 65.8 million tonnes for the whole of the EC. Thus, actual production in the EC is 65% of the water-limited and 54% of the potential production.

Table 7. Actual green maize production of the EC-countries, expressed as a percentage of the calculated potential and water-limited production. Source of actual production: Eurostat (1986, 1987).

	actual production as percentage of:	
	potential	water-limited
Ireland	-	-
United Kingdom	62	69
Denmark	56	70
Netherlands	63	70
Belgium	62	70
Luxembourg	53	64
West Germany	58	62
France	50	62
Portugal	-	-
Spain	31	62
Italy	58	81
Greece	30	17

Table 8. The distribution of green maize production in the EC. Averages over 1982, 1983, 1984 and 1985. Source : Eurostat.

	production volume (% of EC-total)
Ireland	0
United Kingdom	0.4
Denmark	0.5
Netherlands	5.2
Belgium	3.7
Luxembourg	0.2
West Germany	28.3
France	42.5
Portugal	-
Spain	2.4
Italy	16.8
Greece	0.0

Actual production at country level, expressed as a percentage of the potential and water-limited production is given in Table 7. The relative yields in Table 7 are an indication of the management level.
The proportion of actual green maize production in each country in the EC is given in Table 8. At present, France, West Germany and Italy are the main green maize producing countries, together accounting for more than 85% of the total production.

-Grain maize.

Appendix 22 shows the distribution of the grain maize area in the EC as a percentage of the total area per NUTS-1 region. The highest concentrations of grain maize are found in western France, northern Italy, Greece, Portugal and northwestern Spain. In these regions, the proportion of grain maize within the area of arable land is often higher than 10%.
The fresh grain maize yields given by Eurostat have been converted into dry matter yields, using a dry weight content of 86%. Appendix 13 shows that grain maize yields of more than 5.5 tonnes dry matter are achieved in Greece, Spain, northern Italy, northern France, Wallonne (Belgium) and Hessen (Germany), with a maximum of 7.5 tonnes in Greece. In many other regions yields of between 4 and 5.5 tonnes are common. Lower yields are found in southern Italy and the western part of the Iberian peninsula. Yields in Portugal are only 1.6 tonnes. In the Netherlands, Denmark, the United Kingdom and Ireland, climatic conditions are unsuitable for grain maize cultivation.
The total actual production of grain maize within the EC equals 25.3 million tonnes fresh weight or 21.7 million tonnes dry weight. When multiplying the simulated NUTS-1 yields (Appendix 13) by the actual grain maize areas in these regions, water-limited production amounts to 24.4 million tonnes dry weight and potential production to 49.3 tonnes for the whole of the EC. In other words, actual production is 89% of the water-limited and 44% of the potential production. At country level, actual production expressed as a percentage of potential and water-limited production is given in Table 9.

Table 9. Actual grain maize production of the EC-countries, expressed as a percentage of the calculated potential and water-limited production. Source of actual production: Eurostat (1986, 1987).

	actual production as percentage of:	
	potential	water-limited
Ireland	-	-
United Kingdom	-	-
Denmark	-	-
Netherlands	-	-
Belgium	50	73
Luxembourg	-	-
West Germany	55	61
France	42	64
Portugal	12	313
Spain	43	249
Italy	49	94
Greece	71	274

In Portugal, Spain and Greece actual grain maize yields are more than twice the water-limited yields due to irrigation. In these countries, irrigation requirements are probably still not being met, as shown by comparing actual yields with potential yields. In Greece, the relatively high grain maize yields compared with green maize yields are notable. This is probably the result of green maize being used as second crop after the main crop has been harvested.
The proportion of actual grain maize production for each country within the EC is listed in Table 10. At present France, Italy, Spain and Greece are the main grain maize producing countries, together accounting for more than 94% of the total production.

Table 10. The distribution of grain maize production in the EC. Averages over 1982, 1983, 1984 and 1985. Source : Eurostat (1986, 1987).

	production volume (% of EC-total)
Ireland	0
United Kingdom	0
Denmark	0
Netherlands	0
Belgium	0.2
Luxembourg	0
West Germany	4.2
France	43.0
Portugal	1.8
Spain	13.5
Italy	25.8
Greece	11.5

4.4 Oilseed rape

4.4.1 Potential production of oilseed rape

The mean long-term potential seed yields of oilseed rape at LEU-level are shown on Map 13. Per agro-climatic zone, seed yields range from about 2 tonnes dry matter per hectare in Greece to just above 4.5 tonnes in the United Kingdom, Denmark, Ireland and northern Germany (Appendix 7). In a large part of the EC, yields are between 3 and 4 tonnes, and are lower in the most southerly regions and higher in the north.
The potential oilseed rape yields are determined by radiation, temperature and (related to temperature) the length of the growing season (Section 4.1.1). In the crop growth model, the photosynthesis rate of oilseed rape is reduced at high temperatures, leading to yield reductions during hot summers in Mediterranean zones. However, the most important factor causing differences in regional potential yields is the length of the growing season. Oilseed rape is a winter crop. According to crop calendars, in northwestern Europe oilseed rape is sown at the end of the summer, stem extension takes place in early spring, the crop flowers in May and maturity is reached

around the first of August. In southern Europe the growth cycle is shorter: sowing takes place in late autumn and maturity is reached in mid June. For oilseed rape, as for winter wheat, effects concerning the degree of vernalization were not considered in the simulation model. The crop growth model was initiated on the first of January and it was assumed that vernalization requirements were met on this date. The development rate of oilseed rape in the model was not only determined by the temperature sum, as was the case for all other crops, but also by daylength. The critical daylength for development was set at 10 hours and the optimal daylength at 16 hours. Lower potential yields in southern Europe are mainly caused by the shorter growing season. The earliest dates of maturity are calculated for the hot agro-climatic regions in southern Portugal, Spain, Italy and Greece: around the end of May. In central France (Tours, Dijon) maturity is in the model reached at the end of June, in De Bilt during the first half of July and in Denmark and Scotland at the end of July.

When comparing the calculated potential yields of oilseed rape with those of wheat, it is clear that oilseed rape yields are much lower. This is due to several reasons. First of all the composition of the storage organs. The seed of oilseed rape contains about 40% of oil, while wheat grains consist almost completely of carbohydrates and protein. The conversion of assimilates into oil requires much more energy than conversion into proteins or carbohydrates (Penning de Vries *et al.*, 1989). To compensate for this effect, oilseed yields must be multiplied by a factor of 1.6 to make them comparable with wheat yields. However, even then potential wheat yields are still higher, due to the shorter growing season of oilseed rape and a lower harvest index.

4.4.2 Water-limited production of oilseed rape

The mean long-term water-limited seed yields of oilseed rape at LEU-level are shown on Map 14. Seed yields per agro-climatic zone range from about one tonne dry matter per hectare in Mallorca (Spain) and Faro (Portugal) to a maximum of 4.5 tonnes in Nurburg and Freudenstadt (West Germany) (Appendix 7). The water-limited yield in Faro (Portugal) is about 30% of the potential yield, while for example in Freudenstadt (West Germany) the water supply hardly reduces the potential yields at all.

Differences between water-limited and potential yields are caused by the water supply, which is determined by a combination of climate and soil characteristics (Section 4.1.2). Like for wheat, the crop growth model was for oilseed rape applied to all soils that were not excluded for cereal production in the qualitative selection procedure (Section 3.3). The maximum rooting depth of oilseed rape was in the crop growth model set at the same depth as for wheat (125 cm). Furthermore, both crops are winter crops for which simulation started on the first of January. In general, the growing season of oilseed rape is shorter than that of wheat and therefore oilseed rape can sometimes avoid part of the summer drought. However, the relative yield reduction due to drought in different climatic zones and on different soils is comparable for wheat and oilseed rape. The reader is therefore referred to section 4.2.2 for an explanation of yield reductions in the water-limited situation.

4.4.3 Actual production of oilseed rape.

Appendix 23 shows the distribution of the oilseed rape area in the EC as a percentage of the total area per NUTS-1 region. The highest concentrations of oilseed rape are found in Schleswig-Holstein (West Germany), Denmark and East Midlands (United Kingdom) with a share of oilseed rape within the area of arable land of more than 5%. The actual oilseed rape yields are given in fresh seed weight by Eurostat. These yields have been converted into dry matter yields, using a dry matter content of 91%. Appendix 14 shows that the highest oilseed rape yields (about 3 tonnes) are achieved in northern Germany, part of the United Kingdom, and central France. In the context of the present study oilseed rape has been used as indicator crop for all oilseed crops. The most important other oilseed crop is sunflower, which is mainly grown in France and Spain. In France especially, the yields of sunflower are generally lower than those of oilseed rape, probably due to sunflower being a summer crop and oilseed rape a winter one. In the agronomic sense, sunflower is more comparable with grain maize, both being summer crops, than with the winter crop oilseed rape. The oil content of sunflower is slightly higher than that of oilseed rape and the composition of oils in sunflower is more favourable (a higher proportion of linolic acid).

Simulated potential and water-limited yields have been aggregated to NUTS-1 level and are listed in Appendix 14 to allow a comparison between actual and simulated yields to be made.

The total actual production volume of oilseed rape in the EC equals 3.7 million tonnes fresh weight, or 3.4 million tonnes dry weight. When multiplying the simulated NUTS-1 yields by the actual areas in these regions, the water-limited production volume amounts to 4.4 million tonnes dry weight and potential production to 5.2 million tonnes for the whole of the EC. This means that the actual production in the EC is 77% of the water-limited and 65% of the potential production. Actual production at country level, expressed as a percentage of the potential and water-limited production is given in Table 11. The relative yields given in Table 11 are an indication of the management level. High relative yields are achieved in Denmark, the UK, the Netherlands, West Germany and France.

Table 11. Actual oilseed rape production of the EC-countries, expressed as a percentage of the calculated potential and water-limited production. Source of actual production: Eurostat (1986, 1987). (no data available for Portugal and Greece)

	actual production as percentage of:	
	potential	water-limited
Ireland	35	37
United Kingdom	64	74
Denmark	55	84
Netherlands	67	78
Belgium	59	63
Luxembourg	47	56
West Germany	68	76
France	71	77
Portugal	-	-
Spain	37	64
Italy	50	56
Greece	-	-

The proportion of actual oilseed rape production for each country within the EC is listed in Table 12. France, West Germany, the United Kingdom and Denmark are at present the main oilseed rape producing countries, together accounting for more than 98% of the total production.

Table 12. Distribution of oilseed rape production in the EC. Averages over 1982, 1983, 1984 and 1985. Source : Eurostat (1986, 1987).

	production volume (% of EC-total)
Ireland	0.1
United Kingdom	22.7
Denmark	15.8
Netherlands	0.8
Belgium	0.2
Luxembourg	0
West Germany	21.5
France	38.2
Portugal	-
Spain	0.3
Italy	0.3
Greece	-

4.5 Potato

4.5.1 Potential production of potato

The mean long-term potential tuber yields of potato at LEU-level, are shown on Map 15. Average yields per agro-climatic zone range from a minimum of about 10 tonnes dry matter per hectare in Larisa (Greece) to a maximum of about 17 tonnes in Porto (Portugal) (Appendix 8). Over a large area of the EC potential yield amounts to about 15 tonnes dry matter per hectare with little regional variation. At higher elevations (e.g. le Puy, Soria) and in some coastal zones (e.g. Alborg, La Coruna) the yield level may be as high as 16 tonnes dry matter. On the other hand, yields are significantly lower in several Mediterranean zones

Potential potato yields are determined by radiation, temperature, planting date and (related to temperature and planting date) length of the growing season (Section 4.1.1). The potato crop favours mild temperatures. At high temperatures, the crop ages at a higher rate and photosynthesis may be hampered. This occurs during the hot summers in several agro-climatic zones in Greece (e.g. Larisa), the south of Spain (e.g. Cordoba) and eastern Italy (e.g. Foggia). Temperatures may also be too low for optimal growth rates. This results in yields in Scotland being lower in the highlands than at sea level.

The start of the growing season is first of all determined by the planting date. In southern regions the date of planting is mainly determined by the temperature regime and moisture conditions of the soil. The planting date used in the model for these regions was chosen according to crop calendars.

These dates range from the end of February in Greece, southern Italy and the south of the Iberian peninsula, to the beginning of April in the transition zone to the more temperate regions (e.g. Toulouse).

In the humid regions in the northern part of the EC and along the Bay of Biscay, the planting date may be delayed due to excessive wetness of the soil. The planting date is calculated by the model as the first day on which the soil is workable after a certain critical date (Section 4.1.1). Only soils with texture classes coarse, medium and medium-fine were assumed to be suitable for potato growing (Section 2.4). The earliest planting dates can be realized on the coarse-textured soils while the longest delay in planting occurs on the medium-fine-textured soils. On the coarse soils of the humid regions, the earliest average planting dates were calculated for the regions along the Bay of Biscay: after the first week of March. In central France planting starts around the 10th of April while in Belgium, the Netherlands and Germany the planting date is near the 20th of April. In the United-Kingdom and Ireland the calculated planting date on coarse soils is around the 15th of April. On soils with a medium texture, the average planting date for most agro-climatic zones is one to five days later than on the coarse-textured soils. For zones with a very wet start of the season this can amount to more than a week (e.g. Dalwhinnie, Eskdalemuir and La Coruna). On the medium-fine-textured soils an additional delay occurs in almost all zones. This delay amounts to two to ten days. Thus, on these soils the average date of planting may be postponed in some zones until around the first of May (Lerwick, Uccle and Munchen) or even later (Eskdalemuir). The later planting dates on medium-fine soils can lead to a reduction in calculated potential yields of maximally about 4% compared with coarse soils.

For potato the required temperature sum between planting and emergence was set in the model at 170 degree-days, with a base temperature of three degrees centigrade and a maximum germination rate at temperatures of 18 degrees centigrade or higher. The temperatures used are average day temperatures. In the south of the EC the average calculated germination time is about two and a half weeks in zones with the warmest conditions after planting (e.g. Murcia, Faro, Heraklion) and can increase to over four weeks in mountainous zones (e.g. Soria, Potenza, Le Puy). In the humid northern regions, the calculated germination time on coarse soils amounts to three to four weeks. On medium-fine soils germination time is about one to four days shorter than on the coarse soils due to later planting dates and thus higher temperatures during germination.

At high temperatures the crop develops rapidly and will reach its maximum physiological age earlier than at low temperatures.

Emergence date and development rate determine the length of the growing season. For this reason the coastal zones are, in general, relatively favourable. The milder temperatures in these zones result in a longer growing season than further inland. This also applies to mountainous areas in warm regions. The growth duration in Le Puy (at 714 m altitude) is for example 11 days longer than in Lyon (at 201 m altitude). The same effect can be observed when comparing the northern and southern regions. The shortest growing seasons were calculated for the lowlands of Greece and southern Spain, amounting to about 105 days. In these regions this results in harvests at the end of June. In northern Spain, Italy and southern France, the growth duration amounts to about 110 days. Taking into account the dates of emergence, this leads to harvests in the second half of July and the first half of August. Still more northerly, the growing season lasts broadly from 115 to as long as 130 days, harvest dates varying between the end of August in Central France to the beginning of October in northwest Europe. Under very cool or wet conditions at the end of the growing season, like in northern Scotland, the crop may have to be harvested before the end of its life span, at least for the potato variety as defined in the model. In reality, earlier maturing varieties may be used.

4.5.2 Water-limited production of potato

The water-limited yields of potato at LEU-level, are shown on Map 16. Yields per agro-climatic zone range from a minimum of about 2.9 tonnes dry matter per hectare in Faro (Portugal) to a maximum of 15.7 tonnes in Freudenstadt (West Germany) (Appendix 8). The water-limited yield in the agro-climatic zone of Faro is only 19% of the potential yield, while in Freudenstadt and Lerwick the water supply reduces potential yields by less than 5%. In general, the lowest water-limited yields occur on the Iberian Peninsula, in Italy, Greece and the Mediterranean coast of France.

Differences between water-limited and potential yields are caused by the water supply, which is determined by the combination of climate and soil characteristics (Section 4.1.2). Compared with wheat the simulation of potato production has some specific features. Tuber growth starts sooner after emergence than is the case with grain filling in wheat. For this reason yield formation of potatoes extends over a longer period than the yield formation of cereals. The crop growth model was for potato applied to all soils that were not excluded for root crops production in the qualitative selection procedure (Section 3.4). For potato, the maximum rooting depth of the crop was set at 50 cm. This shallow potential rooting depth ensures that variations in soil depth deeper than 50 cm have no influence on the soil water reserves available to the potato crop. In the qualitative selection procedure, more soils were excluded for root crops than for cereals (Chapter 3). These were the soils with a fine texture, with a gravelly phase or with a concretionary phase. For this reason, simulation results for potato are available for a smaller variety of soils than for wheat.

- The temperate zone.

The highest reductions in potential yields are calculated for the least favourable soils: coarse-textured soils without groundwater influence. Some of these coarse soils (podzols, arenosols and regosols) allow a rooting depth of only 40 cm. In regions with a precipitation deficit of less than 100 mm the reduction of the potential yield on shallow coarse soils can amount to more than 30% on level terrain and to about 40% on sloping terrain. With groundwater influence, reductions on shallow level coarse soils are only about 15%, and decrease to 10% if root growth is not hampered. In these humid regions, only minor yield reductions occur on the more favourable, easily rootable medium to medium-fine-textured soils with groundwater influence. Without the influence of groundwater, yields on these soils are comparable with those on coarse soils where groundwater is present.

In regions with precipitation deficits of up to 300 mm, the water-limited potato production on shallow coarse soils without groundwater on sloping terrain is only 30% of the potential production. This applies to central France, Pisa (Italy) and La Coruna (Spain). With groundwater on level terrain the yields on coarse soils increase to about half the potential production. Again, on medium to medium-fine-textured soils, performances are better. Without groundwater and a rootable depth of at least 50 cm, water-limited yields on these soils amount to about 60% of the potential yields. This percentage can be as high as 80%, if groundwater is present. On slopes, these water-limited yields are about

10% lower than on level terrain due to runoff.

- The Mediterranean zone.

Due to the drier climates, differences in soil properties result in a more pronounced variation in potato yields than in the temperate zone. Again, the lowest yields are reached on coarse soils. In regions with annual precipitation deficits of less than 400 mm, the water-limited yield on level coarse soils is only about 30% of the potential yield and can decrease to around 25% on slopes. In Faro (precipitation deficit 896 mm) water-limited yields on the most unfavourable soils, the sloping coarse shallow soils, are less than 1 tonne, which is only 6% of the potential yield. The water-limited potato yields on level, easily rootable soils with medium to medium-fine textures are considerably higher. These range from about 50% of potential to 35%, depending on the precipitation deficit. Yields are further reduced on slopes.
If groundwater is present, yields are always higher. This applies only to relatively small areas in the Mediterranean zone (Map 6). However, in some zones only a small fraction of the soils was considered suitable for potato growing but of these soils a relatively high percentage may have groundwater influence.

4.5.3 Actual production of potato

Appendix 24 shows the distribution of potato area in the EC as a percentage of the total area per NUTS-1 region. The highest concentrations of potato are associated with northeast England, the Netherlands, Vlaams Gewest in Belgium, Nord-Pas-de-Calais in France, parts of Germany, the western part of the Iberian Peninsula and around Napoli in Italy. In most regions, the proportion of potatoes in the area of arable land is less than 5%. In the Netherlands, however, the potato area amounts to about 20% of the arable area and in the NUTS-1 region Noord-Nederland as much as 32%. Noroeste in Spain, where potatoes make up almost 20% of the arable area, is also notable.
The actual potato yields are given in fresh weight by Eurostat. Actual yields are the average yields of early as well as other potatoes. These yields were converted into dry matter yields using a dry matter content of 22%. Appendix 15 shows that the highest potato yields are found in the northwestern part of the EC. Here, potato yields of between 7 and 8.5 tonnes dry matter per hectare are common. In Ireland yields are only about 5 tonnes, while yields of almost 10 tonnes (about 45 tonnes fresh weight) are reached in the southern part of the Netherlands. Further south in the EC, yields are considerably lower. In southern Germany and northern Italy yields are about 6 tonnes, while in southern France, central Spain and Greece they vary between 4 and 5 tonnes. Low yields are reached in central and southern Italy (2.5 to 4 tonnes) and, according to statistics, can decrease to 2 tonnes in Portugal. The simulated potential and water-limited yields have been aggregated to NUTS-1 level and are also listed in Appendix 15 to allow a comparison between actual and simulated yields.
The actual production volume of potato in the EC is 40.1 million tonnes fresh weight, or 8.8 million tonnes dry weight. When multiplying the simulated NUTS-1 yields by the actual potato areas in these regions, the water-limited production volume amounts to 15.0 million tonnes dry weight and the

potential production to 23.5 million tonnes for the whole of the EC. This means that the actual production in the EC is 59% of the water-limited and 37% of the potential production. The actual production at country level, expressed as a percentage of the potential and water-limited production is given in Table 13. The figures in Table 13 are an indication of the management level. In general, the northern member states have the highest relative actual yields. Of these countries, Ireland and Germany seem to do less well. In the southern countries the relative actual yield is especially low when compared with the potential yields, indicating high irrigation requirements.
The proportion of potato production for each country within the EC is listed in Table 14. The United Kingdom, the Netherlands, West Germany, France and Spain are at present the main potato-producing countries, together accounting for more than 80% of the total production.

Table 13. Actual potato production of the EC-countries, expressed as a percentage of the calculated potential and water-limited production. Source of actual production: Eurostat (1986, 1987).

	actual production as percentage of:	
	potential	water-limited
Ireland	32	41
United Kingdom	51	71
Denmark	46	77
Netherlands	55	63
Belgium	50	63
Luxembourg	42	68
West Germany	44	56
France	43	67
Portugal	12	42
Spain	26	46
Italy	26	57
Greece	33	57

Table 14. The distribution of potato production in the EC . Averages over 1982, 1983, 1984 and 1985. Source : Eurostat (1986, 1987).

	production volume (% of EC-total)
Ireland	1.9
United Kingdom	17.4
Denmark	2.7
Netherlands	15.8
Belgium	3.2
Luxembourg	0
West Germany	17.3
France	15.6
Portugal	2.6
Spain	14.7
Italy	6.2
Greece	2.5

4.6 Sugar beet

The physical land evaluation procedure has several similarities for potato and sugar beet. For both root crops, the same soils were excluded in the qualitative selection procedure (Section 3.4). Furthermore, simulating the growth of these crops has some specific characteristics. Grain-filling of cereals starts after flowering and ends when the crop reaches maturity. For root crops, filling of the storage organs starts at a much earlier stage of development. Furthermore, maturity is not clearly defined for root crops.
When sugar beet yields are discussed in this chapter, it is with regard to the weight of the main root in which the sugar is stored.

4.6.1 Potential production of sugar beet

The mean long-term potential sugar beet yields at LEU-level, are shown on Map 17. Yields per agro-climatic zone range from a minimum of about 6 tonnes dry matter per hectare in Lerwick (Scotland) to a maximum of almost 27 tonnes in Porto (Portugal) (Appendix 9). There is obviously a wider range in sugar beet yields than in potato yields. Potential yields of 20 tonnes or more can mainly be reached in agro-climatic zones in France, the northwest of the Iberian peninsula and western Italy. In the north of the EC, the yield potential is lower. In the Netherlands, northern Germany and eastern England, potential yields are about 17 tonnes, while further north in England and in Ireland yields of about 15 tonnes can be reached. Yields decrease to less than 10 tonnes in some parts of Scotland. In a number of Mediterranean zones, potential sugar beet yields are also under 20 tonnes, the lowest occurring in Greece.
Potential sugar beet yields are determined by radiation, temperature, sowing date and (related to temperature and sowing date) the length of the growing season (Section 4.1.1).
In the crop growth model, the photosynthesis rate of sugar beets is less affected by high temperatures than that of potatoes. During very hot summers in Mediterranean zones only minor reductions in growth rate occur. However, temperatures can be too low for optimal growth rates. This results in yields in Scotland being lower in the highlands than at sea level.
The start of the growing season is first of all determined by the sowing date. In southern regions the date of sowing is mainly determined by the temperature regime and moisture conditions of the soil. The sowing dates used in the model for these regions were chosen according to crop calendars. Broadly, sugar beets are sown about two weeks before the planting of potatoes. Sowing dates range from the second week of February in Greece, southern Italy and the south of the Iberian peninsula, to mid-March in the transition zone to the more temperate regions (e.g. Toulouse).
In the humid regions in the northern part of the EC and along the Bay of Biscay, the sowing date may be delayed due to excessive wetness of the soil. The sowing date is calculated by the model as the first day on which the soil is workable after a certain critical date (Section 4.1.1). Only soils with texture classes coarse, medium and medium-fine were assumed to be suitable for sugar beet growing (Section 3.4). The earliest sowing dates can be realized on the coarse-textured soils while the longest delay in sowing occurs on the medium-fine-textured soils. On the coarse soils of the

humid regions, the earliest average sowing dates were calculated for the regions along the Bay of Biscay: around the 20th of February. In central France sowing starts at the end of March, while in Belgium, the Netherlands, Germany, the United-Kingdom and Ireland the calculated sowing date on coarse soils is in the first week of April. On soils with a medium texture, the average sowing date for most agro-climatic zones is one to three days later than on the coarse-textured soils. On the medium-fine-textured soils an additional delay of up to three days was calculated for most zones. Delays of about a week occur in the wet regions along the Bay of Biscay, in Freudenstadt, Brest and Eskdalemuir. Thus, on these soils the average date of sowing may be postponed until mid-April in some zones. The calculated delays in the sowing of sugar beets are less than those for potatoes. This is due to the higher soil tillage requirements for potato planting. The later sowing dates of sugar beets on medium-fine soils compared with coarse soils can lead to a reduction in calculated potential yield of maximally about 4%.

For sugar beets the required temperature sum between sowing and emergence was set in the model at 90 degree-days, with a base temperature of three degrees centigrade and a maximum germination rate at temperatures of 20 degrees centigrade or higher. The temperatures used are average day temperatures. Under the same conditions this results in a faster germination of sugar beets than of potatoes. In the south of the EC, the average calculated germination time is about 10 days in zones with the warmest conditions after sowing (e.g. Murcia, Faro, Heraklion) and about two weeks in many other zones. This can increase to more than three weeks in mountainous zones (e.g. Soria, Potenza, Le Puy). In the humid zones, the calculated germination time on coarse soils amounts to two weeks along the Bay of Biscay and some zones in central France and increases to about three weeks in most other zones. On medium-fine soils the germination time is generally one or two days shorter than on the coarse soils due to later sowing dates and thus higher temperatures during germination.

At high temperatures the crop develops rapidly and will reach its maximum physiological age earlier than at low temperatures.

Emergence date and development rate determine the length of the growing season. In the model, the sugar beet crop has the ability to maintain green leaves for a longer time than the potato crop. In other words, sugar beets have a longer growing season. The shortest growing seasons were calculated for the lowlands of Greece, southern Spain and Portugal, amounting to about 160 days. In these regions this results in harvests during August. In northern Spain, Italy and southern France, the growth duration varies widely from 175 to 210 days. Taking into account the dates of emergence, this leads to harvests in September and October. In the model, the last day on which the crop can be harvested was set at the first day of November. In most of the northern regions this date determines the end of the growing season. In these regions this results in a growing season of 190 to 200 days.

4.6.2 Water-limited production of sugar beet

The mean long-term water-limited yields of sugar beet at LEU-level are shown on Map 18. The yields per agro-climatic zone range from a minimum of about 3.6 tonnes dry matter per hectare in the agro-climatic zone of Beja (Portugal) to a maximum of 19.8 tonnes in Santander (Spain)

(Appendix 9). The water-limited yield in the agro-climatic zone of Beja is only 17% of the potential yield, while in Freudenstadt, Nurburg and Lerwick the water supply hardly reduces the potential yields at all. Large areas with water-limited yields lower than 8 tonnes occur on the Iberian Peninsula, in Italy, Greece and a small Mediterranean strip of France. Further north the water-limited yields approach to the potential yields more closely.
Differences between water-limited and potential yields are caused by the water supply, which is determined by the combination of climate and soil characteristics (Section 4.1.2).
Like for potato, the crop growth model was for sugar beet applied to all soils that were not excluded for root crop production in the qualitative selection procedure (Section 3.4). However, in the simulation model, the maximum rooting depth of the crop was set at 50 cm for potatoes and 80 cm for sugar beets. This means that for sugar beet, potential root growth is hampered in a greater proportion of the suitable soils. First of all these are the podzols, arenosols, regosols, rankers and rendzinas (rooting depth 40 cm). Planosols have a rooting depth of 60 cm. Furthermore, some soils with groundwater influence limit the root growth of sugar beets. These are the gleyic soils (with the exception of cambisols) and fluvisols, which have a rooting depth of only 60 cm if their texture is coarse.

- The temperate zone.

The highest reductions in potential yields are calculated by the model for the least favourable soils: coarse-textured soils without groundwater influence. Some of these coarse soils (podzols, arenosols and regosols) allow a rooting depth of only 40 cm. In regions with a precipitation deficit of less than 100 mm (Map 5) the calculated reduction of the potential yield on 40 cm deep coarse soils can amount to 25 to 30% on level terrain and up to about 35% on sloping terrain. On these soils yield reductions of sugar beets are lower than those of potatoes, indicating that sugar beets are less sensitive to drought because of their more elaborate rooting system. With groundwater influence, reductions on 40 cm deep level coarse soils are only about 15% and decrease to 10% if the rooting depth is 60 cm. In these humid regions, yield reductions on the 120 cm deep medium and medium-fine-textured soils without groundwater influence are less than 10%. If groundwater is present, yields only slightly increase on these soils and may be even lower due to oxygen deficiency. On slopes, yields can be reduced by an additional 3%.
In regions with precipitation deficits of up to 300 mm, the water-limited production on shallow (40 cm) coarse soils without groundwater on sloping terrain is only 20% of the potential production. This applies to central France, Pisa (Italy) and La Coruna (Spain). With groundwater on level terrain the yields on coarse soils increase to about 40% of potential production. Again, performances are better on deep medium to medium-fine-textured soils. Without groundwater, water-limited yields on these soils amount to about 55% of the potential yields. This percentage can be as high as 85%, if groundwater is present. On slopes, water-limited yields are about 10% lower than on level terrain due to runoff.

- The Mediterranean zone.

Due to the drier climates, differences in soil properties result in a more pronounced variation in sugar beet yields than in the temperate zone. Again, the lowest yields are reached on coarse soils. In regions with annual precipitation deficits of less than 400 mm, the water-limited yield on level coarse soils is about 20% of the potential yield and decreases further on slopes. In Faro (precipitation deficit 896 mm) water-limited yields on the most unfavourable soils, the sloping coarse shallow soils, are negligible: less than 5% of the potential yield. The water-limited sugar beet yields on deep level soils with medium to medium-fine textures are considerably higher. These range from about 45% of potential to 35%, depending on the precipitation deficit. Yields are further reduced on slopes.

If groundwater is present, yields are always higher. This applies only to relatively small areas in the Mediterranean region (Map 6) but in some zones, where only a small fraction of the soil surface was considered suitable for sugar beet growing a relatively large proportion of the suitable area may consist of soils with groundwater influence (Section 4.5.2).

4.6.3 Actual production of sugar beet

Appendix 25 shows the distribution of sugar beet area in the EC as a percentage of the total area per NUTS-1 region. The highest concentrations of sugar beet are associated with north-east England, Denmark, the Netherlands, Belgium, northern France, north and east Germany and Emilia-Romagna in Italy. In most regions, the proportion of sugar beets within the area of arable land is less than 5%. Regions with a proportion higher than 10% are Nord-Pas-de-Calais in France, Emilia-Romagna in Italy, all regions of the Netherlands and Belgium and East Anglia in England.

The actual sugar beet yields are given in fresh weight by Eurostat. To be able to compare them directly with the simulated yields, actual yields have been converted into dry matter yields, using a dry matter content of 20%. The highest actual sugar beet yields are found in the Netherlands, Belgium, France, southern Germany and Greece (Appendix 16). Here, sugar beet yields of between 10 and 12.5 tonnes dry matter per hectare are common. Yields of between 6 and 8 tonnes dry matter occur widely in Spain, southern and central Italy and southwestern England with the lowest yield (about 4 tonnes) occurring in Campania, Italy. The simulated potential and water-limited yields have been aggregated to NUTS-1 level and are also listed in Appendix 16 to allow a comparison between actual and simulated yields.

The actual production volume of sugar beet in the EC is 94.3 million tonnes fresh weight, or 18.9 million tonnes dry weight. When multiplying the simulated NUTS-1 yields by the actual sugar beet areas in these regions, the water-limited production volume amounts to 25.4 million tonnes dry weight and the potential production to 36.4 million tonnes for the whole of the EC. This means that the actual production in the EC is 74% of the water-limited and 52% of the potential production. The actual production at country level, expressed as a percentage of the potential and water-limited production is given in Table 15. These figures are an indication of the management level. In Portugal, Spain and Greece the actual yields are higher than the water-limited yields due to irrigation. In these countries the irrigation requirements are probably still not being met or growth limiting factors other than water still play an important role, as shown by comparing the actual yields with the potential yields.

The proportion of sugar beet production for each country within the EC is listed in Table 16. France, West Germany, the United Kingdom and Italy are at present the main sugar beet producing countries, together accounting for more than 70% of the total production.

Table 15. Actual sugar beet production of the EC-countries, expressed as a percentage of the calculated potential and water-limited production. Source of actual production: Eurostat (1986, 1987).

	actual production as percentage of:	
	potential	water-limited
Ireland	59	65
United Kingdom	52	66
Denmark	54	73
Netherlands	64	74
Belgium	56	70
Luxembourg	-	-
West Germany	52	61
France	56	77
Portugal	32	166
Spain	37	116
Italy	43	83
Greece	78	151

Table 16. The distribution of sugar beet production in the EC. Averages over 1982, 1983, 1984 and 1985. Source : Eurostat (1986, 1987).

	production volume (% of EC-total)
Ireland	1.7
United Kingdom	9.1
Denmark	3.5
Netherlands	7.4
Belgium	6.4
Luxembourg	-
West Germany	20.4
France	30.9
Portugal	0.1
Spain	2.4
Italy	10.8
Greece	2.4

4.7 Grass

The simulation results only apply to intensive mechanized grassland farming. This type of farming requires suitability of the soil for operations such as ploughing, fertilizer spreading and mowing. Furthermore, only a high-yielding variety (perennial Ryegrass) under a regular mowing regime was considered.

4.7.1 Potential production of grass

The mean long-term potential grass yields at LEU-level are shown on Map 19. The yields range from a minimum of about 13 tonnes dry matter per hectare in the agro-climatic zone of Dalwhinnie (Scotland) to a maximum of about 28 tonnes in Faro (southern Portugal) (Appendix 10). Broadly, yields increase when going from north to south. This increase proceeds more rapidly along the coast than inland.
Potential grass yields are determined by radiation, temperature and (related to these factors) the length of the growing season (Section 4.1.1). Because it was assumed that the grass sward remains vegetative all year due to frequent cuttings, phenological development plays no role. There are, however, minimum temperature requirements for grass growth. For this reason production usually stops during the winter. In general, coastal zones are relatively more favourable. The mild temperatures in these regions result in a relatively long growing season. The grass growth model defines grass growth as starting after a temperature sum of 300 degree days, accumulated since the first of January. For the agro-climatic zones with the mildest winters (Malaga, Faro, Messina, Hiraklion) this criterion is met before the end of January. In mountainous areas on the other hand, the growing season for grass is generally shorter due to low temperatures in winter and therefore, especially in northern Europe, yields at high elevations are lower than at sea level (e.g. Dalwhinnie, Clerveaux, Freudenstadt, Hof, Penhas Douradas). In Hof, for example, grass growth does not start before May.
If day temperatures become too high they hamper photosynthesis. This occurs during the hot summers of a number of agro-climatic zones located in Greece and in the south of Spain (e.g. Cordoba) and Italy (e.g. Foggia). In warm regions, mountainous areas may benefit from the more moderate temperatures in summer, but this effect does generally not outweigh the shortening of the growing season, e.g. in Penhas Douradas (Portugal), L'Aquilla (Italy) and the central plateau of Spain.

4.7.2 Water-limited production of grass

The mean long-term water-limited yields of grass at LEU-level, are shown on Map 20. The yields per agro-climatic zone range from a minimum of about 5.9 tonnes dry matter per hectare in Valladolid (Spain) to a maximum of 22.5 tonnes in Biaritz (France) (Appendix 10). The water-limited yield in Faro (Portugal) is only a quarter of the potential yield, while in the north of Scotland water supply hardly reduces potential yields at all. In general the lowest water-limited yields occur in Spain, Italy, Greece and a small Mediterranean strip of France.
Differences between water-limited and potential yields are caused by the water supply, which is determined by the combination of climate and soil characteristics (Section 4.1.2). Compared with wheat (Section 4.2) the simulation of grass production has some specific features. The final yield of grass is the result of additional harvests during the growing season. For this reason yield formation of grass extends over a much longer period than the yield formation of cereals. In the grass growth model the maximum rooting depth of the crop was set at 30 cm. This potential rooting depth is only

limited in lithosols, but these were excluded beforehand (Section 3.2). The depth of all suitable soils therefore allows optimal grass rooting, and variations in depth of these soils have no influence on the soil water reserves available to the grass crop. For deeper rooting crops, such as wheat (125 cm) the range in soil depths below 30 cm has a considerable influence on the available soil moisture reserve. During the qualitative evaluation procedure, less soils were excluded for grass than for cereals. As well as soils suitable for cereal cultivation, soils with poor or temporary poor drainage (gleysols and stagnogleyic soils) were categorized as being suitable for grass cultivation. For this reason, simulation results for grass are available for a wider variety of soils. Furthermore, the fraction of runoff on slopes of 8 to15% was maximally 0.15 for grass and 0.25 for cereals.

- The temperate zone.

The highest reductions of the potential yields are calculated by the model for the soils with the lowest water supplying capacity: coarse-textured soils without groundwater influence. In regions with a precipitation deficit of less than 100 mm, the reductions on these soils can amount to more than 20% (on level terrain). With groundwater influence, reductions due to drought on coarse soils are only about 10%. On undulating terrain, yields are lower due to runoff. In these humid regions, drought on the more favourable medium to medium-fine-textured soils with groundwater influence, causes only minor yield reductions. Without the influence of groundwater, reductions on these soils are comparable with the reductions on coarse soils where groundwater is present. On soils with a fine texture, intermediate yields are reached, due to their water-supplying capacity. On these soils oxygen deficiency may hamper growth in wet years.
In regions with precipitation deficits of up to 300 mm, grass production on coarse soils without groundwater is only about half of the potential production. This occurs in central France, Pisa (Italy) and La Coruna (Spain). Again, performances are better on medium to medium-fine-textured soils. Without groundwater, water-limited yields amount to about 65% of the potential yields. This percentage can be as high as 90% if groundwater is present. On slopes of 8 to 15%, water-limited yields are about 10% lower than on level terrain.

- The Mediterranean zone.

Due to the drier climates, differences in soil properties result in a more pronounced variation of grass yields than in the temperate zone. Again the lowest yields are reached on coarse soils. In Napoli, where the annual precipitation deficit is 363 mm, the calculated water-limited yield on level coarse soils is 62% less than the potential yield. In Faro (precipitation deficit 896 mm) this is 82%. Additionally, the water-limited yield in Faro is 10% lower on a coarse soil on a slope with a steepness of 8 to 15%, than on a level coarse soil. The water-limited grass yields on level soils with medium to medium-fine textures, range from 60% of potential to less than 40%, depending on the precipitation deficit. Yields are further reduced on slopes. On fine-textured soils grass production is at least 90% of the production on medium to medium-fine-textured soils.
If groundwater is present, yields are always higher. This applies only to relatively small areas in the Mediterranean region (Map 6) but in some zones, where only a small fraction of the soil surface was considered suitable for grass cultivation a relatively large proportion of the suitable area may consist of soils with groundwater influence. This is illustrated by the agro-climatic zone of Tricala in Greece,

where one third of the suitable area has groundwater influence.

4.7.3 Actual production of grass

For the NUTS-1 regions, grass yields are not given by Eurostat. For these regions only the area of permanent grassland is published (Eurostat, 1987). Appendix 18 indicates that Ireland and several regions in the United Kingdom have a high proportion of grassland in their agricultural area. Countries with a relatively small fraction of grassland are Denmark, Portugal and Spain. The grassland areas also include extensive grassland farming, such as the moorlands of northwestern Europe, Alpine grazing land and the Mediterranean rangelands (e.g. the maquis or garrigues in France or the macchia in Italy).

In the agricultural yearbook (Eurostat, 1988) some national production figures are listed for temporary and permanent grassland. These figures are incomplete for Greece, Ireland, Luxembourg, the Netherlands, Portugal and the United Kingdom. Some of the production figures are estimates. Furthermore, it is not clearly specified to which type of product the figures apply (hay, freshly cut grass, freshly grazed grass, silage grass). An inventory of grassland productivity in the EC has been made by Lee (1984). However, in this publication only point data are given, many of them being measured at experimental sites. These figures cannot be transformed in a straightforward way to the average farm production of grass. It can therefore be concluded that no reliable data on grass production are available.

Theoretically, it is possible to estimate grass production on a certain area of grass from the numbers of livestock that feed on the grass and their food requirements. Eurostat publications (1987, 1988) give the number of these animals. Figures on food requirements are also available. To be able to estimate grass consumption by animals however, one should know the amount of food in the ration other than grass, the structure of the grass (hay, fresh grass, silage grass), and the quality of the grass (especially energy and protein contents). This information was not available for the EC-countries. The approach was therefore considered to be inappropriate.

Cooper (1970) reviewed a number of experiments done throughout the world, in which dry matter yields of established swards grown without limitations of water or soil nutrients were measured. The mowing system of the experimental swards in western Europe involved five to eight harvests at four to five week intervals during the growing season. The yield of perennial Ryegrass amounted to more than 25 tonnes dry matter per hectare in Aberystwyth (Wales) and to about 20 tonnes per hectare in Cambridge (UK) and the Netherlands. A lower potential of 17 tonnes per hectare was recorded for Hurley (south England). In subtropical climates in the United States and in Australia, yields of up to 30 tonnes per hectare were measured, but these concerned other grass species. Of course, experimental results only apply to a specific site and to the weather conditions of the year in which the measurements were taken. The results of the simulations are an average of (in most cases) 26 years. This makes a direct comparison difficult, but the calculated potential yields seem to correspond with measured yields.

Water-limited yields are even more difficult to verify with experiments, especially for the whole of the EC. Again specific conditions of the experimental site, such as physical soil properties and weather are often not known. A complicating factor when it comes to grass, is the variety of species and management practices. The calculated water-limited yields only apply to mowing. If the grass is grazed, extra losses will be introduced. These have been estimated by Lantinga (1985) to amount to 15 to 20% of the production.

Assumptions made in the crop growth model to calculate grass production, justify some prudence when comparing the simulation results with the actual situation. The model results only apply to intensive mechanized grassland farming. Large areas of extensively managed grassland occur in the EC. These extensively managed grasslands are mainly located in the less favourable areas. Depending on the specific conditions of each of these more or less extensive cultivation systems, specific models will need to be developed to calculate grass yields. Otherwise, alternative methods will have to be used, for example estimating yields using experimental results under well-described conditions.

5 DISCUSSION

This report discusses the results of a mixed qualitative/quantitative physical land evaluation procedure for a number of arable crops and grass within the European Communities. An agro-ecological characterization of the EC has been given by means of a quantitative estimation of the potential and water-limited crop yields as a function of soil and climate conditions. For this purpose a crop growth simulation model was applied in combination with a GIS.
In the crop growth simulation model, physiological crop parameters were used which mainly apply to the growth of crops under conditions that prevail throughout northwestern Europe. In order to adapt the crop growth simulations to local conditions within the whole of the EC, region-specific information was gathered on crop calendars. For example, dates of planting, emergence, flowering, maturity and harvesting of the crops. These data were used for the right initiation time of the calculations and to estimate the development rates of the crops. For maize, two varieties were defined, mainly differing in their rate of development. For all other crops only one standard variety was considered, and for this variety potential and water-limited yields were calculated for all land evaluation units within the EC. In reality, many different varieties are grown within the EC. These varieties have specific properties and may be better adapted to local conditions. Furthermore, for crops such as potato, early as well as late varieties exist which can have different yield potentials. However, defining more varieties requires a considerable amount of additional information from detailed experiments. In many cases this information does not exist, or is difficult to obtain. It was therefore decided not to specify more varieties, assuming that the standard variety still gives a good indication of the average production potential in a region. This restriction should however be kept in mind when comparing the results with detailed local situations.
In this study, crop simulation for the winter crops wheat and oilseed rape was initiated on the first of January for all regions. For grass, the beginning of growth was estimated by a critical temperature sum after the first of January. For the other crops a sowing date was chosen according to local crop calendars. For humid regions the model calculated a delay in sowing under conditions of excessive wetness. For Mediterranean zones a fixed sowing date was chosen. However, in these southern zones, sowing dates can vary considerably, especially when irrigation is applied. In Italy, for example, sugar beets are sown in autumn as well as in spring. Furthermore, some crops are sown as a second crop, for example fodder maize after wheat. In this study only one planting date was considered, namely the date in spring when crops would be sown in the absence of irrigation.
The water-limited yields take no account of the negative effects of moist conditions for harvesting of the crops. Especially in the most humid zones the number of available machinery workdays may limit the choice of crops more than the biological constraints, and may require cultivation of varieties with a short growth duration. Also, the quality of the harvested products was not assessed. Quality aspects are, for example, the moisture content of grains, the feeding value of green maize, the oil content of oilseed, the sugar content of sugar beets or the size distribution of potatoes.
Simulations were carried out for weather records of 26 years (when available). As an indication of regional yield potentials, only average yields were used, though in individual years much lower or higher yields may occur. The agro-climatic map consisted of 109 zones, each zone characterized by one weather station. This is still rather broad for the whole of the EC, where a large variation in weather types exists. However, the zones were based on an agro-climatic atlas for cereal growing

and were therefore expected to represent a climatological unity concerning agricultural crop production. Some of the selected weather stations are located near coasts or at airports, sites that are not fully representative of agricultural fields. When performing this study no digitized altitude maps were available, which prevented a more detailed estimation of the effects of altitude on crop production.

The digitized soil map of the EC proved to be a useful basis for land evaluation. However, the amount of soil data for the soil associations on the map is still rather limited. For each soil association, only information on the dominant soil is given. The dominant soils cover only about 60% of the soil area. More information on associated soils is therefore needed. Input data for the soil water balance of the crop growth model were derived from basic information of topsoils, such as texture, slope and soil name (Reinds *et al.*, 1992; Reinds and Van Lanen, 1992). This derivation is accompanied by many uncertainties. It would be useful if more specific soil data, such as rooting depth of the soil, subsoil texture, groundwater depth and water retention data were available for the soil map.

In addition, the scale of the map plays an important role, for example in the qualitative selection of soils suitable for crop production. According to the soil map, a mapping unit can be characterized as unsuitable for mechanized cereal cultivation due to steep slopes, but part of the mapping unit may consist of land that has no sleep slopes at all. Suitable areas may therefore occur within the area that was judged unsuitable. The opposite situation, that unsuitable areas are included in suitable map units, may also occur. The degree to which the occurrence of deviating soils is obscured, depends on map scale and cartographic detail. On the 1:1 million scale soil map of the EC the cartographic detail varies between countries. When looking at the soil map it can be seen, for example, that in West Germany the mapping units are on average smaller than in Greece.

From the qualitative selection of soils suitable for mechanized crop cultivation, it was estimated that 48% of the total EC-area can be used for grass cultivation, 44% for rotations with only cereals and oilcrops and 28% for rotations including root crops. The area for root crop rotations falls within that for cereals and oilcrops, and the area for cereals and oilcrops falls within that for grass. A relatively high percentage of unsuitable land occurs in Mediterranean regions. The actual figures indicate that 56% of the total EC-area is agricultural land (including land under permanent crops), 30% of the total area is arable land and 21% of the total area is grassland. The estimated and actual land use figures cannot be directly compared because no accurate land use map of Europe is currently available, making it impossible to verify whether the areas classified as suitable correspond with the actual land use. Furthermore, either grass, arable crops or fruit trees may be grown on land suitable for all these crops, while potential agricultural land can also be used for non-agricultural purposes. In addition, the qualitative selection was not used to assess climatic constraints on crop production. The qualitative selection was only meant to *a priori* exclude soils where mechanized crop cultivation is impossible due to soil characteristics that prohibit accessibility or workability (slope, drainage) or minimum crop establishment (rooting depth, salinity). For soils classified as suitable, the combined effects of soil and climate characteristics on crop production were determined by simulating potential and water-limited yields with the crop growth simulation model. Based on the simulated water-limited yield figures one can distinguish between good soils and poor soils in terms of sufficiency of moisture availability within a certain agro-climatic zone. There has been no post-simulation operation to exclude soils with very low water-limited yields.

The assumption that coarse-textured soils have a low water-holding capacity is not universally valid.

Humus-rich and fine sandy soils may retain as much water as medium-textured soils. This means that the calculated water-limited yield potential on course-textured soils may give a too pessimistic impression. However, the simulated yield figures for coarse-textured soils are not used independently but are combined with those of other texture classes in the regional aggregation procedure. The fact that the widespread occurrence of coarse-textured soils has a depressing effect on the average regional water-limited yield potential still remains a plausible result of the regional assessment.

Comparison between simulated and actual yields indicates that the yield gap in many cases is still high. For wheat for example, the average actual yields within the EC are 60% of the calculated water-limited yields and 45% of the potential yields. For this assessment of relative actual yields, the average simulated yields were used of all land classified as suitable in the qualitative selection procedure. This is not necessarily land with the same average conditions as the land where the actual production takes place. If actual production is close to the water-limited production in regions with a favourable natural moisture regime, then constraints due to pests, diseases, nutrient supply and sub-optimal farming practices are probably small. In drier regions, the factor irrigation should also be taken into account because this can substantially increase the actual yields. Implications of the yield gap for land use in the EC have been extensively covered by Van Lanen *et al.* (1992b) and WRR (1992).

Potential and water-limited yields can only be achieved under optimal management conditions with regard to weed, pest and disease control, soil tillage, timing etc. In southern European countries especially, water requirements may be too high to reach potential yields (De Koning *et al.*, 1992; WRR, 1992). Low relative actual yields may be due to physical factors which are difficult to manage and which have not been taken into account in the simulation model, for example, the inaccessibility of land due to severe wetness.

The reliability of the estimated regional crop production potential can still be improved, especially when more basic data on soils, weather and crops become available. However, the results have proved to be coherent and give good insight into the agricultural potential offered by the physical conditions prevailing within Europe. Furthermore, in a follow-up study the results of the physical land evaluation proved to be useful in assessing inputs (irrigation water, labour, nutrients, pesticides, machines) needed to obtain the calculated potential and water-limited yields in various crop rotations (De Koning et al., 1992). Finally, the main purpose was to implement all the results in the GOAL-model of the WRR. This implementation was successfully completed and has resulted in valuable instruments for the support of agricultural policy making (WRR, 1992).

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Appendix 1 LIST OF WORKING DOCUMENTS OF PROJECT 'PRODUCTION POTENTIAL OF RURAL AREAS WITHIN THE EUROPEAN COMMUNITIES'

1. Crop production potential of rural areas within the European Communities. I: GIS and datamodel.
   J.D. Bulens and A.K. Bregt. 74 pp.

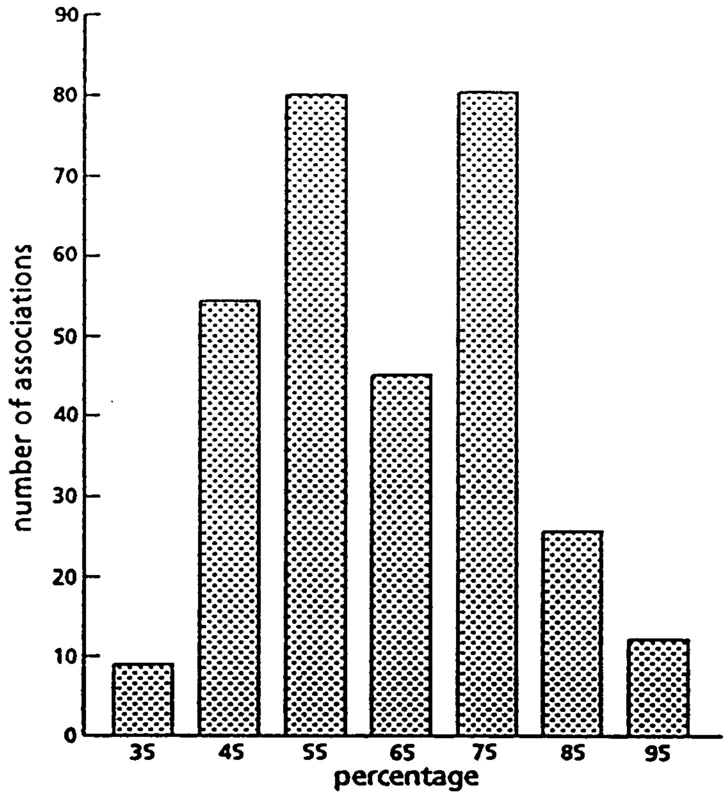
2. Crop production potential of rural areas within the European Communities. II: A physical land evaluation procedure for annual crops and grass.
   G.J. Reinds and H.A.J. Van Lanen. 26 pp.

3. Crop production potential of rural areas within the European Communities. III. Soils, climate and administrative regions.
   G.J. Reinds, G.H.J. De Koning and J.D. Bulens. 32 pp.

4. Crop production potential of rural areas within the European Communities. IV. Potential, water-limited and actual crop production.
   G.H.J. De Koning, C.A. Van Diepen (this report).

5. Crop production potential of rural areas within the European Communities. V. Qualitative suitability assessment for forestry and perennial crops.
   H.A.J. Van Lanen, C.M.A. Hendriks and J.D. Bulens. 188 pp.

Appendix 2. Distribution of the relative area covered by the dominant soils units within the European Communities.



Appendix 3

Requirements for mechanized grass cultivation	
texture	less than 70% clay (EC-fine or coarser)
slope	not to exceed 15%
drainage	better than very poor
rooting depth	more than 10 cm
phase	gravelly and concretionary phase allowed
salinity	no excessive salinity
alkalinity	no excessive alkalinity

Requirements for mechanized cereal cultivation	
texture	less than 70% clay (EC-fine or coarser)
slope	not to exceed 15%
drainage	better than temporary poor
rooting depth	more than 10 cm
phase	gravelly and concretionary phase allowed
salinity	no excessive salinity
alkalinity	no excessive alkalinity

Requirements for mechanized root crop cultivation	
texture	less than 50% clay (medium fine or coarser)
slope	not to exceed 15%
drainage	better than temporary poor
rooting depth	more than 10 cm
phase	no phase allowed
salinity	no excessive salinity
alkalinity	no excessive alkalinity

Appendix 4. Potential (pot.y.) and water-limited (w.l.y.) wheat yield (dry matter) in each agro-climatic zone (kg/ha)

	pot.y.	w.l.y.		pot.y.	w.l.y.
Dalwhinnie	6701	6281	Bordeaux	9212	7649
Tynemouth	8752	7848	Toulouse	8499	6994
Lerwick	6673	6444	Nimes	8649	4769
Stornoway	8406	6648	Marseille	8573	3288
Aberdeen	8606	7578	Nice	8522	6819
Tiree	9818	8513	Perpignan	8412	2980
Edinburgh	8657	6885	Ajaccio	9326	7982
Eskdalemuir	7996	7753	La Coruna	9917	7757
Valley	9623	7460	Valladolid	9006	2083
Manchester	8755	5567	Barcelona	8705	6626
Waddington	8879	7088	Madrid	8419	2579
Birmingham	7596	6677	Santander	9617	9217
Glamorgan	9506	7966	Leon	9150	2563
London	9078	8111	Soria	9117	2764
Plymouth	10401	8101	Zaragoza	8536	2609
Durnemouth	9655	6550	Ciudad Real	8859	4117
Belfast	8638	7912	Murcia	8085	3722
Valentia	9643	8776	Cordoba	7522	6514
Cork	9684	8856	Granada	8035	4436
Shannon	8991	7790	Malaga	8318	6345
Dublin	9563	8423	Palma de Mallorca	8710	3638
Alborg	8481	4901	Mahon Menorca	9270	6777
Kobenhavn	8008	6583	Badajoz	8489	3923
De Bilt	8230	6905	Lisboa	9013	5176
Uccle	8241	7608	Porto	10341	6448
Clerveaux	8947	8876	Penhas Douradas	9411	2191
Schleswig	8433	6935	Braganca	8997	2239
Hamburg	8333	6483	Faro	8826	3585
Emden-Nesserland	8321	6752	Beja	8729	4581
Hannover	8093	6268	Milano	6862	6223
Essen	7893	7522	Domodossola	7546	7087
Kassel	7848	7017	Verona	7057	5474
Nurburg	7917	7918	Venezia	7076	6026
Hof	8753	8651	Pisa	8431	7163
Freudenstadt	9305	9300	Pescara	7715	5761
Geisenheim	7973	6645	Roma	8508	6521
Stuttgart	8127	7871	Napoli	8202	7113
Nurnberg	8055	7299	L'Aguila	7866	4651
Munchen	8380	8236	Foggia	7521	4128
Brest	10499	9958	Potenza	8694	4684
Trappes	8874	7236	Brindisi	8861	6516
Paris	8910	6072	Messina	8018	7644
Nancy	8281	6946	Trapani	8555	6691
Strasbourg	7987	7184	Catania	8279	5582
Nantes	9382	8718	Alghero	9404	7909
Bourges	8728	6528	Cagliari	8854	5931
Dijon	8325	6378	Thessaloniki	6423	4942
Limoges	8962	8583	Kerkyra	6243	5589
Lyon	8365	6893	Kalamath	7722	6990
Tours	8735	7492	Kawala	7627	5460
Geneva	8252	6642	Larisa	5925	3624
Grenoble	8586	8163	Tricala	7185	6770
Le Puy en Velay	9255	4763	Athinai	5991	4535
Biaritz	9809	8775	Hiraklion	6083	5739
Les Escaldes	8603	6346			

Appendix 5. Potential (pot.y.) and water-limited (w.l.y.) green maize yield (dry matter) in each agro-climatic zone (kg/ha)

	pot.y.	w.l.y.		pot.y.	w.l.y.
Dalwhinnie	1546	1546	Bordeaux	25482	17737
Tynemouth	10336	10287	Toulouse	24071	15589
Lerwick	516	516	Nimes	24245	11025
Stornoway	3338	3269	Marseille	24385	9654
Aberdeen	7193	7051	Nice	22448	13047
Tiree	6372	6261	Perpignan	22756	9054
Edinburgh	10170	9775	Ajaccio	25697	12214
Eskdalemuir	4175	4109	La Coruna	25443	11431
Valley	13490	12987	Valladolid	25701	7689
Manchester	15208	13117	Barcelona	22313	13311
Waddington	15368	13958	Madrid	23091	8446
Birmingham	13299	12656	Santander	23708	21285
Glamorgan	16074	15197	Leon	28103	9752
London	17122	16361	Soria	26419	10184
Plymouth	17729	15820	Zaragoza	23632	9757
Durnemouth	17742	14805	Ciudad Real	22626	7770
Belfast	10753	10627	Murcia	21815	8980
Valentia	11854	11569	Cordoba	19622	8148
Cork	11721	11603	Granada	20476	6740
Shannon	14001	13480	Malaga	23279	9031
Dublin	13149	12858	Palma de Mallorca	22327	8498
Alborg	16978	11831	Mahon Menorca	23678	8795
Kobenhavn	20711	18417	Badajoz	22419	6854
De Bilt	18460	16717	Lisboa	26164	6270
Uccle	20621	19159	Porto	28362	8207
Clerveaux	20825	20758	Penhas Douradas	19928	7305
Schleswig	17649	15674	Braganca	26287	6482
Hamburg	19993	16930	Faro	25278	6494
Emden-Nesserland	18918	17274	Beja	23932	7266
Hannover	20432	16596	Milano	21521	16345
Essen	20078	18917	Domodossola	22404	20467
Kassel	20773	18603	Verona	22032	15530
Nurburg	14266	14174	Venezia	21439	16278
Hof	14965	14817	Pisa	23311	12944
Freudenstadt	14687	14598	Pescara	21945	13110
Geisenheim	23213	21403	Roma	23146	9508
Stuttgart	23260	22299	Napoli	22755	11164
Nurnberg	22827	21215	L'Aguila	23598	10158
Munchen	21351	20961	Foggia	20906	8732
Brest	17580	16940	Potenza	27630	12045
Trappes	22091	19151	Brindisi	23541	10245
Paris	23563	18042	Messina	21242	9077
Nancy	21883	19577	Trapani	22934	9633
Strasbourg	23465	22063	Catania	21495	7895
Nantes	24650	20036	Alghero	24249	9664
Bourges	24155	16700	Cagliari	23095	8469
Dijon	24825	20258	Thessaloniki	20220	12791
Limoges	23961	22171	Kerkyra	18787	11789
Lyon	25407	20138	Kalamath	20536	9141
Tours	24835	20222	Kawala	22926	14364
Geneva	27230	23671	Larisa	18094	8827
Grenoble	26526	24159	Tricala	20278	13241
Le Puy en Velay	25034	16588	Athinai	16252	9272
Biaritz	23892	20114	Hiraklion	19915	8669
Les Escaldes	24701	19998			

Appendix 6. Potential (pot.y.) and water-limited (w.l.y.) grain maize yield (dry matter) in each agro-climatic zone (kg/ha)

	pot.y.	w.l.y.		pot.y.	w.l.y.
Dalwhinnie	-	-	Bordeaux	14067	8144
Tynemouth	-	-	Toulouse	13582	5657
Lerwick	-	-	Nimes	12694	1904
Stomoway	-	-	Marseille	12615	749
Aberdeen	-	-	Nice	11796	2901
Tiree	-	-	Perpignan	12062	1064
Edinburgh	-	-	Ajaccio	13482	1805
Eskdalemuir	-	-	La Coruna	13792	2966
Valley	-	-	Valladolid	14633	656
Manchester	-	-	Barcelona	11454	3237
Waddington	-	-	Madrid	12095	471
Birmingham	-	-	Santander	12912	11099
Glamorgan	-	-	Leon	16301	2346
London	-	-	Soria	15195	1930
Plymouth	-	-	Zaragoza	12039	784
Durnemouth	-	-	Ciudad Real	11220	166
Belfast	-	-	Murcia	10947	685
Valentia	-	-	Cordoba	9735	490
Cork	-	-	Granada	10775	85
Shannon	-	-	Malaga	11767	352
Dublin	-	-	Palma de Mallorca	11128	161
Alborg	-	-	Mahon Menorca	11883	282
Kobenhavn	-	-	Badajoz	11288	263
De Bilt	-	-	Lisboa	13678	243
Uccle	-	-	Porto	15264	1286
Clerveaux	-	-	Penhas Douradas	-	-
Schleswig	-	-	Braganca	14901	473
Hamburg	-	-	Faro	12949	192
Emden-Nesserland	-	-	Beja	12483	357
Hannover	-	-	Milano	11891	7085
Essen	-	-	Domodossola	12056	10474
Kassel	-	-	Verona	11956	6017
Nurburg	-	-	Venezia	11822	7097
Hof	-	-	Pisa	12419	3303
Freudenstadt	-	-	Pescara	11794	3908
Geisenheim	12357	10630	Roma	12035	805
Stuttgart	12171	11244	Napoli	12115	2237
Nurnberg	-	-	L'Aguila	13131	1485
Munchen	-	-	Foggia	10677	514
Brest	-	-	Potenza	15085	2093
Trappes	11475	9284	Brindisi	11900	651
Paris	12511	7871	Messina	10926	688
Nancy	11320	9408	Trapani	11794	646
Strasbourg	12753	11453	Catania	11112	349
Nantes	13356	8995	Alghero	12410	626
Bourges	13195	7091	Cagliari	11854	305
Dijon	13602	9533	Thessaloniki	10704	3581
Limoges	13084	11500	Kerkyra	10388	3691
Lyon	14156	9551	Kalamath	10691	757
Tours	13645	9460	Kawala	11925	3877
Geneva	15317	11974	Larisa	9274	1094
Grenoble	14680	12428	Tricala	10108	3350
Le Puy en Velay	-	-	Athinai	9310	2604
Biaritz	12867	10343	Hiraklion	10898	905
Les Escaldes	14453	10556			

Appendix 7. Potential (pot.y.) and water-limited (w.l.y.) oilseed rape yield (dry matter) in each agro-climatic zone (kg/ha)

	pot.y.	w.l.y.		pot.y.	w.l.y.
Dalwhinnie	3989	3389	Bordeaux	3741	3281
Tynemouth	4310	3951	Toulouse	3519	3245
Lerwick	4062	3813	Nimes	3402	2346
Stornoway	4478	2770	Marseille	3274	1749
Aberdeen	4623	3969	Nice	3026	2401
Tiree	4871	4019	Perpignan	3014	1046
Edinburgh	4402	3616	Ajaccio	3371	3067
Eskdalemuir	4286	4167	La Coruna	3651	2810
Valley	4482	3766	Valladolid	4179	2241
Manchester	4137	2876	Barcelona	2922	2114
Waddington	4368	3726	Madrid	3446	1579
Birmingham	3955	3710	Santander	3419	3300
Glamorgan	4503	4062	Leon	4281	2513
London	4411	4179	Soria	4352	3357
Plymouth	4475	3795	Zaragoza	3218	1177
Durnemouth	4554	3536	Ciudad Real	3838	2693
Belfast	4312	4071	Murcia	2536	1095
Valentia	4227	3943	Cordoba	2332	2119
Cork	4575	4307	Granada	3098	2221
Shannon	4095	3746	Malaga	2469	1728
Dublin	4519	4223	Palma de Mallorca	2836	857
Alborg	4788	2229	Mahon Menorca	3112	2189
Kobenhavn	4221	3595	Badajoz	2884	1449
De Bilt	4008	3448	Lisboa	2983	1651
Uccle	3829	3638	Porto	3679	2319
Clerveaux	4403	4382	Penhas Douradas	3458	2351
Schleswig	4537	3538	Braganca	3916	1814
Hamburg	4118	3293	Faro	2917	984
Emden-Nesserland	4258	3552	Beja	3015	1730
Hannover	3887	3224	Milano	3026	2960
Essen	3828	3632	Domodossola	3436	3339
Kassel	3758	3560	Verona	3134	2899
Nurburg	4426	4399	Venezia	2971	2776
Hof	4330	4233	Pisa	3266	3028
Freudenstadt	4622	4599	Pescara	2991	2547
Geisenheim	3684	3577	Roma	3010	2551
Stuttgart	3872	3867	Napoli	2889	2665
Nurnberg	3561	3488	L'Aguila	3387	3137
Munchen	3952	3879	Foggia	2762	1999
Brest	4462	4339	Potenza	4007	3526
Trappes	3989	3595	Brindisi	3041	2401
Paris	3981	3327	Messina	2628	2543
Nancy	3764	3583	Trapani	2866	2084
Strasbourg	3602	3534	Catania	2756	1947
Nantes	3963	3842	Alghero	3267	2858
Bourges	3707	3362	Cagliari	2990	2031
Dijon	3838	3705	Thessaloniki	2675	2463
Limoges	3675	3613	Kerkyra	2191	2171
Lyon	3770	3540	Kalamath	2550	2436
Tours	3796	3679	Kawala	3115	2849
Geneva	3961	3845	Larisa	2748	2333
Grenoble	3923	3905	Tricala	2877	2849
Le Puy en Velay	4178	4013	Athinai	1924	1481
Biaritz	3643	3267	Hiraklion	2082	1961
Les Escaldes	3914	3737			

Appendix 8. Potential (pot.y.) and water-limited (w.l.y.) potato yield (dry matter) in each agro-climatic zone (kg/ha)

	pot.y.	w.l.y.		pot.y.	w.l.y.
Dalwhinnie	13610	12565	Bordeaux	15180	8115
Tynemouth	14988	12927	Toulouse	14882	8082
Lerwick	12019	11610	Nimes	14948	6680
Stornoway	13886	11530	Marseille	14780	5287
Aberdeen	14789	12775	Nice	15176	7741
Tiree	14730	13562	Perpignan	14769	5146
Edinburgh	14856	10794	Ajaccio	15697	6819
Eskdalemuir	14239	13382	La Coruna	16837	8457
Valley	15436	10284	Valladolid	15398	4974
Manchester	15352	10658	Barcelona	14922	10216
Waddington	15576	10651	Madrid	14382	6084
Birmingham	14532	10666	Santander	16360	14620
Glamorgan	15865	11306	Leon	16180	7975
London	15768	10985	Soria	16126	6995
Plymouth	16184	10363	Zaragoza	14755	6960
Durnemouth	16032	8607	Ciudad Real	13698	6598
Belfast	14705	12470	Murcia	13687	7747
Valentia	14935	12599	Cordoba	12759	8322
Cork	15266	12694	Granada	14210	7271
Shannon	14891	11100	Malaga	14730	7840
Dublin	15343	11057	Palma de Mallorca	14267	4245
Alborg	16509	8187	Mahon Menorca	15130	5094
Kobenhavn	15966	10622	Badajoz	13278	5756
De Bilt	15251	12894	Lisboa	15610	3609
Uccle	14917	12032	Porto	16963	6437
Clerveaux	16311	14280	Penhas Douradas	16963	4872
Schleswig	16002	12660	Braganca	15584	8129
Hamburg	15846	11108	Faro	14980	2910
Emden-Nesserland	15713	13162	Beja	14477	3906
Hannover	15556	11214	Milano	13730	8999
Essen	14967	13176	Domodossola	15177	12175
Kassel	15137	11966	Verona	13598	8760
Nurburg	15298	14382	Venezia	13864	9297
Hof	16219	15211	Pisa	14966	7588
Freudenstadt	15978	15690	Pescara	14387	6237
Geisenheim	15071	10444	Roma	14634	4676
Stuttgart	15437	12662	Napoli	14489	6243
Nurnberg	15462	11991	L'Aguila	14756	5970
Munchen	15970	14858	Foggia	13551	5096
Brest	16003	11213	Potenza	16032	5757
Trappes	15930	10848	Brindisi	15359	5607
Paris	15895	9306	Messina	14665	6523
Nancy	15600	12457	Trapani	15170	6093
Strasbourg	15359	12216	Catania	14759	4771
Nantes	15770	8516	Alghero	15300	5923
Bourges	15407	8822	Cagliari	14684	3958
Dijon	15333	10436	Thessaloniki	12024	7713
Limoges	16260	11203	Kerkyra	12725	9633
Lyon	15336	9347	Kalamath	12760	6817
Tours	15461	8660	Kawala	14374	8910
Geneva	16132	9849	Larisa	9970	4846
Grenoble	15876	11872	Tricala	12822	10353
Le Puy en Velay	16793	8145	Athinai	11658	5646
Biaritz	15508	11973	Hiraklion	12975	5112
Les Escaldes	15924	10049			

Appendix 9. Potential (pot.y.) and water-limited (w.l.y.) sugar beet yield (dry matter) in each agro-climatic zone (kg/ha)

	pot.y.	w.l.y.		pot.y.	w.l.y.
Dalwhinnie	8079	7786	Bordeaux	22403	12068
Tynemouth	14024	13382	Toulouse	21526	10112
Lerwick	6052	6019	Nimes	21444	7026
Stomoway	9736	8853	Marseille	21388	5867
Aberdeen	11505	10867	Nice	20405	8538
Tiree	12119	11631	Perpignan	20485	5627
Edinburgh	13319	11623	Ajaccio	23090	7419
Eskdalemuir	9808	9553	La Coruna	24648	6850
Valley	15668	13291	Valladolid	22598	4581
Manchester	15973	12290	Barcelona	19725	11765
Waddington	16307	12951	Madrid	20155	6201
Birmingham	15105	13147	Santander	22585	19791
Glamorgan	16995	14378	Leon	23997	8443
London	17359	14746	Soria	23035	7709
Plymouth	18414	13788	Zaragoza	20738	7599
Durnemouth	18060	11783	Ciudad Real	18752	6058
Belfast	13690	13005	Murcia	18287	8719
Valentia	15134	14027	Cordoba	15030	8705
Cork	15157	14315	Granada	17908	6295
Shannon	15394	13571	Malaga	18631	9547
Dublin	15558	13809	Palma de Mallorca	18858	6236
Alborg	15771	10033	Mahon Menorca	20396	6369
Kobenhavn	17279	14155	Badajoz	18493	6708
De Bilt	16685	14248	Lisboa	23289	4206
Uccle	18076	15806	Porto	26804	5681
Clerveaux	19515	18939	Penhas Douradas	20503	6349
Schleswig	16336	14025	Braganca	22880	7886
Hamburg	17747	13419	Faro	21762	4011
Emden-Nesserland	17160	14657	Beja	20816	3623
Hannover	17996	13456	Milano	18994	11499
Essen	17533	15967	Domodossola	19632	16185
Kassel	17932	15203	Verona	19260	11297
Nurburg	15543	15457	Venezia	18789	11711
Hof	16479	16222	Pisa	20851	7959
Freudenstadt	16551	16393	Pescara	19473	7710
Geisenheim	19370	15884	Roma	20357	5596
Stuttgart	20031	18100	Napoli	20242	6944
Nurnberg	19800	17339	L'Aguila	20703	5961
Munchen	19567	18764	Foggia	17417	5638
Brest	18450	15843	Potenza	23132	6498
Trappes	20412	15410	Brindisi	20854	6363
Paris	20829	13500	Messina	18073	7303
Nancy	19849	16776	Trapani	20379	7323
Strasbourg	20497	18009	Catania	19028	5142
Nantes	21707	13376	Alghero	21521	6400
Bourges	21252	12562	Cagliari	20141	5018
Dijon	21592	15934	Thessaloniki	16257	8748
Limoges	21815	16645	Kerkyra	13225	8545
Lyon	22196	13580	Kalamath	17092	7535
Tours	21345	13162	Kawala	19292	9552
Geneva	23027	15511	Larisa	13920	5777
Grenoble	23157	18083	Tricala	16304	10621
Le Puy en Velay	22410	10691	Athinai	12457	6599
Biaritz	22189	16298	Hiraklion	11546	5890
Les Escaldes	22802	15499			

Appendix 10. Potential (pot.y.) and water-limited (w.l.y.) grass yield (dry matter) in each agro-climatic zone (kg/ha)

	pot.y.	w.l.y.		pot.y.	w.l.y.
Dalwhinnie	13410	12791	Bordeaux	24137	16383
Tynemouth	19456	18737	Toulouse	23914	13520
Lerwick	14835	14649	Nimes	25497	8731
Stomoway	17468	17329	Marseille	26062	8118
Aberdeen	17761	16060	Nice	25664	10764
Tiree	19465	18999	Perpignan	26435	6810
Edinburgh	18112	16000	Ajaccio	27052	10662
Eskdalemuir	14853	14275	La Coruna	25734	12693
Valley	20457	16770	Valladolid	23524	5656
Manchester	19251	16978	Barcelona	26672	11381
Waddington	19376	16776	Madrid	25924	7851
Birmingham	18430	15519	Santander	24717	21428
Glamorgan	20537	17406	Leon	23831	7560
London	20319	17147	Soria	21996	6935
Plymouth	22498	18058	Zaragoza	26697	8105
Durnemouth	20725	15255	Ciudad Real	24504	8459
Belfast	18319	16862	Murcia	25639	8568
Valentia	20527	19545	Cordoba	22781	9571
Cork	19969	18534	Granada	24766	8498
Shannon	19754	17673	Malaga	27551	8832
Dublin	19651	16934	Palma de Mallorca	26820	8242
Alborg	16752	10899	Mahon Menorca	27076	9184
Kobenhavn	17748	13584	Badajoz	26019	7994
De Bilt	18445	16756	Lisboa	28076	7861
Uccle	19582	16891	Porto	27175	11366
Clerveaux	18664	16042	Penhas Douradas	18633	6453
Schleswig	17527	14846	Braganca	24161	7210
Hamburg	18024	15324	Faro	28370	6610
Emden-Nesserland	18480	16764	Beja	26692	8681
Hannover	18099	15332	Milano	21964	15869
Essen	19087	17609	Domodossola	20821	17128
Kassel	18251	15736	Verona	22505	13731
Nurburg	16164	15360	Venezia	22485	15052
Hof	15667	13840	Pisa	24701	11508
Freudenstadt	16926	16372	Pescara	24727	11168
Geisenheim	19655	13887	Roma	26505	9412
Stuttgart	19643	17135	Napoli	26084	10441
Numberg	18223	14989	L'Aguila	22282	7803
Munchen	17849	17219	Foggia	24762	8059
Brest	22748	18526	Potenza	24514	9632
Trappes	20791	15867	Brindisi	27072	9156
Paris	21542	14673	Messina	26239	9175
Nancy	19066	15395	Trapani	27136	8878
Strasbourg	19688	16311	Catania	26612	8234
Nantes	23371	15456	Alghero	27210	9693
Bourges	20989	13721	Cagliari	26917	8980
Dijon	21026	13704	Thessaloniki	23724	8547
Limoges	20978	16438	Kerkyra	23180	9125
Lyon	22441	15139	Kalamath	25093	9017
Tours	23012	14186	Kawala	24842	8670
Geneva	22152	15835	Larisa	21065	6808
Grenoble	22559	16860	Tricala	22957	8842
Le Puy en Velay	20410	11012	Athinai	23074	6345
Biaritz	25491	22646	Hiraklion	24912	6604
Les Escaldes	21852	15349			

Appendix 11. Potential (pot.y.), water-limited. (w.l.y.) and actual (act.y.) wheat yield (dry matter) in each NUTS-1 region (kg/ha)
Source actual production: Eurostat (1986, 1987), averages over 1982, 1983, 1984 and 1985.

	POT.Y.	W.L.Y.	ACT.Y.
Schleswig-Holstein	8404	6797	5985
Hamburg	8343	6873	5418
Niedersachsen	8203	6627	4830
Bremen	8333	7193	4900
Nordrhein-Westfalen	7941	7293	5166
Hessen	7969	6884	4851
Rheinland-Pfalz	7987	7027	4473
Baden-Wurttemberg	8591	8325	4431
Bayern	8114	7485	4725
Saarland	7987	7205	3969
Ile de France	8864	6471	5670
Bassin Parisien	8791	6798	5292
Nord-Pas-de-Calais	8538	7200	5712
Est	8272	7194	4473
Ouest	9308	8513	4158
Sud-Ouest	9032	7698	3717
Centre-Est	8587	6595	3906
Mediterranee	8583	5623	2646
Nord-Ovest	7080	6400	3192
Lombardia	7082	6197	4074
Nord-Est	7160	5911	4242
Emilia-Romagna	7163	6144	4292
Centro	8219	6608	2646
Lazio	8474	6709	2184
Campania	8312	6668	1974
Abruzzi-Molise	7740	5287	2058
Sud	8245	5935	1302
Sicilia	8486	6414	1512
Sardegna	8971	6881	966
Noord-Nederland	8281	7087	5439
Oost-Nederland	8217	6790	6258
Zuid-Nederland	8134	6796	6006
West-Nederland	8230	7403	6447

	POT.Y.	W.L.Y.	ACT.Y.
Vlaams gewest	8163	6992	5061
Region Wallonne	8397	7259	5229
Brussel	8241	7948	4557
Luxembourg (G.D.)	8217	6314	3318
North	8214	7657	5565
Yorkshire &Humber.	8858	6719	5838
East Midlands	8857	7394	5649
East Anglia	8924	7370	5754
South East	9345	7193	5586
South West	10295	8050	5250
West Midlands	8324	7076	5166
North West	8949	5842	4809
Wales	9554	7798	5061
Scotland	8969	7829	6006
Northern Ireland	8874	7859	4788
Ireland	9440	8453	5817
Denmark	8232	5808	5523
Ellas (North)	6931	5125	2050
Ellas (Central)	6618	5616	2050
Ellas (E. and S. isl)	6251	5315	2050
Noroeste	9777	7674	1680
Noreste	8692	3316	2604
Madrid	8491	2810	1764
Centro	8823	3021	1848
Este	8625	4987	2856
Sur	8243	4533	2604
Norte do continente	9445	4235	1117
Sud doContinente	8958	5054	1117

Appendix 12. Potential (pot.y.),water-limited (w.l.y.) and actual (act.y.) green maize yield (dry matter) in each NUTS-1 region (kg/ha).
Source actual production: Eurostat (1986, 1987), averages over 1982, 1983, 1984 and 1985.

	POT.Y.	W.L.Y.	ACT.Y.
Schleswig-Holstein	18383	16027	9990
Hamburg	19729	17337	10162
Niedersachsen	19597	17003	10861
Bremen	19954	18017	15338
Nordrhein-Westfalen	20199	18655	11773
Hessen	22875	21385	13473
Rheinland-Pfalz	23406	21810	12636
Baden-Wurttemberg	19720	19053	12645
Bayern	22576	21208	12910
Saarland	23388	21751	16092
Ile de France	23258	18202	15617
Bassin Parisien	22851	18092	12435
Nord-Pas-de-Calais	21920	19262	14731
Est	22707	20333	12447
Ouest	23455	19606	11744
Sud-Ouest	24160	18138	9180
Centre-Est	25213	19584	11394
Mediterranee	23862	13422	9395
Nord-Ovest	22079	17142	12230
Lombardia	21767	16718	14338
Nord-Est	21708	16704	12663
Emilia-Romagna	21613	16059	12352
Centro	22927	12392	11044
Lazio	23110	9814	10108
Campania	23742	11366	9423
Abruzzi-Molise	22098	11807	9369
Sud	22539	9658	10250
Sicilia	22575	9199	9179
Sardegna	23789	9431	17631
Noord-Nederland	18707	17409	11889
Oost-Nederland	18667	16798	11844
Zuid-Nederland	18937	17104	11799
West-Nederland	18437	17249	12003

	POT.Y.	W.L.Y.	ACT.Y.
Vlaams gewest	19695	17573	13068
Region Wallonne	21732	19241	12123
Brussel	20621	19845	13320
Luxembourg (G.D.)	22222	18301	11709
North	6135	6013	-
Yorkshire & Humber.	14890	13836	12433
East Midlands	15557	14431	10658
East Anglia	15762	14203	9774
South East	17288	15376	9801
South West	17582	15718	10951
West Midlands	14363	13511	10863
North West	15427	13411	11998
Wales	15009	14346	11862
Scotland	6858	6701	-
Northern Ireland	11362	11151	-
Ireland	12680	12402	-
Denmark	18956	15316	10667
Ellas (North)	21244	13223	3383
Ellas (Central)	18285	10062	3383
Ellas (E. and S isl)	19767	8977	3383
Noroeste	25162	13683	4731
Noreste	24127	11187	12142
Madrid	23435	9076	13102
Centro	24413	8293	12504
Este	22787	11727	9304
Sur	22042	7336	13719
Norte do continente	26268	7132	-
Sud do Continente	25629	6573	-

Appendix 13. Potential (pot.y.) ,water-limited (w.l.y.) .and actual (act.y.) grain maize yield (dry matter) in each NUTS-1 region (kg/ha)
Source actual production: Eurostat (1986, 1987), averages over 1982, 1983, 1984 and 1985.

	POT.Y.	W.L.Y.	ACT.Y.
Schleswig-Holstein	-	-	4945
Hamburg	-	-	4881
Niedersachsen	-	-	4945
Bremen	-	-	-
Nordrhein-Westfalen	12358	10530	5354
Hessen	12413	10934	5569
Rheinland-Pfalz	12673	11217	5246
Baden-Wurttemberg	12463	11514	5096
Bayern	12173	11153	5440
Saarland	12653	11081	3806
Ile de France	12352	8278	6450
Bassin Parisien	12583	8180	5440
Nord-Pas-de-Calais	12514	8479	5568
Est	12217	10020	6042
Ouest	13448	9264	5332
Sud-Ouest	13340	8345	5440
Centre-Est	13983	9555	4644
Mediterranee	12737	3654	4945
Nord-Ovest	12187	7603	5375
Lombardia	11913	7228	6536
Nord-Est	11886	7429	6364
Emilia-Romagna	11902	6810	6622
Centro	12227	3059	5805
Lazio	12054	983	5246
Campania	12704	2214	2838
Abruzzi-Molise	11838	2933	3956
Sud	11564	735	2193
Sicilia	11624	572	5031
Sardegna	12368	671	5418
Noord-Nederland	-	-	-
Oost-Nederland	-	-	-
Zuid-Nederland	-	-	-
West-Nederland	-	-	-

	POT.Y.	W.L.Y.	ACT.Y.
Vlaams gewest	-	-	6429
Region Wallonne	12423	8563	6257
Brussel	-	-	4881
Luxembourg (G.D.)	11654	8900	-
North	-	-	-
Yorkshire & Humber.	-	-	-
East Midlands	-	-	-
East Anglia	-	-	-
South East	-	-	-
South West	-	-	-
West Midlands	-	-	-
North West	-	-	-
Wales	-	-	-
Scotland	-	-	-
Northern Ireland	-	-	-
Ireland	-	-	-
Denmark	-	-	-
Ellas (North)	11114	3547	7482
Ellas (Central)	9977	2370	7482
Ellas (E. and S. isl)	10801	1112	7482
Noroeste	13736	4959	2580
Noreste	12754	2298	6622
Madrid	12415	685	7138
Centro	13263	850	6708
Este	11713	2330	5074
Sur	11254	272	7482
Norte do continente	14473	759	1643
Sud do Continente	13340	262	1643

Appendix 14. Potential (pot.y.), water-limited. (w.l.y.) and actual (act.y.) oilseed rape yield (dry matter) in each NUTS-1 region (kg/ha)
Source actual production: Eurostat (1986, 1987), averages over 1982, 1983, 1984 and 1985.

	POT.Y.	W.L.Y.	ACT.Y.
Schleswig-Holstein	4421	3536	3094
Hamburg	4162	3608	2912
Niedersachsen	4101	3392	2548
Bremen	4118	3688	-
Nordrhein-Westfalen	3853	3617	2548
Hessen	3704	3613	2457
Rheinland-Pfalz	3625	3528	2184
Baden-Wurttemberg	4103	4086	2548
Bayern	3649	3577	2639
Saarland	3602	3558	2184
Ile de France	3929	3403	3094
Bassin Parisien	3883	3504	2821
Nord-Pas-de-Calais	3896	3626	2548
Est	3783	3692	2730
Ouest	3955	3853	2639
Sud-Ouest	3622	3292	2457
Centre-Est	3846	3649	2639
Mediterranee	3324	2470	2275
Nord-Ovest	3128	3058	-
Lombardia	3102	2975	-
Nord-Est	3082	2840	-
Emilia-Romagna	3000	2851	-
Centro	3160	2837	1638
Lazio	3004	2611	1365
Campania	3115	2829	-
Abruzzi-Molise	3013	2482	1638
Sud	2937	2412	1820
Sicilia	2839	2050	-
Sardegna	3205	2692	-
Noord-Nederland	4149	3647	2730
Oost-Nederland	4031	3391	2821
Zuid-Nederland	3956	3386	2184
West-Nederland	4008	3684	2548

	POT.Y.	W.L.Y.	ACT.Y.
Vlaams gewest	3897	3384	2093
Region Wallonne	3893	3661	2275
Brussel	3829	3798	-
Luxembourg (G.D.)	3729	3178	1729
North	4286	4051	2366
Yorkshire & Humber.	4363	3700	2639
East Midlands	4352	3938	2821
East Anglia	4378	3726	2912
South East	4476	3806	3003
South West	4476	3805	2639
West Midlands	4162	3777	2821
North West	4234	3003	3094
Wales	4494	3978	2639
Scotland	4607	3931	-
Northern Ireland	4365	4045	-
Ireland	4399	4110	1547
Denmark	4483	2941	2457
Ellas (North)	2881	2638	-
Ellas (Central)	2230	2003	-
Ellas (E. and S. isl)	2181	1934	-
Noroeste	3633	2867	-
Noreste	3455	1834	1456
Madrid	3540	1837	-
Centro	3813	2275	1183
Este	3090	1892	2275
Sur	2885	1741	819
Norte do continente	3606	1928	-
Sud do Continente	3031	1726	-

Appendix 15. Potential (pot.y.), water-limited.(w.l.y.) and actual (act.y.) potato yield (dry matter) in each NUTS-1 region (kg/ha)
Source actual production: Eurostat (1986, 1987), averages over 1982, 1983, 1984 and 1985.

	POT.Y.	W.L.Y.	ACT.Y.
Schleswig-Holstein	15982	12000	6908
Hamburg	15848	10708	7046
Niedersachsen	15634	11891	7321
Bremen	15853	11111	6754
Nordrhein-Westfalen	15128	12784	7519
Hessen	15112	11126	5869
Rheinland-Pfalz	15246	11192	5874
Baden-Wurttemberg	15633	13504	6292
Bayern	15514	12334	6595
Saarland	15373	13463	4829
Ile de France	15841	9894	6864
Bassin Parisien	15622	10295	7574
Nord-Pas-de-Calais	15317	10983	8949
Est	15448	11897	5846
Ouest	15606	9277	5528
Sud-Ouest	15464	9779	4956
Centre-Est	15759	9225	4428
Mediterranee	15190	7307	4246
Nord-Ovest	14104	9194	4609
Lombardia	13906	9311	5379
Nord-Est	13894	9442	5918
Emilia-Romagna	13906	8947	5918
Centro	14757	6740	2816
Lazio	14626	5106	3927
Campania	14750	6164	3861
Abruzzi-Molise	14364	5940	3223
Sud	14584	5674	2585
Sicilia	15048	5701	3817
Sardegna	15021	5303	3718
Noord-Nederland	15522	13675	7579
Oost-Nederland	15326	13079	9438
Zuid-Nederland	15211	12870	9801
West-Nederland	15182	13399	9009

	POT.Y.	W.L.Y.	ACT.Y.
Vlaams gewest	15110	12310	7585
Region Wallonne	15331	11048	7684
Brussel	14779	12054	6572
Luxembourg (G.D.)	15617	9497	6528
North	14521	13091	7964
Yorkshire & Humber.	15484	10983	8360
East Midlands	15492	11074	8492
East Anglia	15632	10172	8360
South East	15899	9580	6600
South West	16144	10390	7590
West Midlands	15079	10892	8712
North West	15507	10897	8316
Wales	15687	10802	6490
Scotland	14642	12806	7876
Northern Ireland	14879	11900	5764
Ireland	15145	11850	4851
Denmark	16206	9590	7419
Ellas (North)	12902	8120	4213
Ellas (Central)	12240	7182	4213
Ellas (E. and S. isl)	12959	5084	4213
Noroeste	16567	11844	3608
Noreste	15088	7852	4246
Madrid	14382	6104	4862
Centro	15028	5990	4268
Este	14723	9180	3938
Sur	14063	6238	4202
Norte do continente	15982	4996	1848
Sud do Continente	15426	3745	1848

Appendix 16. Potential (pot.y.), water-limited. (w.l.y.) and actual (act.y.) sugar beet yield (dry matter) in each NUTS-1 region (kg/ha)
Source actual production: Eurostat (1986, 1987), averages over 1982, 1983, 1984 and 1985.

	POT.Y.	W.L.Y.	ACT.Y.		POT.Y.	W.L.Y.	ACT.Y.
Schleswig-Holstein	16665	13689	8415	Vlaams gewest	17461	14808	10635
Hamburg	17748	13361	8120	Region Wallonne	19079	14841	10250
Niedersachsen	17464	14121	8740	Brussel	18024	16382	9975
Bremen	17752	13512	4200	Luxembourg (G.D.)	20025	12760	8880
Nordrhein-Westfalen	17690	15570	9645	North	11070	10528	-
Hessen	19228	16291	9320	Yorkshire & Humber.	16048	13165	8560
Rheinland-Pfalz	20038	16797	10100	East Midlands	16326	13282	8695
Baden-Wurttemberg	19032	17504	10110	East Anglia	16458	12801	8560
Bayern	19760	17507	10880	South East	17692	12924	6758
Saarland	20502	18777	6955	South West	18290	13774	7772
Ile. de France	20717	14218	11360	West Midlands	15876	13567	8920
Bassin Parisien	20291	14538	11460	North West	16257	12648	8515
Nord-Pas-de-Calais	19290	15181	10425	Wales	16432	13929	6645
Est	20890	17028	9880	Scotland	11783	11086	-
Ouest	21006	14058	10165	Northern Ireland	14172	13072	-
Sud-Ouest	21881	13408	-	Ireland	15283	13942	9050
Centre-Est	22138	13431	10850	Denmark	16582	12308	9010
Mediterranee	21325	8856	-	Ellas (North)	17399	8948	12026
Nord-Ovest	19638	11909	9320	Ellas (Central)	14069	7579	12026
Lombardia	18917	11827	9840	Ellas (E.and S. isl)	12578	5966	12026
Nord-Est	18899	11972	9690	Noroeste	23633	13871	-
Emilia-Romagna	18861	11266	8847	Noreste	21237	9318	7720
Centro	20416	7461	6180	Madrid	20155	6244	8400
Lazio	20362	5990	9887	Centro	21544	6156	7620
Campania	20730	6865	3913	Este	19819	10534	-
Abruzzi-Molise	19465	7087	8340	Sur	18512	6567	7280
Sud	19092	6356	6200	Norte do continente	24394	4938	7658
Sicilia	19979	6678	-	Sud do Continente	22872	4290	7658
Sardegna	20949	5949	6747				
Noord-Nederland	16975	14824	9640				
Oost-Nederland	16866	14532	12147				
Zuid-Nederland	17002	14524	10540				
West-Nederland	16631	14688	11293				

Appendix 17. Potential (pot.y.) and water-limited (w.l.y.) grass yield (dry matter) in each NUTS-1 region (kg/ha)

	POT.Y.	W.L.Y.
Schleswig-Holstein	17621	14848
Hamburg	17982	15364
Niedersachsen	18134	15614
Bremen	18024	15572
Nordrhein-Westfalen	18673	16543
Hessen	19251	14795
Rheinland-Pfalz	19545	15379
Baden-Wurttemberg	18211	16564
Bayern	18035	15388
Saarland	19688	16237
Ile de France	21184	15129
Bassin Parisien	20990	15134
Nord-Pas-de-Calais	20471	16084
Est	19761	15116
Ouest	23164	15923
Sud-Ouest	23625	16785
Centre-Est	21615	14283
Mediterranee	24470	11459
Nord-Ovest	22366	15168
Lombardia	21840	15744
Nord-Est	21737	15798
Emilia-Romagna	22715	13444
Centro	24550	10649
Lazio	26077	9528
Campania	25692	10230
Abruzzi-Molise	23812	9282
Sud	25880	8948
Sicilia	26986	8693
Sardegna	26577	9239
Noord-Nederland	18466	17318
Oost-Nederland	18498	16637
Zuid-Nederland	18633	16876
West-Nederland	18445	17230

	POT.Y.	W.L.Y.
Vlaams gewest	19041	16611
Region Wallonne	20131	15612
Brussel	19582	17000
Luxembourg (G.D.)	19001	15450
North	16362	15743
Yorkshire & Humber.	18966	17009
East Midlands	19478	16483
East Anglia	19546	16598
South East	20461	16123
South West	22265	17893
West Midlands	19374	16356
North West	19543	17517
Wales	20503	17038
Scotland	18255	17394
Northern Ireland	18624	16930
Ireland	19834	17987
Denmark	17278	12289
Ellas (North)	23523	8370
Ellas (Central)	23479	7360
Ellas (E. and S. isl)	24761	6744
Noroeste	25244	14757
Noreste	25175	9926
Madrid	25366	7838
Centro	24227	7702
Este	25841	10211
Sur	25491	8207
Norte do continente	25202	8285
Sud do Continente	27710	7945

Appendix 18. Total area, agricultural area (AA), arable area, permanent grassland area, and percentage AA, arable and permanent grassland of total for NUTS-1 region and countries.
Source: Eurostat (1986, 1987), averages over 1982, 1983, 1984 and 1985.

	total (1000 ha)	AA (1000 ha)	arable (1000 ha)	grass (1000 ha)	AA /total (%)	arable /total (%)	grass /total (%)
Schleswig-Holstein	1574.0	1089.8	599.6	480.7	69.2	38.1	30.5
Hamburg	64.8	15.5	8.1	5.5	23.9	12.5	8.5
Niedersachsen	4767.2	2736.0	1630.2	1080.8	57.4	34.2	22.7
Bremen	37.1	10.5	2.1	8.3	28.3	5.7	22.4
Nordrhein-Westfalen	3395.5	1619.3	1094.4	510.3	47.7	32.2	15.0
Hessen	2135.2	778.6	512.8	258.8	36.5	24.0	12.1
Rheinland-Pfalz	1984.0	729.4	428.8	224.0	36.8	21.6	11.3
Baden-Wurttemberg	3614.8	1515.3	839.7	626.3	41.9	23.2	17.3
Bayern	7060.2	3455.7	2085.0	1343.3	48.9	29.5	19.0
Saarland	228.5	67.6	38.7	28.0	29.6	16.9	12.3
West Germany	24861.1	12017.7	7239.4	4566.0	48.2	29.1	18.3
Ile de France	1200.0	610.0	579.0	25.9	50.8	48.3	2.2
Bassin Parisien	14609.6	9791.0	6515.0	3172.3	67.0	44.6	21.7
Nord-Pas-de-Calais	1208.4	923.0	667.0	255.0	76.4	55.2	21.1
Est	4838.6	2302.0	1043.0	1236.4	47.6	21.6	25.6
Ouest	8660.0	6286.0	4473.0	1642.3	72.6	51.7	19.0
Sud-Ouest	10592.8	5367.0	2833.0	2275.5	50.7	26.7	21.5
Centre-Est	7203.4	3561.0	1246.0	2197.6	49.4	17.3	30.5
Mediterranee	7067.2	2592.0	550.0	1401.2	36.7	7.8	19.8
France	55380.1	31432.0	17906.0	12206.2	56.8	32.3	22.0
Nord-Ovest	3404.5	1574.4	707.0	651.2	46.2	20.8	19.1
Lombardia	2462.4	1215.9	801.9	335.4	49.4	32.6	13.6
Nord-Est	3996.7	1728.9	808.4	607.3	43.3	20.2	15.2
Emilia-Romagna	2247.4	1399.9	1002.8	144.6	62.3	44.6	6.4
Centro	4198.7	2228.1	1390.0	437.6	53.1	33.1	10.4
Lazio	1761.9	1040.4	551.3	231.4	59.1	31.3	13.1
Campania	1421.4	873.2	431.2	162.2	61.4	30.3	11.5
Abruzzi-Molise	1591.9	921.3	500.4	264.8	57.9	31.4	16.6
Sud	4685.9	3134.0	1475.2	636.9	66.9	31.5	13.6
Sicilia	2744.1	1999.9	1080.0	295.4	72.9	39.4	10.8
Sardegna	2478.1	1666.9	319.3	1186.4	67.3	12.9	47.9
Italy	30993.0	17782.9	9067.5	4953.2	57.4	29.3	16.0
Noord-Nederland	858.2	575.2	234.9	339.0	67.0	27.4	39.5
Oost-Nederland	1006.3	561.7	189.0	362.1	55.8	18.8	36.0
Zuid-Nederland	703.2	386.2	181.6	196.2	54.9	25.8	27.9
West-Nederland	899.2	493.1	237.3	243.9	54.8	26.4	27.1
Netherlands	3466.9	2016.2	842.8	1141.2	58.2	24.3	32.9
Vlaams gewest	1349.3	619.9	353.0	254.5	45.9	26.2	18.9
Region Wallonne	1690.6	769.4	382.5	385.4	45.5	22.6	23.0
Brussel	16.3	0.5	0.3	0.2	3.1	1.8	1.2
Belgium	3056.2	1389.8	735.8	640.1	45.5	24.1	20.9

Appendix 18. (Continued) Total area, agricultural area (AA), arable area, permanent grassland area, and percentage AA, arable and permanent grassland of total for NUTS-1 region and countries. Source: Eurostat (1986, 1987), averages over 1982, 1983, 1984 and 1985.

	total (1000 ha)	AA (1000 ha)	arable (1000 ha)	grass (1000 ha)	AA /total (%)	arable /total (%)	grass /total (%)
Luxembourg (G.D.)	265.0	127.6	55.3	70.6	48.2	20.9	26.6
North	1620.4	1200.6	286.6	913.8	74.1	17.7	56.4
Yorkshire & Humber.	1532.8	1194.6	637.5	556.2	77.9	41.6	36.3
East Midlands	1570.6	1239.2	876.4	360.8	78.9	55.8	23.0
East Anglia	1252.1	988.2	863.4	114.9	78.9	69.0	9.2
South East	2799.3	1687.3	1144.1	512.3	60.3	40.9	18.3
South West	2399.2	1889.0	768.4	1115.3	78.7	32.0	46.5
West Midlands	1298.4	971.0	501.8	459.1	74.8	38.6	35.4
North West	726.7	468.0	139.8	327.3	64.4	19.2	45.0
Wales	2054.5	1639.9	262.8	1376.5	79.8	12.8	67.0
Scotland	7896.2	5961.1	1121.8	4835.2	75.5	14.2	61.2
Northern Ireland	1402.0	1041.6	316.0	723.0	74.3	22.5	51.6
United Kingdom	24552.3	18280.5	6918.6	11294.4	74.5	28.2	46.0
Ireland	6965.3	5713.3	1099.1	4611.8	82.0	15.8	66.2
Denmark	4332.3	2834.1	2601.3	220.6	65.4	60.0	5.1
Ellas (North)	5974.0	-	-	-	-	-	-
Ellas (Central)	6278.3	-	-	-	-	-	-
Ellas (E and S. isl)	1609.6	-	-	-	-	-	-
Greece	13861.9	5741.2	2913.4	1789.0	41.4	21.0	12.9
Noroeste	4706.5	1419.4	577.2	810.2	30.2	12.3	17.2
Noreste	7358.0	3853.7	2219.9	1298.8	52.4	30.2	17.7
Madrid	835.3	421.4	224.1	145.3	50.5	26.8	17.4
Centro	22410.6	13106.7	8348.2	3271.6	58.5	37.3	14.6
Este	6363.3	2562.7	1054.7	328.0	40.3	16.6	5.2
Sur	10185.8	5596.6	3022.2	833.3	54.9	29.7	8.2
Spain	51859.5	26960.5	15446.3	6687.2	52.0	29.8	12.9
Norte do continente	4670.6	-	-	-	-	-	-
Sud do continente	4659.5	-	-	-	-	-	-
Portugal	9330.2	4531.8	2905.8	761.0	48.6	31.1	8.2
EC	228923.8	128827.6	67731.3	48942.1	56.3	29.6	21.3

Appendix 19. Total cereal area, and cereal area as percentage of total area, agricultural area (AA) and arable area (arab.), for NUTS-1 regions and countries.
Source: Eurostat (1986, 1987), averages over 1982, 1983, 1984 and 1985.

	cereal (1000 ha)	cereal /total (%)	cereal /AA (%)	cereal /arab. (%)
Schleswig-Holstein	378.1	24.0	34.7	63.1
Hamburg	4.4	6.8	28.5	54.6
Niedersachsen	1158.4	24.3	42.3	71.1
Bremen	1.6	4.2	15.0	75.0
Nordrhein-Westfalen	790.6	23.3	48.8	72.2
Hessen	392.1	18.4	50.4	76.5
Rheinland-Pfalz	337.3	17.0	46.2	78.7
Baden-Wurttemberg	577.4	16.0	38.1	68.8
Bayern	1312.6	18.6	38.0	63.0
Saarland	31.7	13.9	46.9	81.8
West Germany	4984.2	20.1	41.5	68.8
Ile de France	456.5	38.0	74.8	78.8
Bassin Parisien	4173.3	28.6	42.6	64.1
Nord-Pas-de-Calais	399.7	33.1	43.3	59.9
Est	652.7	13.5	28.4	62.6
Ouest	1553.0	17.9	24.7	34.7
Sud-Ouest	1485.5	14.0	27.7	52.4
Centre-Est	664.2	9.2	18.7	53.3
Mediterranee	247.1	3.5	9.5	44.9
France	9632.0	17.4	30.6	53.8
Nord-Ovest	441.7	13.0	28.1	62.5
Lombardia	429.1	17.4	35.3	53.5
Nord-Est	509.2	12.7	29.5	63.0
Emilia-Romagna	403.8	18.0	28.8	40.3
Centro	770.2	18.3	34.6	55.4
Lazio	277.3	15.7	26.6	50.3
Campania	215.9	15.2	24.7	50.1
Abruzzi-Molise	269.3	16.9	29.2	53.8
Sud	953.5	20.3	30.4	64.6
Sicilia	532.1	19.4	26.6	49.3
Sardegna	129.6	5.2	7.8	40.6
Italy	4931.7	15.9	27.7	54.4
Noord-Nederland	66.4	7.7	11.5	28.3
Oost-Nederland	33.0	3.3	5.9	17.5
Zuid-Nederland	27.1	3.9	7.0	14.9
West-Nederland	70.8	7.9	14.4	29.8
Netherlands	197.3	5.7	9.8	23.4

	cereal (1000 ha)	cereal /total (%)	cereal /AA (%)	cereal /arab. (%)
Vlaams gewest	134.5	10.0	21.7	38.1
Region Wallonne	224.1	13.3	29.1	58.6
Brussel	0.2	1.1	35.0	58.3
Belgium	358.8	11.7	25.8	48.8
Luxembourg (G.D.)	34.6	13.1	27.1	62.6
North	158.9	9.8	13.2	55.5
Yorkshire & Humber.	433.6	28.3	36.3	68.0
East Midlands	592.8	37.7	47.8	67.6
East Anglia	584.4	46.7	59.1	67.7
South East	807.4	28.8	47.9	70.6
South West	418.7	17.4	22.2	54.5
West Midlands	298.9	23.0	30.8	59.6
North West	63.9	8.8	13.7	45.7
Wales	67.8	3.3	4.1	25.8
Scotland	526.5	6.7	8.8	46.9
Northern Ireland	51.7	3.7	5.0	16.4
United Kingdom	4004.6	16.3	21.9	57.9
Ireland	403.4	5.8	7.1	36.7
Denmark	1683.8	38.9	59.4	64.7
Greece	1505.0	10.9	26.2	51.6
Noroeste	227.9	4.8	16.1	39.5
Noreste	1234.0	16.8	32.0	55.6
Madrid	103.6	12.4	24.6	46.2
Centro	4303.0	19.2	32.8	51.5
Este	493.6	7.8	19.3	46.8
Sur	1225.3	12.0	21.9	40.5
Spain	7587.4	14.6	28.1	49.1
Portugal	974.0	10.4	21.5	33.5

Appendix 20. Total wheat area, and wheat area as percentage of total area, agricultural area (AA) and arable area (arab.), for NUTS-1 regions and countries.
Source: Eurostat (1986, 1987), averages over 1982, 1983, 1984 and 1985.

	wheat (1000 ha)	wheat /total (%)	wheat /AA (%)	wheat /arab. (%)
Schleswig-Holstein	147.8	9.4	13.6	24.6
Hamburg	1.5	2.3	9.7	18.5
Niedersachsen	288.4	6.0	10.5	17.7
Bremen	0.5	1.3	4.5	22.6
Nordrhein-Westfalen	227.4	6.7	14.0	20.8
Hessen	138.8	6.5	17.8	27.1
Rheinland-Pfalz	111.8	5.6	15.3	26.1
Baden-Wurttemberg	220.5	6.1	14.6	26.3
Bayern	480.0	6.8	13.9	23.0
Saarland	6.7	2.9	9.9	17.2
West Germany	1623.3	6.5	13.5	22.4
Ile de France	287.7	24.0	47.2	49.7
Bassin Parisien	2457.8	16.8	25.1	37.7
Nord-Pas-de-Calais	234.8	19.4	25.4	35.2
Est	256.3	5.3	11.1	24.6
Ouest	786.1	9.1	12.5	17.6
Sud-Ouest	465.3	4.4	8.7	16.4
Centre-Est	269.6	3.7	7.6	21.6
Mediterranee	133.2	1.9	5.1	24.2
France	4890.6	8.8	15.6	27.3
Nord-Ovest	167.5	4.9	10.6	23.7
Lombardia	118.7	4.8	9.8	14.8
Nord-Est	98.1	2.5	5.7	12.1
Emilia-Romagna	312.2	13.9	22.3	31.1
Centro	589.1	14.0	26.4	42.4
Lazio	216.8	12.3	20.8	39.3
Campania	153.1	10.8	17.5	35.5
Abruzzi-Molise	214.0	13.4	23.2	42.8
Sud	750.1	16.0	23.9	50.8
Sicilia	519.4	18.9	26.0	48.1
Sardegna	80.5	3.2	4.8	25.2
Italy	3219.4	10.4	18.1	35.5
Noord-Nederland	38.4	4.5	6.7	16.3
Oost-Nederland	23.1	2.3	4.1	12.2
Zuid-Nederland	16.2	2.3	4.2	8.9
West-Nederland	60.1	6.7	12.2	25.3
Netherlands	137.7	4.0	6.8	16.3

	wheat (1000 ha)	wheat /total (%)	wheat /AA (%)	wheat /arable (%)
Vlaams gewest	62.5	4.6	10.1	17.7
Region Wallonne	124.4	7.4	16.2	32.5
Brussel	0.1	0.6	20.0	33.3
Belgium	187.0	6.1	13.5	25.4
Luxembourg (G.D.)	6.9	2.6	5.4	12.4
North	43.1	2.7	3.6	15.0
Yorkshire & Humber.	189.4	12.4	15.9	29.7
East Midlands	355.6	22.6	28.7	40.6
East Anglia	339.1	27.1	34.3	39.3
South East	473.1	16.9	28.0	41.3
South West	178.3	7.4	9.4	23.2
West Midlands	137.1	10.6	14.1	27.3
North West	11.5	1.6	2.4	8.2
Wales	9.6	0.5	0.6	3.7
Scotland	52.9	0.7	0.9	4.7
Northern Ireland	1.9	0.1	0.2	0.6
United Kingdom	1791.3	7.3	9.8	25.9
Ireland	68.1	1.0	1.2	6.2
Denmark	273.4	6.3	9.6	10.5
Greece	852.4	6.1	14.8	29.3
Noroeste	35.4	0.8	2.5	6.1
Noreste	237.6	3.2	6.2	10.7
Madrid	37.5	4.5	8.9	16.7
Centro	1011.6	4.5	7.7	12.1
Este	111.6	1.8	4.4	10.6
Sur	608.6	6.0	10.9	20.1
Spain	2043.3	3.9	7.6	13.2
Portugal	261.0	2.8	5.8	9.0

Appendix 21. Total green maize area (gre.m.), and green maize area as percentage of total area, agricultural area (AA) and arable area (arab.), for NUTS-1 regions and countries.
Source: Eurostat (1986, 1987), averages over 1982, 1983, 1984 and 1985.

	gre.m. (1000 ha)	gre.m. /total (%)	gre.m. /AA (%)	gre.m. /arab. (%)
Schleswig-Holstein	48.3	3.1	4.4	8.0
Hamburg	0.6	0.9	3.7	7.0
Niedersachsen	145.4	3.0	5.3	8.9
Bremen	0.3	0.8	2.9	14.3
Nordrhein-Westfalen	125.4	3.7	7.7	11.5
Hessen	38.3	1.8	4.9	7.5
Rheinland-Pfalz	18.7	0.9	2.6	4.4
Baden-Wurttemberg	93.6	2.6	6.2	11.1
Bayern	344.3	4.9	10.0	16.5
Saarland	3.5	1.5	5.2	9.0
West Germany	818.3	3.3	6.8	11.3
Ile de France	2.0	0.2	0.3	0.3
Bassin Parisien	316.7	2.2	3.2	4.9
Nord-Pas-de-Calais	33.0	2.7	3.6	4.9
Est	85.1	1.8	3.7	8.2
Ouest	652.1	7.5	10.4	14.6
Sud-Ouest	119.6	1.1	2.2	4.2
Centre-Est	63.6	0.9	1.8	5.1
Mediterranee	2.7	0.0	0.1	0.5
France	1274.8	2.3	4.1	7.1
Nord-Ovest	62.0	1.8	3.9	8.8
Lombardia	150.7	6.1	12.4	18.8
Nord-Est	130.0	3.3	7.5	16.1
Emilia-Romagna	42.2	1.9	3.0	4.2
Centro	33.6	0.8	1.5	2.4
Lazio	14.1	0.8	1.4	2.6
Campania	12.1	0.9	1.4	2.8
Abruzzi-Molise	9.0	0.6	1.0	1.8
Sud	6.2	0.1	0.2	0.4
Sicilia	3.0	0.1	0.2	0.3
Sardegna	3.1	0.1	0.2	1.0
Italy	466.0	1.5	4.1	7.1
Noord-Nederland	16.2	1.9	2.8	6.9
Oost-Nederland	62.2	6.2	11.1	32.9
Zuid-Nederland	69.7	9.9	18.1	38.4
West-Nederland	7.8	0.9	1.6	3.3
Netherlands	155.9	4.5	7.7	18.5

	gre.m. (1000 ha)	gre.m. /total (%)	gre.m. /AA (%)	gre.m. /arab. (%)
Vlaams gewest	64.8	4.8	10.5	18.4
Region Wallonne	37.1	2.2	4.8	9.7
Brussel	0.0	0.0	0.0	0.0
Belgium	101.9	3.3	7.3	13.9
Luxembourg (G.D.)	5.6	2.1	4.4	10.1
North	0.0	0.0	0.0	0.0
Yorkshire & Humber.	0.2	0.0	0.0	0.0
East Midlands	0.6	0.0	0.0	0.1
East Anglia	3.3	0.3	0.3	0.4
South East	5.8	0.2	0.3	0.5
South West	3.6	0.2	0.2	0.5
West Midlands	0.8	0.1	0.1	0.2
North West	0.3	0.0	0.1	0.2
Wales	0.7	0.0	0.0	0.3
Scotland	0.0	0.0	0.0	0.0
Northern Ireland	0.0	0.0	0.0	0.0
United Kingdom	15.4	0.1	0.1	0.2
Ireland	0.0	0.0	0.0	0.0
Denmark	16.4	0.4	0.6	0.6
Greece	3.4	0.0	0.1	0.1
Noroeste	-	-	-	-
Noreste	-	-	-	-
Madrid	-	-	-	-
Centro	-	-	-	-
Este	-	-	-	-
Sur	-	-	-	-
Spain	106	0.2	0.4	0.7
Portugal	-	-	-	-

Appendix 22. Total grain maize area (gra.m.), and grain maize area as percentage of total area, agricultural area (AA) and arable area (arab.), for NUTS-1 regions and countries.
Source: Eurostat (1986, 1987), averages over 1982, 1983, 1984 and 1985.

	gra.m. (1000 ha)	gra.m. /total (%)	gra.m. /AA (%)	gra.m. /arab. (%)
Schleswig-Holstein	0.4	0.0	0.0	0.1
Hamburg	0.1	0.2	0.6	1.2
Niedersachsen	37.6	0.8	1.4	2.3
Bremen	0.0	0.0	0.0	0.0
Nordrhein-Westfalen	49.9	1.5	3.1	4.6
Hessen	5.1	0.2	0.7	1.0
Rheinland-Pfalz	3.3	0.2	0.5	0.8
Baden-Wurttemberg	29.8	0.8	2.0	3.5
Bayern	46.7	0.7	1.4	2.2
Saarland	0.2	0.1	0.3	0.6
West Germany	173.0	0.7	1.4	2.4
Ile de France	105.1	8.8	17.2	18.1
Bassin Parisien	499.7	3.4	5.1	7.7
Nord-Pas-de-Calais	1.8	0.2	0.2	0.3
Est	70.0	1.4	3.0	6.7
Ouest	251.7	2.9	4.0	5.6
Sud-Ouest	632.2	6.0	11.8	22.3
Centre-Est	138.5	1.9	3.9	11.1
Mediterranee	19.2	0.3	0.7	3.5
France	1718.2	3.1	5.5	9.6
Nord-Ovest	143.8	4.2	9.1	20.3
Lombardia	177.9	7.2	14.6	22.2
Nord-Est	373.9	9.4	21.6	46.2
Emilia-Romagna	49.5	2.2	3.5	4.9
Centro	85.6	2.0	3.8	6.2
Lazio	30.6	1.7	2.9	5.6
Campania	43.3	3.0	5.0	10.0
Abruzzi-Molise	23.0	1.4	2.5	4.6
Sud	28.7	0.6	0.9	1.9
Sicilia	4.0	0.1	0.2	0.4
Sardegna	3.8	0.2	0.2	1.2
Italy	963.8	3.1	5.4	10.6
Noord-Nederland	0.1	0.0	0.0	0.0
Oost-Nederland	0.1	0.0	0.0	0.1
Zuid-Nederland	0.1	0.0	0.0	0.1
West-Nederland	0.1	0.0	0.0	0.0
Netherlands	0.4	0.0	0.0	0.1

	gra.m. (1000 ha)	gra.m. /total (%)	gra.m. /AA (%)	gra.m. /arab. (%)
Vlaams gewest	5.5	0.4	0.9	1.6
Region Wallonne	1.2	0.1	0.1	0.3
Brussel	0.0	0.0	0.0	0.0
Belgium	6.7	0.2	0.5	0.9
Luxembourg (G.D.)	0.0	0.0	0.0	0.0
North	0.0	0.0	0.0	0.0
Yorkshire & Humber.	0.0	0.0	0.0	0.0
East Midlands	0.0	0.0	0.0	0.0
East Anglia	0.0	0.0	0.0	0.0
South East	0.0	0.0	0.0	0.0
South West	0.0	0.0	0.0	0.0
West Midlands	0.0	0.0	0.0	0.0
North West	0.0	0.0	0.0	0.0
Wales	0.0	0.0	0.0	0.0
Scotland	0.0	0.0	0.0	0.0
Northern Ireland	0.0	0.0	0.0	0.0
United Kingdom	0.0	0.0	0.0	0.0
Ireland	0.0	0.0	0.0	0.0
Denmark	0.0	0.0	0.0	0.0
Greece	335.0	2.4	5.8	11.5
Noroeste	140.1	3.0	9.9	24.3
Noreste	93.0	1.3	2.4	4.2
Madrid	9.9	1.2	2.3	4.4
Centro	165.5	0.7	1.3	2.0
Este	41.7	0.7	1.6	4.0
Sur	74.1	0.7	1.3	2.5
Spain	526.2	1.0	2.0	3.4
Portugal	242.0	2.6	5.3	8.3

Appendix 23. Total oilseed rape area (oil.r.), and oilseed rape area as percentage of total area, agricultural area (AA) and arable area (arab.), for NUTS-1 regions and countries.
Source: Eurostat (1986, 1987), averages over 1982, 1983, 1984 and 1985.

	oil.r. (1000 ha)	oil.r. /total (%)	oil.r. /AA (%)	oil.r. /arab. (%)
Schleswig-Holstein	90.9	5.8	8.3	15.2
Hamburg	0.6	0.9	3.9	7.4
Niedersachsen	34.0	0.7	1.2	2.1
Bremen	0.1	0.3	1.0	4.8
Nordrhein-Westfalen	19.6	0.6	1.2	1.8
Hessen	18.6	0.9	2.4	3.6
Rheinland-Pfalz	10.0	0.5	1.4	2.3
Baden-Wurttemberg	34.1	0.9	2.3	4.1
Bayern	56.8	0.8	1.6	2.7
Saarland	0.9	0.4	1.3	2.3
West Germany	265.6	1.1	2.2	3.7
Ile de France	15.0	1.2	2.5	2.6
Bassin Parisien	224.0	1.5	2.3	3.4
Nord-Pas-de-Calais	2.6	0.2	0.3	0.4
Est	75.3	1.6	3.3	7.2
Ouest	51.6	0.6	0.8	1.2
Sud-Ouest	50.6	0.5	0.9	1.8
Centre-Est	46.1	0.6	1.3	3.7
Mediterranee	8.5	0.1	0.3	1.5
France	473.7	0.9	1.5	2.6
Nord-Ovest	0.0	0.0	0.0	0.0
Lombardia	0.0	0.0	0.0	0.0
Nord-Est	0.0	0.0	0.0	0.0
Emilia-Romagna	0.0	0.0	0.0	0.0
Centro	4.0	0.1	0.2	0.3
Lazio	2.9	0.2	0.3	0.5
Campania	0.0	0.0	0.0	0.0
Abruzzi-Molise	0.4	0.0	0.0	0.1
Sud	0.2	0.0	0.0	0.0
Sicilia	0.0	0.0	0.0	0.0
Sardegna	0.0	0.0	0.0	0.0
Italy	7.5	0.0	0.0	0.1
Noord-Nederland	5.9	0.7	1.0	2.5
Oost-Nederland	4.1	0.4	0.7	2.2
Zuid-Nederland	0.0	0.0	0.0	0.0
West-Nederland	0.1	0.0	0.0	0.0
Netherlands	10.1	0.3	0.5	1.2

	oil.r. (1000 ha)	oil.r. /total (%)	oil.r. /AA (%)	oil.r. /arab. (%)
Vlaams gewest	0.0	0.0	0.0	0.0
Region Wallonne	2.4	0.1	0.3	0.6
Brussel	0.0	0.0	0.0	0.0
Belgium	2.4	0.1	0.2	0.3
Luxembourg (G.D.)	0.5	0.2	0.4	0.9
North	13.6	0.8	1.1	4.7
Yorkshire & Humber.	47.5	3.1	4.0	7.5
East Midlands	74.4	4.7	6.0	8.5
East Anglia	37.8	3.0	3.8	4.4
South East	67.1	2.4	4.0	5.9
South West	10.2	0.4	0.5	1.3
West Midlands	17.6	1.4	1.8	3.5
North West	2.9	0.4	0.6	2.1
Wales	0.5	0.0	0.0	0.2
Scotland	0.0	0.0	0.0	0.0
Northern Ireland	0.0	0.0	0.0	0.0
United Kingdom	271.6	1.1	1.5	3.9
Ireland	3.0	0.0	0.1	0.3
Denmark	216.8	5.0	7.6	8.3
Greece	0.0	0.0	0.0	0.0
Noroeste	0.0	0.0	0.0	0.0
Noreste	2.9	0.0	0.1	0.1
Madrid	0.0	0.0	0.0	0.0
Centro	1.5	0.0	0.0	0.0
Este	0.8	0.0	0.0	0.1
Sur	4.1	0.0	0.1	0.1
Spain	9.3	0.0	0.0	0.1
Portugal	0.0	0.0	0.0	0.0

Appendix 24. Total potato area , and potato area as percentage of total area, agricultural area (AA) and arable area (arab.), for NUTS-1 regions and countries.
Source: Eurostat (1986, 1987), averages over 1982, 1983, 1984 and 1985.

	potato (1000 ha)	potato /total (%)	potato /AA (%)	potato /arab. (%)
Schleswig-Holstein	4.8	0.3	0.4	0.8
Hamburg	0.0	0.0	0.0	0.0
Niedersachsen	73.1	1.5	2.7	4.5
Bremen	0.0	0.0	0.0	0.0
Nordrhein-Westfalen	18.4	0.5	1.1	1.7
Hessen	10.9	0.5	1.4	2.1
Rheinland-Pfalz	12.7	0.6	1.7	3.0
Baden-Wurttemberg	18.1	0.5	1.2	2.2
Bayern	87.1	1.2	2.5	4.2
Saarland	0.6	0.2	0.8	1.4
West Germany	225.4	0.9	1.9	3.1
Ile de France	5.0	0.4	0.8	0.9
Bassin Parisien	72.0	0.5	0.7	1.1
Nord-Pas-de-Calais	37.3	3.1	4.0	5.6
Est	5.8	0.1	0.3	0.6
Ouest	36.9	0.4	0.6	0.8
Sud-Ouest	19.0	0.2	0.4	0.7
Centre-Est	18.9	0.3	0.5	1.5
Mediterranee	12.0	0.2	0.5	2.2
France	206.8	0.4	0.7	1.2
Nord-Ovest	12.0	0.4	0.8	1.7
Lombardia	4.2	0.2	0.3	0.5
Nord-Est	11.9	0.3	0.7	1.5
Emilia-Romagna	7.6	0.3	0.5	0.8
Centro	12.1	0.3	0.5	0.9
Lazio	8.5	0.5	0.8	1.5
Campania	31.2	2.2	3.6	7.2
Abruzzi-Molise	18.3	1.1	2.0	3.6
Sud	28.3	0.6	0.9	1.9
Sicilia	7.1	0.3	0.4	0.7
Sardegna	2.0	0.1	0.1	0.6
Italy	142.9	0.5	0.8	1.6
Noord-Nederland	76.2	8.9	13.3	32.4
Oost-Nederland	29.7	2.9	5.3	15.7
Zuid-Nederland	16.1	2.3	4.2	8.9
West-Nederland	42.7	4.7	8.7	18.0
Netherlands	164.7	4.7	8.2	19.5

	potato (1000 ha)	potato /total (%)	potato /AA (%)	potato /arab. (%)
Vlaams gewest	28.8	2.1	4.6	8.2
Region Wallonne	8.2	0.5	1.1	2.2
Brussel	0.0	0.0	0.0	0.0
Belgium	37.0	1.2	2.7	5.0
Luxembourg (G.D.)	1.0	0.4	0.8	1.8
North	4.0	0.2	0.3	1.4
Yorkshire & Humber.	23.4	1.5	2.0	3.7
East Midlands	29.2	1.9	2.4	3.3
East Anglia	29.0	2.3	2.9	3.4
South East	18.2	0.7	1.1	1.6
South West	9.6	0.4	0.5	1.2
West Midlands	17.9	1.4	1.8	3.6
North West	9.5	1.3	2.0	6.8
Wales	5.8	0.3	0.4	2.2
Scotland	34.6	0.4	0.6	3.1
Northern Ireland	14.0	1.0	1.3	4.4
United Kingdom	195.1	0.8	1.1	2.8
Ireland	34.2	0.5	0.6	3.1
Denmark	31.9	0.7	1.1	1.2
Greece	53.4	0.4	0.9	1.8
Noroeste	112.0	2.4	7.9	19.4
Noreste	43.0	0.6	1.1	1.9
Madrid	3.2	0.4	0.8	1.4
Centro	85.3	0.4	0.7	1.0
Este	36.0	0.6	1.4	3.4
Sur	40.0	0.4	0.7	1.3
Spain	330.9	0.6	1.2	2.1
Portugal	126.0	1.4	2.8	4.3

Appendix 25. Total sugar beet area (sug.b.z), and sugar beet area as percentage of total area, agricultural area (AA) and arable area (arab), for NUTS-1 regions and countries.
Source: Eurostat (1986, 1987), averages over 1982, 1983, 1984 and 1985.

	sug.b. (1000 ha)	sug.b. /total (%)	sug.b. /AA (%)	sug.b. /arab. (%)
Schleswig-Holstein	18.3	1.2	1.7	3.0
Hamburg	0.0	0.0	0.0	0.0
Niedersachsen	153.9	3.2	5.6	9.4
Bremen	0.0	0.0	0.0	0.0
Nordrhein-Westfalen	82.2	2.4	5.1	7.5
Hessen	22.0	1.0	2.8	4.3
Rheinland-Pfalz	22.5	1.1	3.1	5.2
Baden-Wurttemberg	23.0	0.6	1.5	2.7
Bayern	83.0	1.2	2.4	4.0
Saarland	0.0	0.0	0.0	0.0
West Germany	404.8	1.6	3.4	5.6
Ile de France	50.2	4.2	8.2	8.7
Bassin Parisien	378.6	2.6	3.9	5.8
Nord-Pas-de-Calais	76.7	6.3	8.3	11.5
Est	6.3	0.1	0.3	0.6
Ouest	1.2	0.0	0.0	0.0
Sud-Ouest	0.0	0.0	0.0	0.0
Centre-Est	4.4	0.1	0.1	0.4
Mediterranee	0.0	0.0	0.0	0.0
France	517.4	0.9	1.6	2.9
Nord-Ovest	4.7	0.1	0.3	0.7
Lombardia	15.3	0.6	1.3	1.9
Nord-Est	32.0	0.8	1.8	4.0
Emilia-Romagna	111.6	5.0	8.0	11.1
Centro	37.5	0.9	1.7	2.7
Lazio	5.2	0.3	0.5	0.9
Campania	2.0	0.1	0.2	0.5
Abruzzi-Molise	7.6	0.5	0.8	1.5
Sud	25.8	0.5	0.8	1.7
Sicilia	0.0	0.0	0.0	0.0
Sardegna	3.8	0.2	0.2	1.2
Italy	245.4	0.8	1.4	2.7
Noord-Nederland	39.6	4.6	6.9	16.8
Oost-Nederland	23.8	2.4	4.2	12.6
Zuid-Nederland	27.8	4.0	7.2	15.3
West-Nederland	38.0	4.2	7.7	16.0
Netherlands	129.2	3.7	6.4	15.3

	sug.b. (1000 ha)	sug.b. /total (%)	sug.b. /AA (%)	sug.b. /arab. (%)
Vlaams gewest	40.5	3.0	6.5	11.5
Region Wallonne	76.4	4.5	9.9	20.0
Brussel	0.0	0.0	0.0	0.0
Belgium	116.9	3.8	8.4	15.9
Luxembourg (G.D.)	0.0	0.0	0.0	0.0
North	0.0	0.0	0.0	0.0
Yorkshire & Humber.	24.9	1.6	2.1	3.9
East Midlands	44.3	2.8	3.6	5.1
East Anglia	107.7	8.6	10.9	12.5
South East	5.8	0.2	0.3	0.5
South West	0.8	0.0	0.0	0.1
West Midlands	17.3	1.3	1.8	3.4
North West	0.7	0.1	0.2	0.5
Wales	0.2	0.0	0.0	0.1
Scotland	0.0	0.0	0.0	0.0
Northern Ireland	0.0	0.0	0.0	0.0
United Kingdom	201.5	0.8	1.1	2.9
Ireland	34.7	0.5	0.6	3.2
Denmark	74.1	1.7	2.6	2.8
Greece	37.8	0.3	0.7	1.3
Noroeste	0.0	0.0	0.0	0.0
Noreste	11.6	0.2	0.3	0.5
Madrid	.2	0.0	0.0	0.1
Centro	117.5	0.5	0.9	1.4
Este	.0	0.0	0.0	0.0
Sur	53.1	0.5	0.9	1.8
Spain	182.4	0.4	0.7	1.2
Portugal	2.0	0.0	0.0	0.1

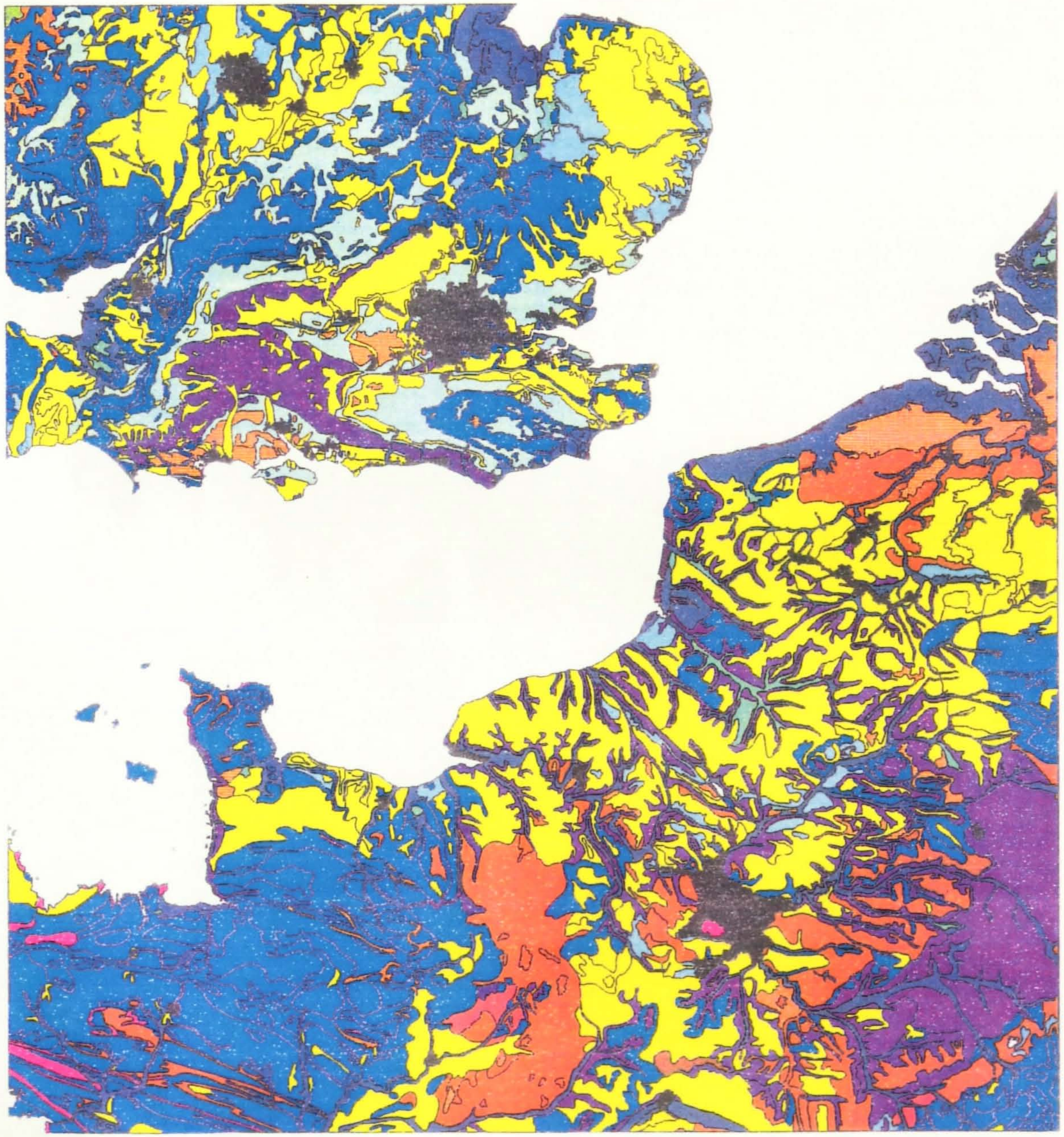
Appendix 26. Estimated suitable soil area for extensive grass cultivation for NUTS-1 regions and countries within the EC. The suitable area is expressed as percentage of the total area.

Region/country	% suitable	Region/country	% suitable
Schleswig-Holstein	99	Vlaams gewest	99
Hamburg	87	Region Wallonne	99
Niedersachsen	99	Brussel	48
Bremen	91	Belgium	99
Nordrhein-Westfalen	93		
Hessen	99	Luxembourg (G.D.)	99
Rheinland-Pfalz	95		
Baden-Wurttemberg	96	North	91
Bayern	90	Yorkshire & Humber.	97
Saarland	95	East Midlands	98
West Germany	95	East Anglia	99
		South East	91
Ile de France	85	South West	98
Bassin Parisien	99	West Midlands	93
Nord-Pas-de-Calais	96	North West	86
Est	89	Wales	84
Ouest	98	Scotland	94
Sud-Ouest	91	Northern Ireland	95
Centre-Est	77	United Kingdom	93
Mediterranee	82		
France	92	Ireland	98
Nord-Ovest	67	Denmark	99
Lombardia	79		
Nord-Est	71	Ellas (North)	42
Emilia-Romagna	81	Ellas (Central)	39
Centro	73	Ellas (East, S. isl)	29
Lazio	71	Greece	39
Campania	61		
Abruzzi-Molise	69	Noroeste	61
Sud	70	Noreste	86
Sicilia	78	Madrid	85
Sardegna	67	Centro	83
Italy	72	Este	90
		Sur	88
Noord-Nederland	99	Spain	83
Oost-Nederland	99		
Zuid-Nederland	100	Norte do continente	69
West-Nederland	96	Sud do Continente	74
Netherlands	99	Portugal	71

MAP 1

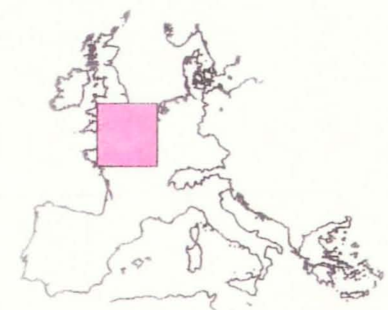
PART OF THE SOIL MAP OF THE EC

SCALE 1 : 2500000



LEGEND

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



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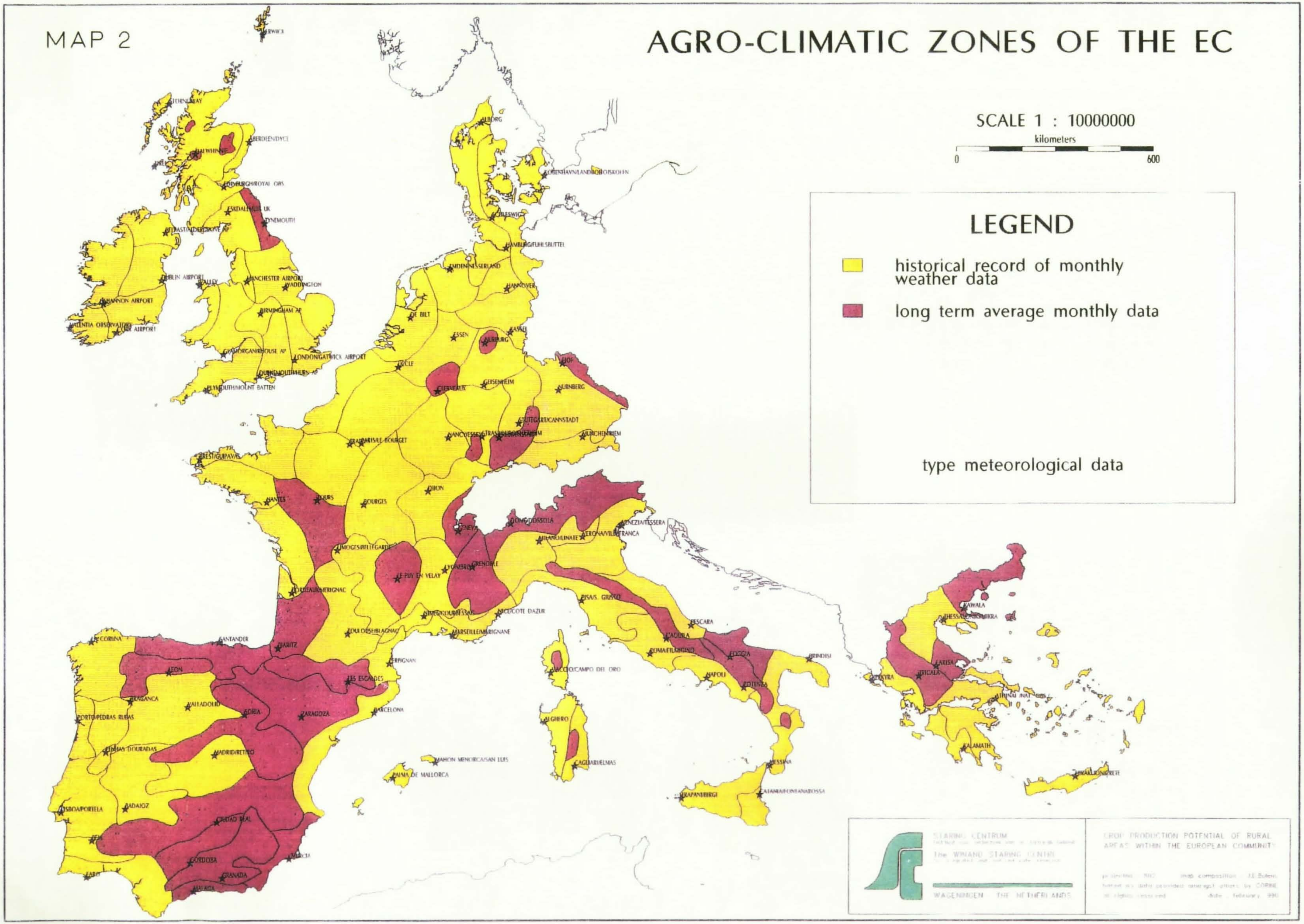
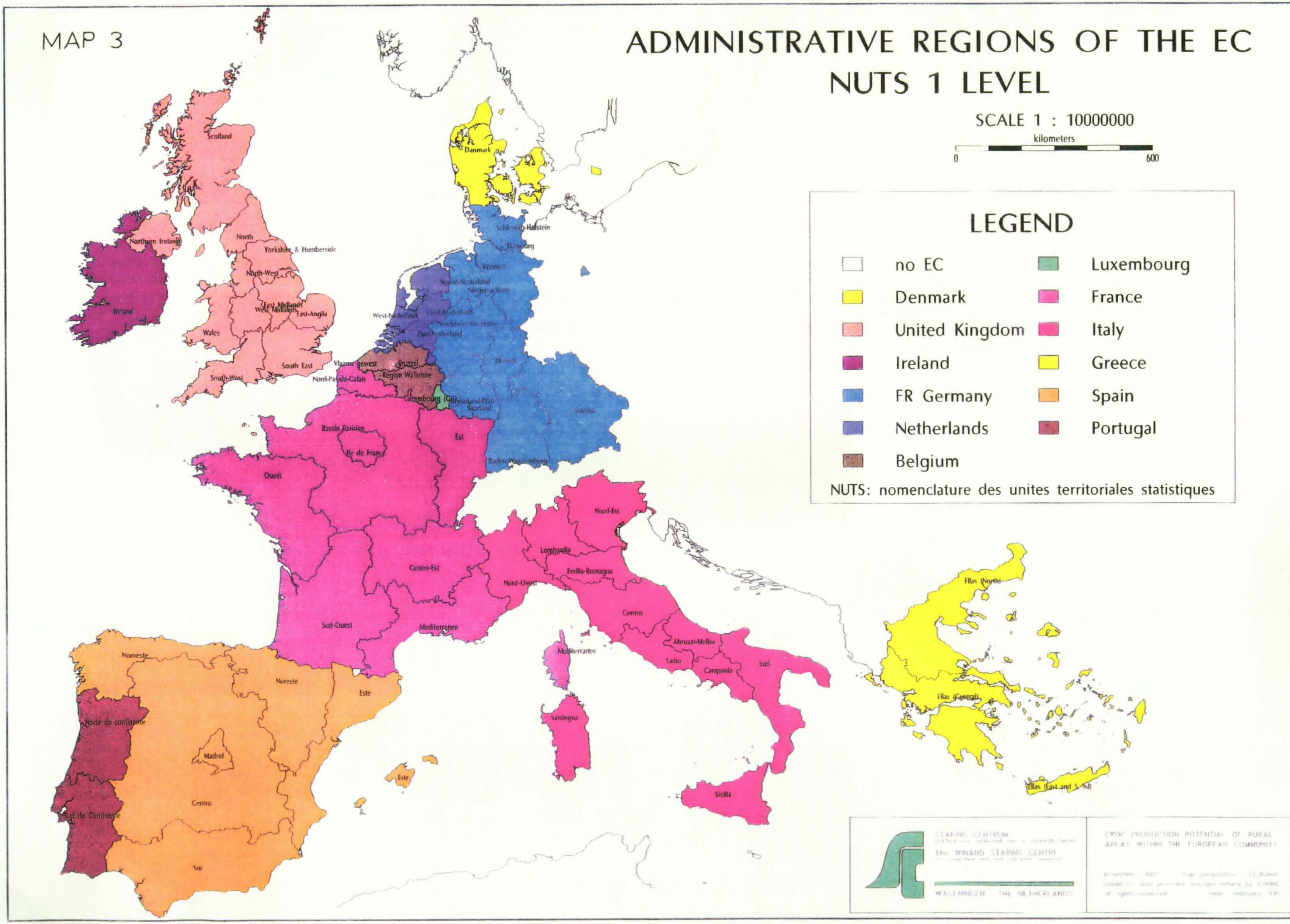
MAP 2

AGRO-CLIMATIC ZONES OF THE EC




MAP 3
ADMINISTRATIVE REGIONS OF THE EC
NUTS 1 LEVEL
SCALE 1 : 10000000
kilometers
0
600
LEGEND
no EC
Denmark
United Kingdom
Ireland
FR Germany
Netherlands
Belgium
Luxembourg
France
Italy
Greece
Spain
Portugal
NUTS: nomenclature des unites territoriales statistiques
Scotland
Northern Ireland
North
Yorkshire & Humberside
North-West
East Midlands
West Midlands
East-Anglia
Wales
South East
South-West
Ireland
Danmark
Schleswig-Holstein
Bremen
Niedersachsen
Hessen
Bayern
Saarland
Baden-Württemberg
Noord-Nederland
Oost-Nederland
West-Nederland
Zuid-Nederland
Vlaams Gewest
Brussel
Region Wallonne
Nord-Pas-de-Calais
Bassin Parisien
Ile de France
Est
Ouest
Centre-Est
Sud-Ouest
Mediterranee
Nord-Est
Lombardia
Emilia-Romagna
Nord-Ovest
Centro
Abruzzi-Molise
Lazio
Campania
Sud
Sardegna
Sicilia
Ellas (North)
Ellas (Central)
Ellas (East and S. Kl)
Noroeste
Noreste
Este
Madrid
Centro
Sur
Norte do continente
Sul do Continente
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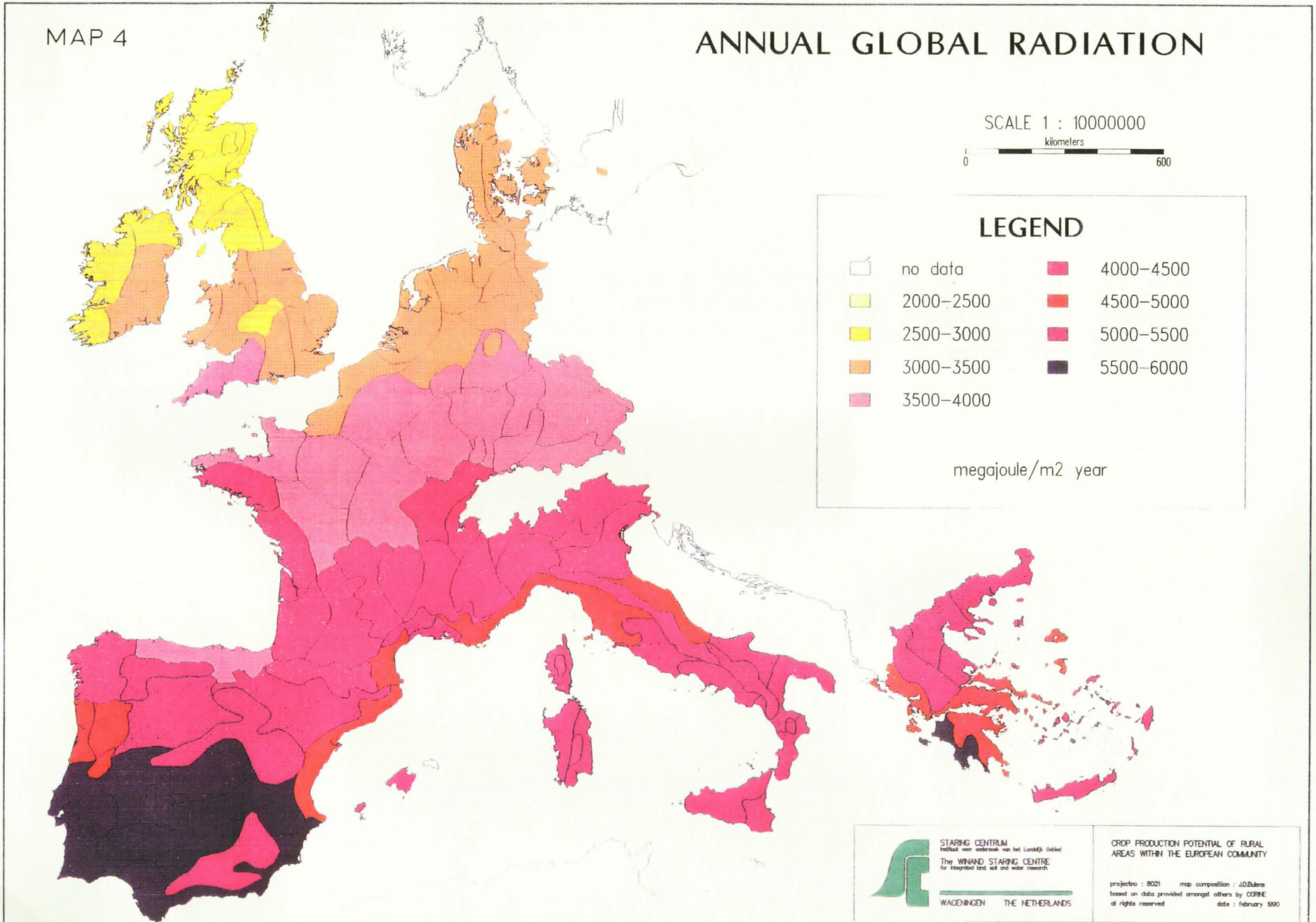
MAP 4
ANNUAL GLOBAL RADIATION
SCALE 1 : 10000000
kilometers
0
600
LEGEND
no data
2000-2500
2500-3000
3000-3500
3500-4000
4000-4500
4500-5000
5000-5500
5500-6000
megajoule/m2 year
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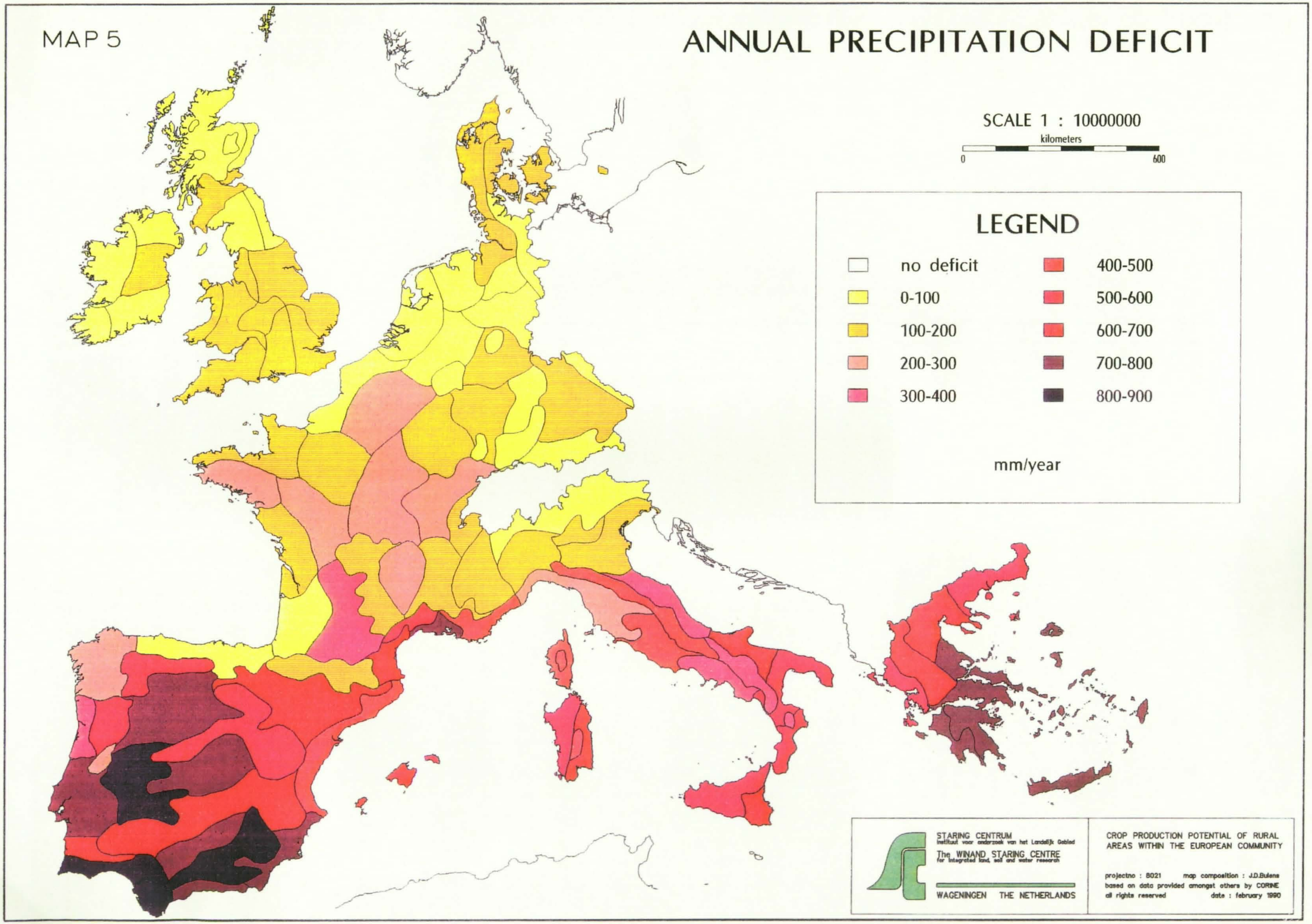
MAP 5
ANNUAL PRECIPITATION DEFICIT
SCALE 1 : 10000000
kilometers
0
600
LEGEND
no deficit
0-100
100-200
200-300
300-400
400-500
500-600
600-700
700-800
800-900
mm/year
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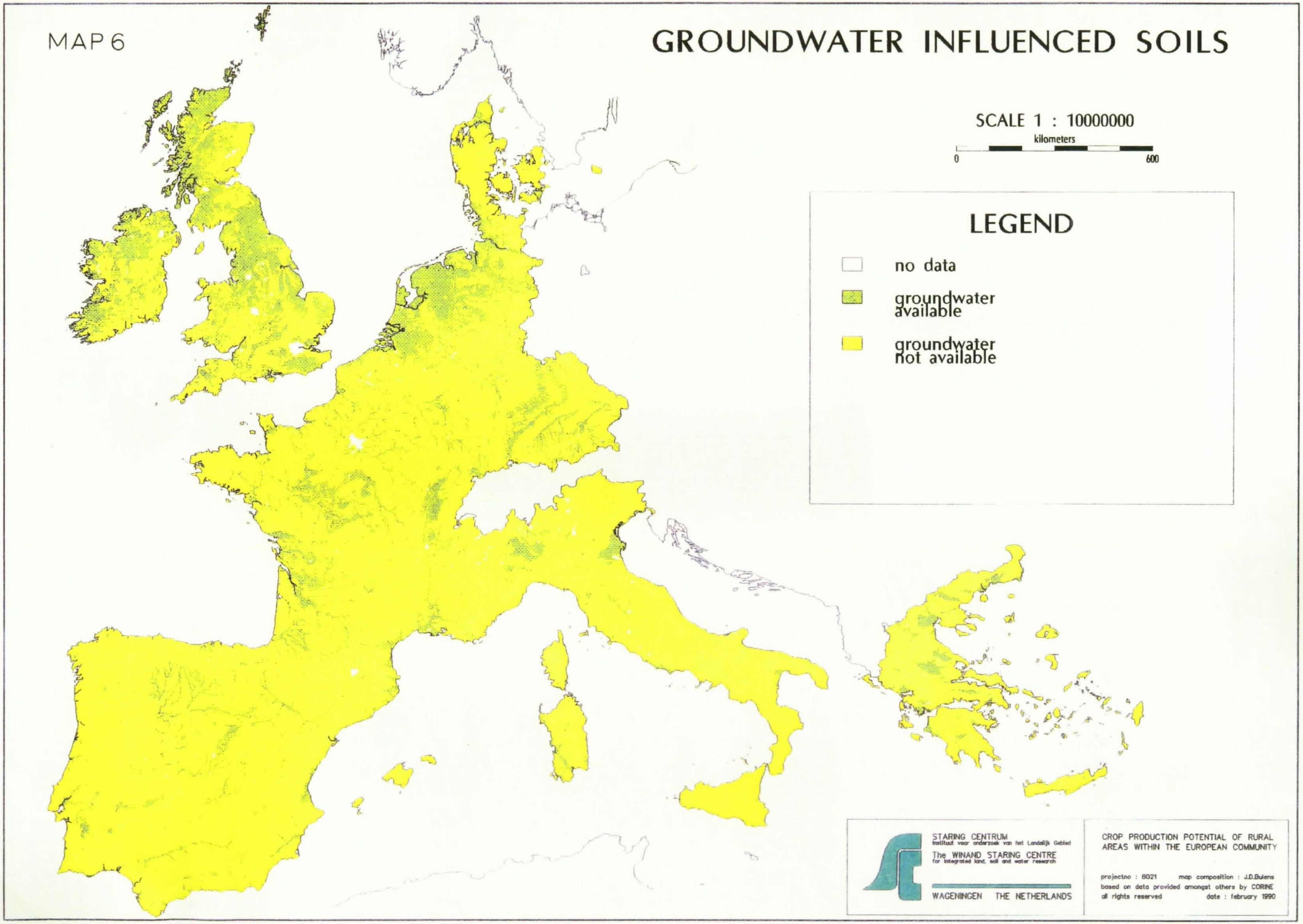
MAP 6
GROUNDWATER INFLUENCED SOILS
SCALE 1 : 10000000
kilometers
0
600
LEGEND
no data
groundwater available
groundwater not available
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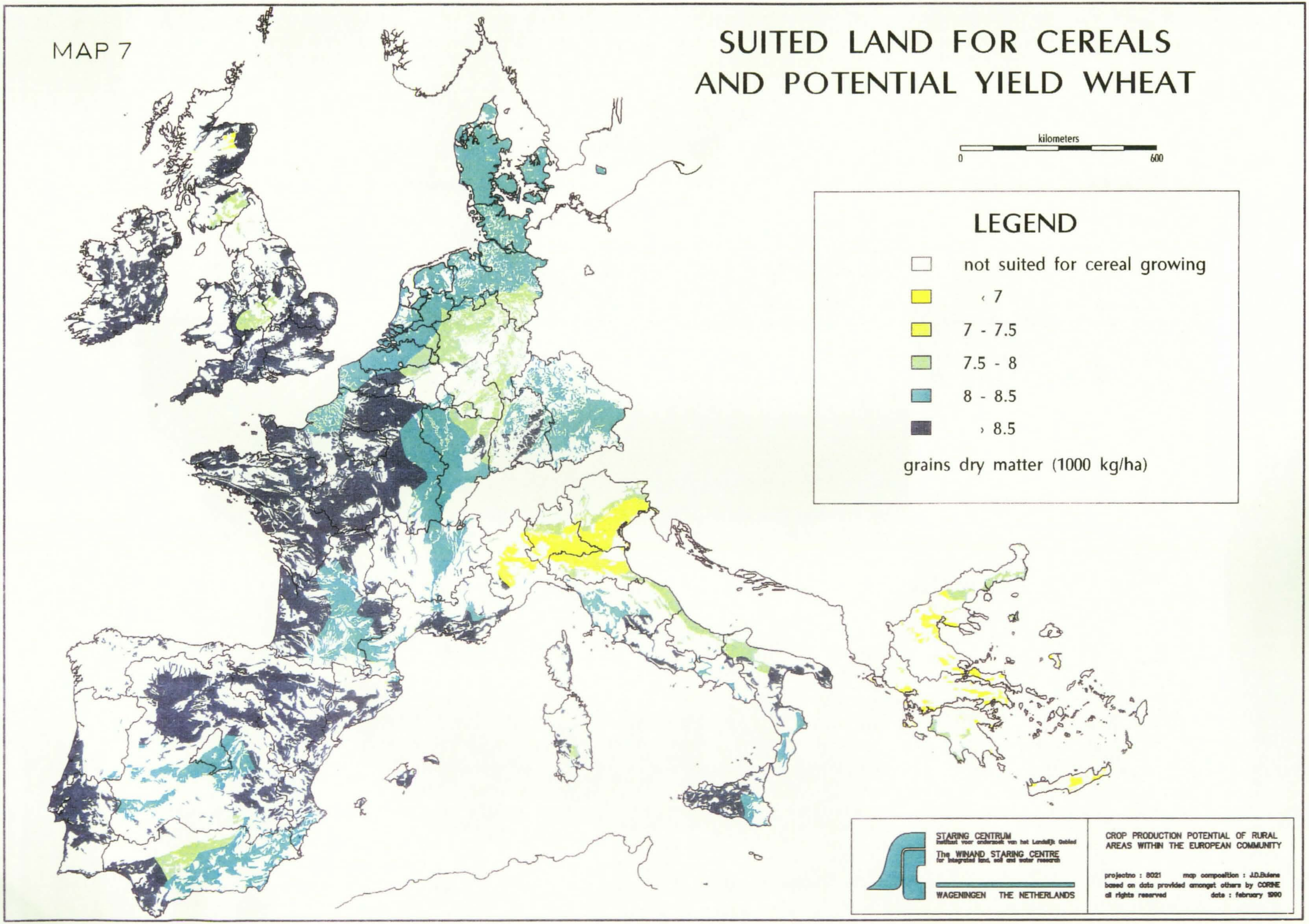
MAP 7
SUITED LAND FOR CEREALS AND POTENTIAL YIELD WHEAT
kilometers
0
600
LEGEND
not suited for cereal growing
‹ 7
7 - 7.5
7.5 - 8
8 - 8.5
› 8.5
grains dry matter (1000 kg/ha)
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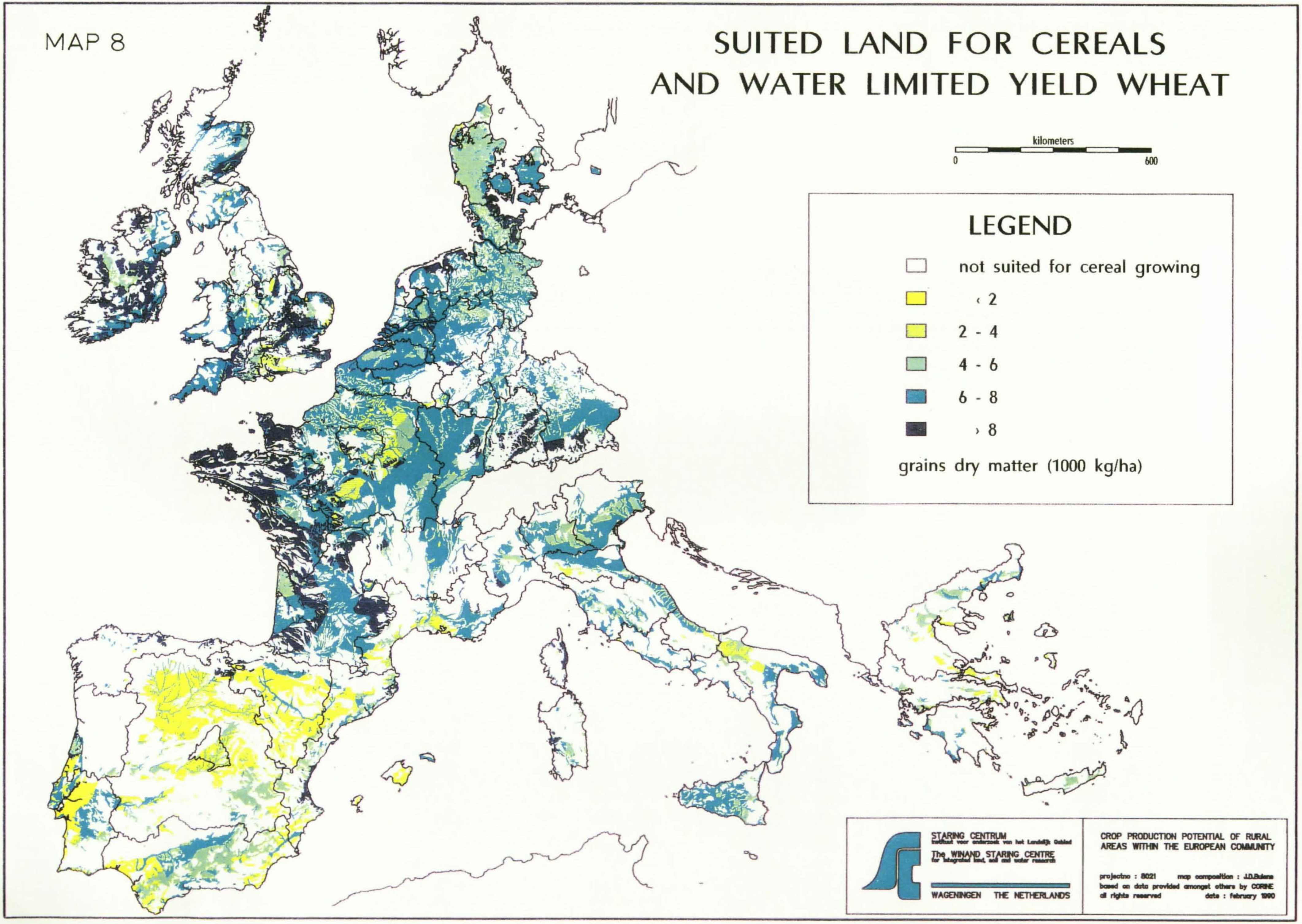
MAP 8
SUITED LAND FOR CEREALS
AND WATER LIMITED YIELD WHEAT
kilometers
0
600
LEGEND
not suited for cereal growing
‹ 2
2 - 4
4 - 6
6 - 8
› 8
grains dry matter (1000 kg/ha)
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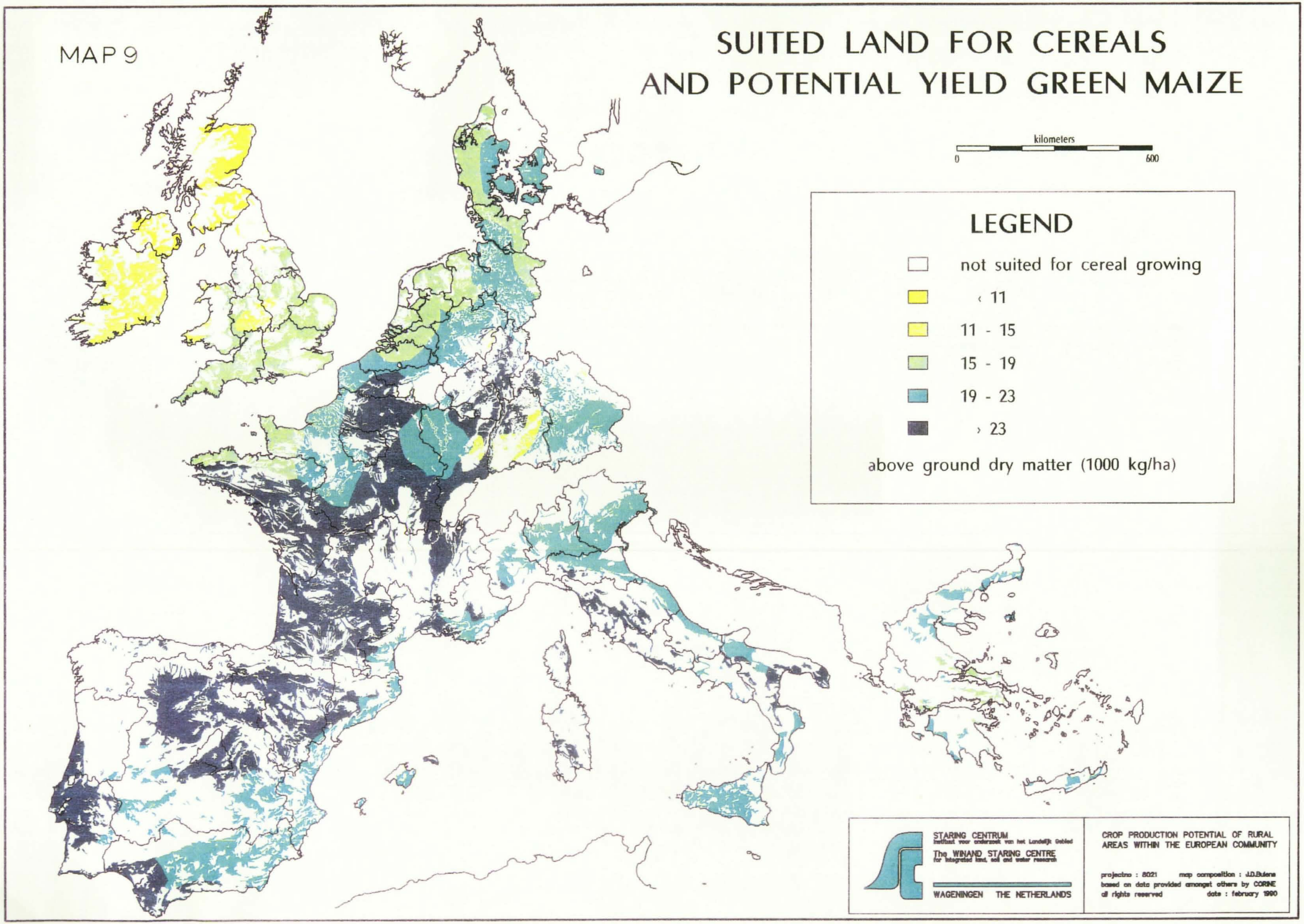
MAP 9
SUITED LAND FOR CEREALS
AND POTENTIAL YIELD GREEN MAIZE
kilometers
0
600
LEGEND
not suited for cereal growing
‹ 11
11 - 15
15 - 19
19 - 23
› 23
above ground dry matter (1000 kg/ha)
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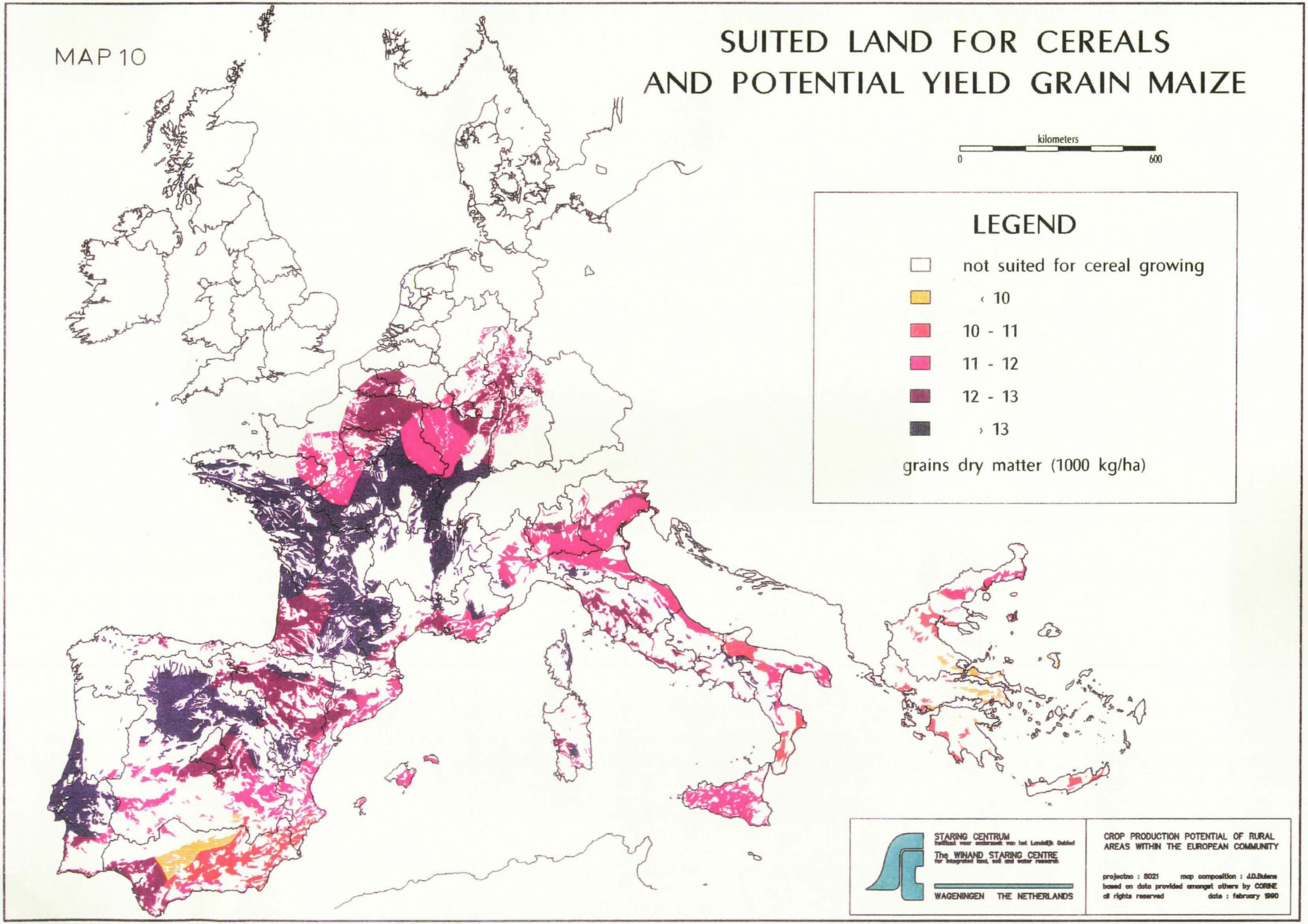
MAP 10
SUITED LAND FOR CEREALS
AND POTENTIAL YIELD GRAIN MAIZE
kilometers
0
600
LEGEND
not suited for cereal growing
‹ 10
10 - 11
11 - 12
12 - 13
› 13
grains dry matter (1000 kg/ha)
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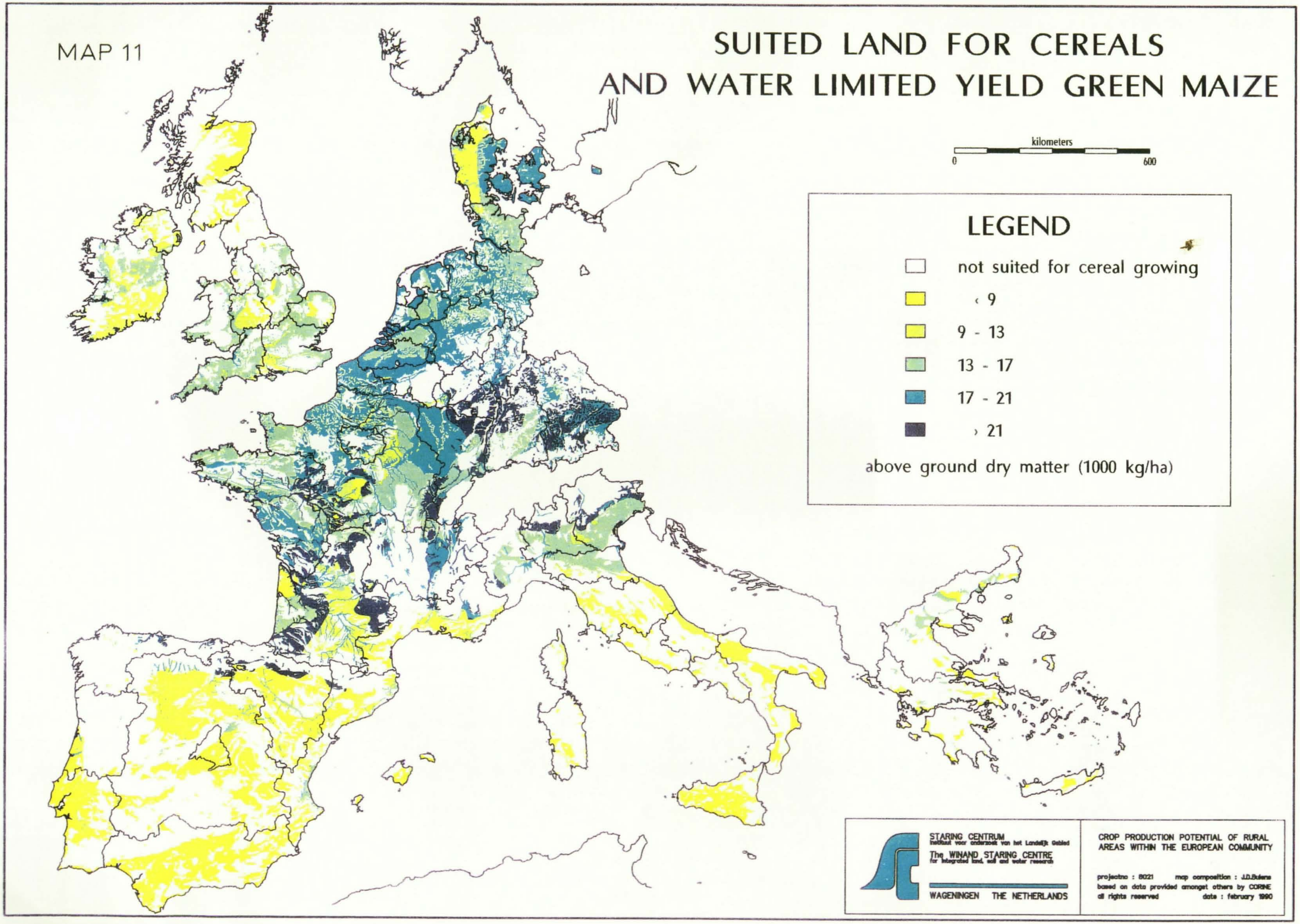

MAP 11
SUITED LAND FOR CEREALS
AND WATER LIMITED YIELD GREEN MAIZE
kilometers
0
600
LEGEND
not suited for cereal growing
< 9
9 - 13
13 - 17
17 - 21
> 21
above ground dry matter (1000 kg/ha)
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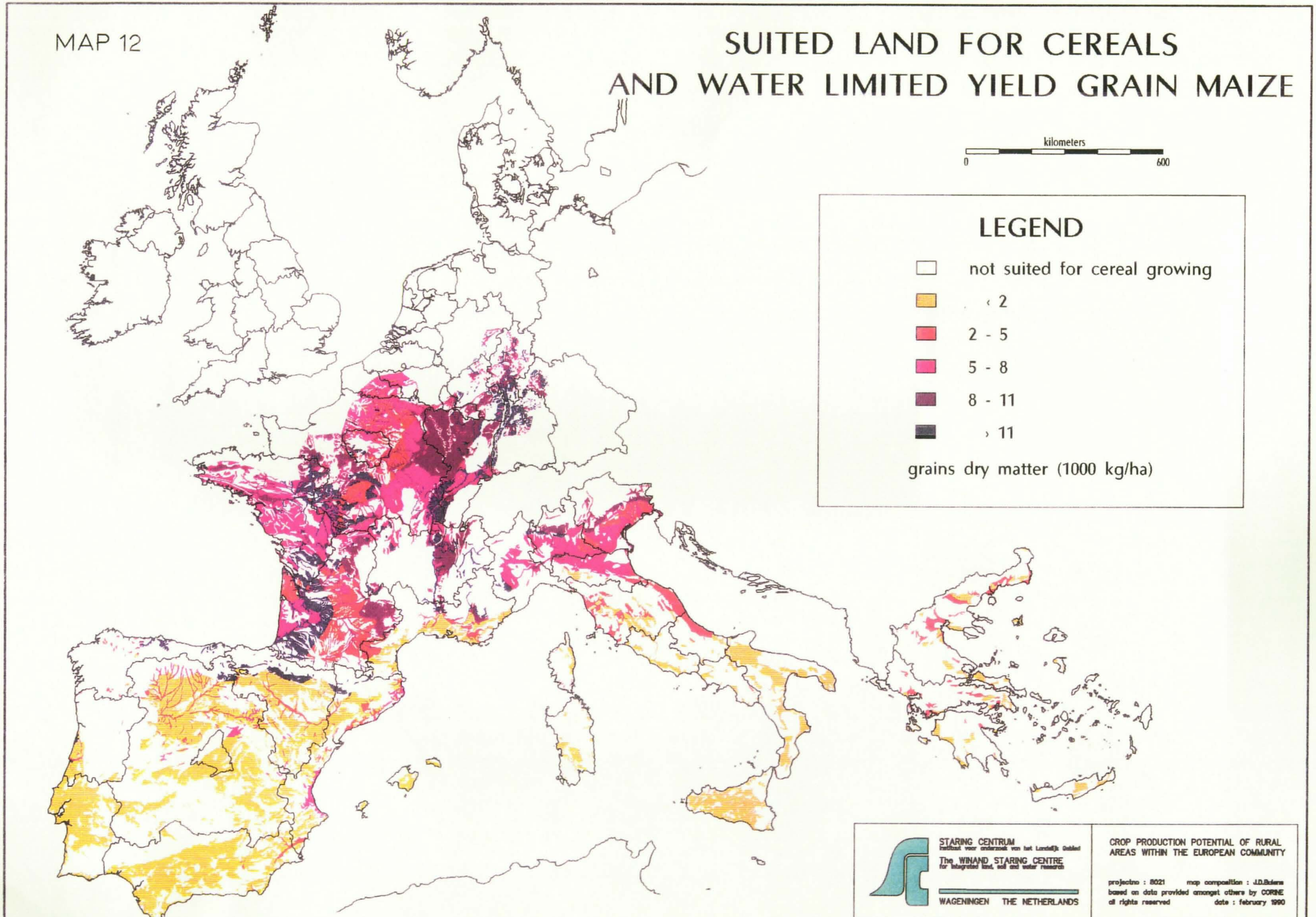
MAP 12
SUITED LAND FOR CEREALS AND WATER LIMITED YIELD GRAIN MAIZE
kilometers
0
600
LEGEND
not suited for cereal growing
‹ 2
2 - 5
5 - 8
8 - 11
› 11
grains dry matter (1000 kg/ha)
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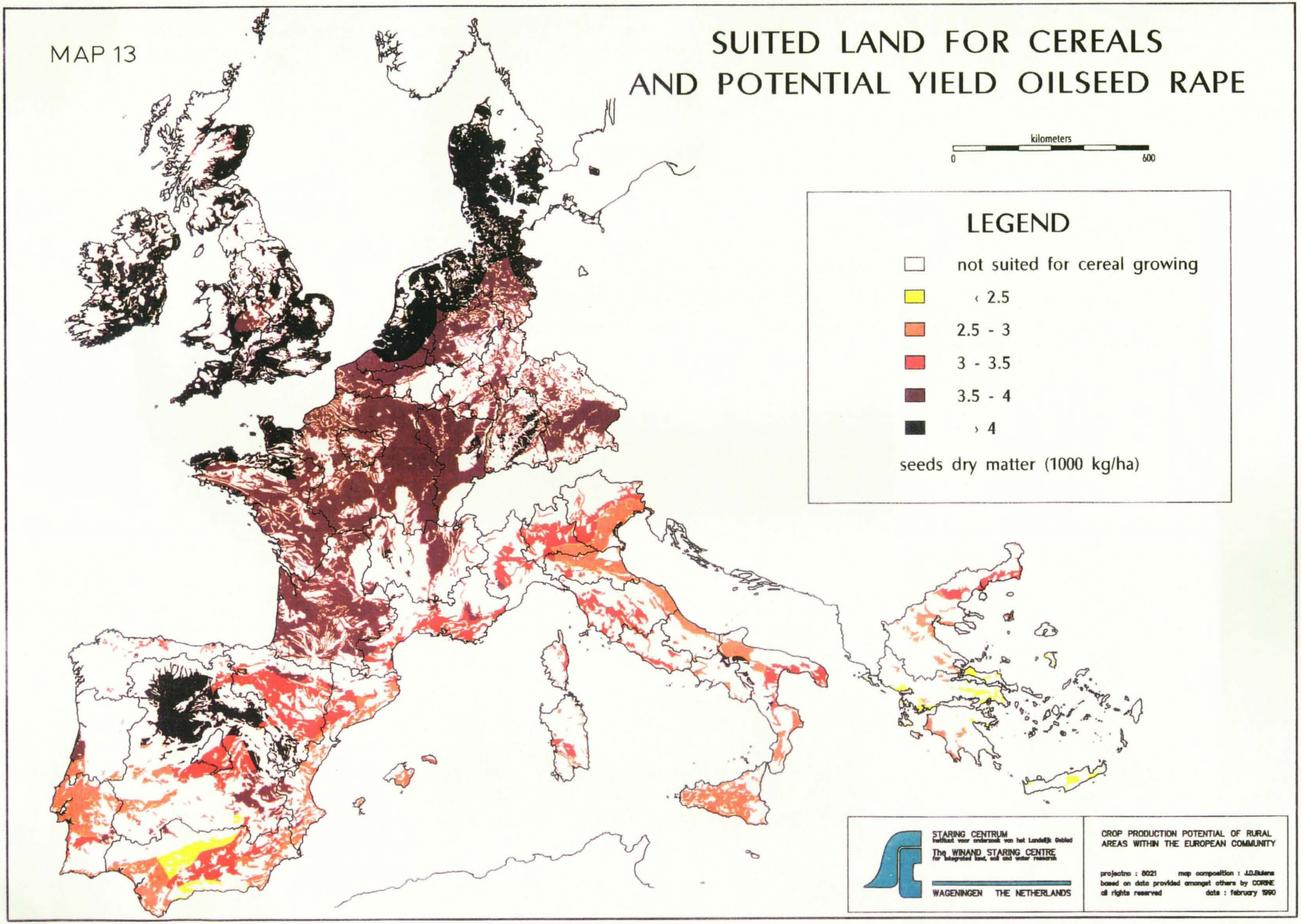
MAP 13
SUITED LAND FOR CEREALS
AND POTENTIAL YIELD OILSEED RAPE
kilometers
0
600
LEGEND
not suited for cereal growing
‹ 2.5
2.5 - 3
3 - 3.5
3.5 - 4
› 4
seeds dry matter (1000 kg/ha)
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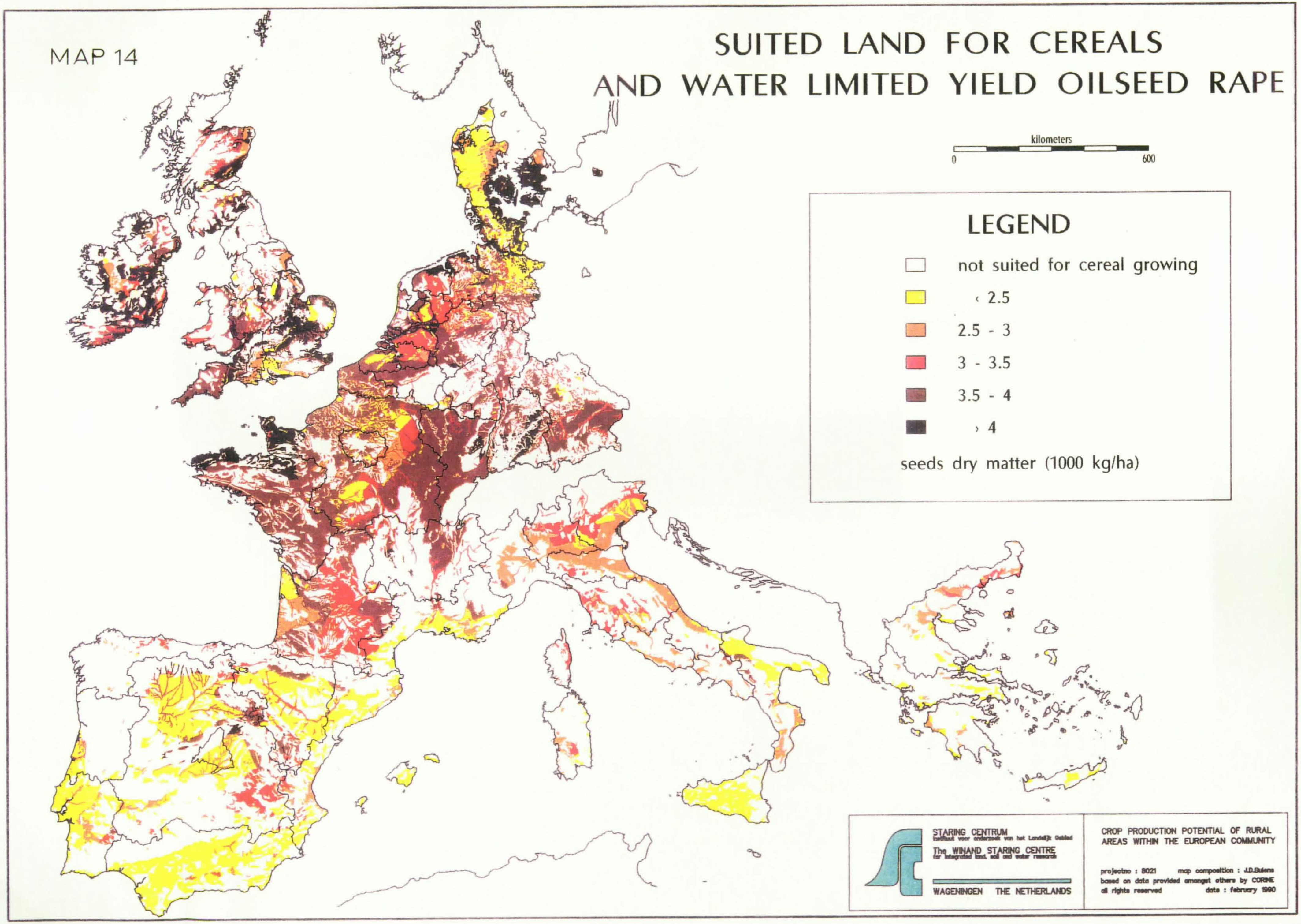
MAP 14
SUITED LAND FOR CEREALS
AND WATER LIMITED YIELD OILSEED RAPE
kilometers
0
600
LEGEND
not suited for cereal growing
‹ 2.5
2.5 - 3
3 - 3.5
3.5 - 4
› 4
seeds dry matter (1000 kg/ha)
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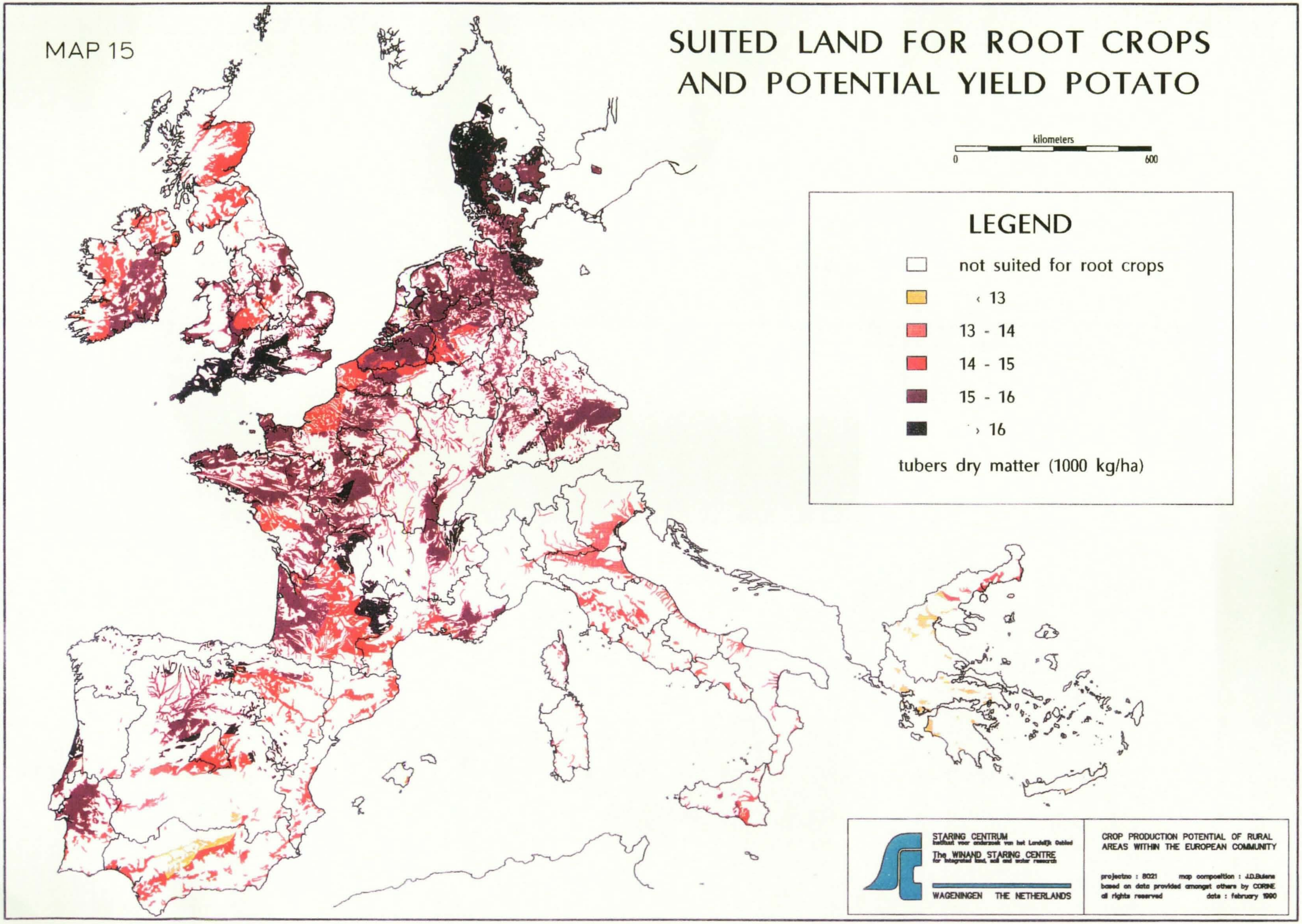
MAP 15
SUITED LAND FOR ROOT CROPS AND POTENTIAL YIELD POTATO
kilometers
0
600
LEGEND
not suited for root crops
‹ 13
13 - 14
14 - 15
15 - 16
› 16
tubers dry matter (1000 kg/ha)
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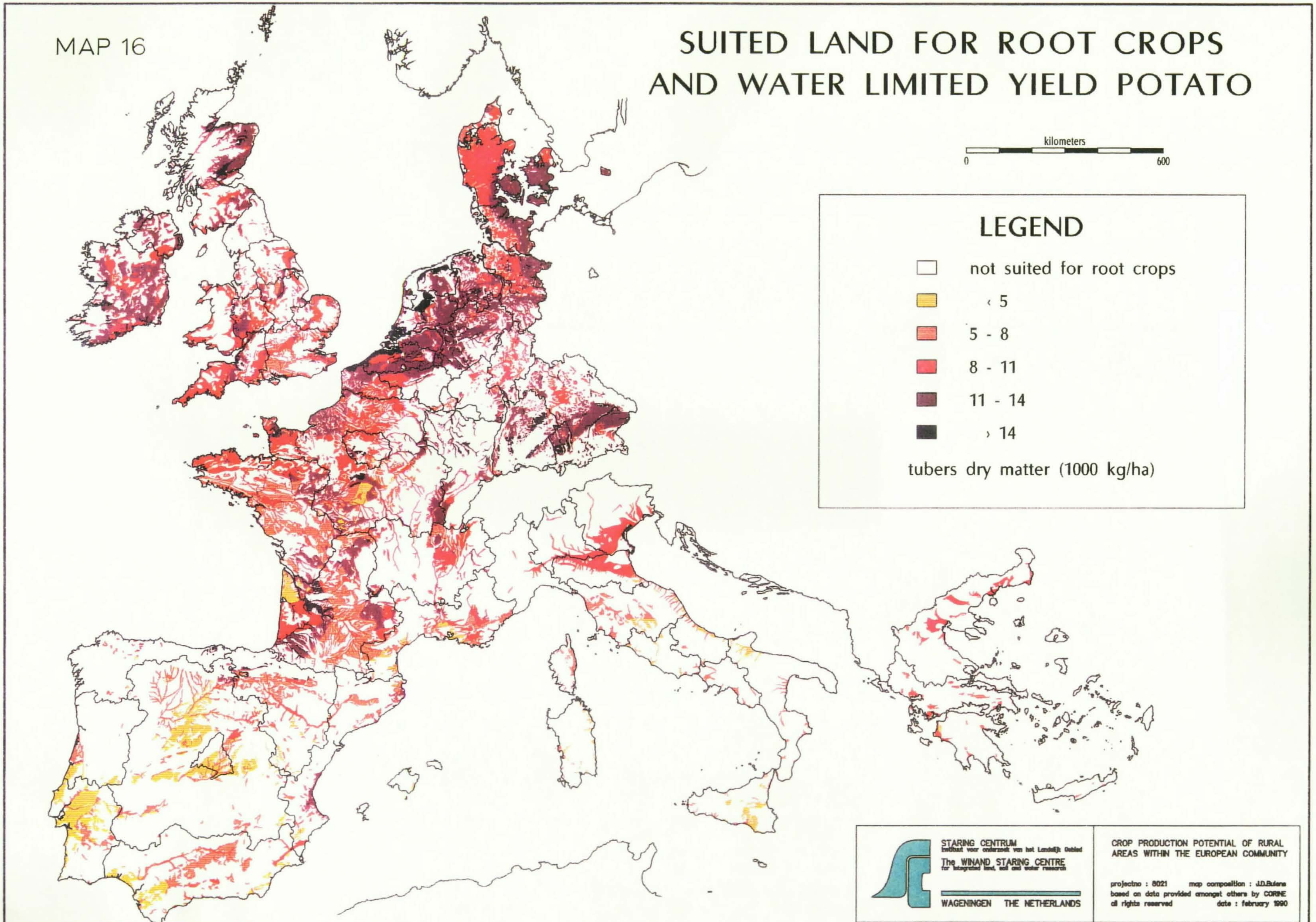
MAP 16
SUITED LAND FOR ROOT CROPS
AND WATER LIMITED YIELD POTATO
kilometers
0
600
LEGEND
not suited for root crops
‹ 5
5 - 8
8 - 11
11 - 14
› 14
tubers dry matter (1000 kg/ha)
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AREAS WITHIN THE EUROPEAN COMMUNITY
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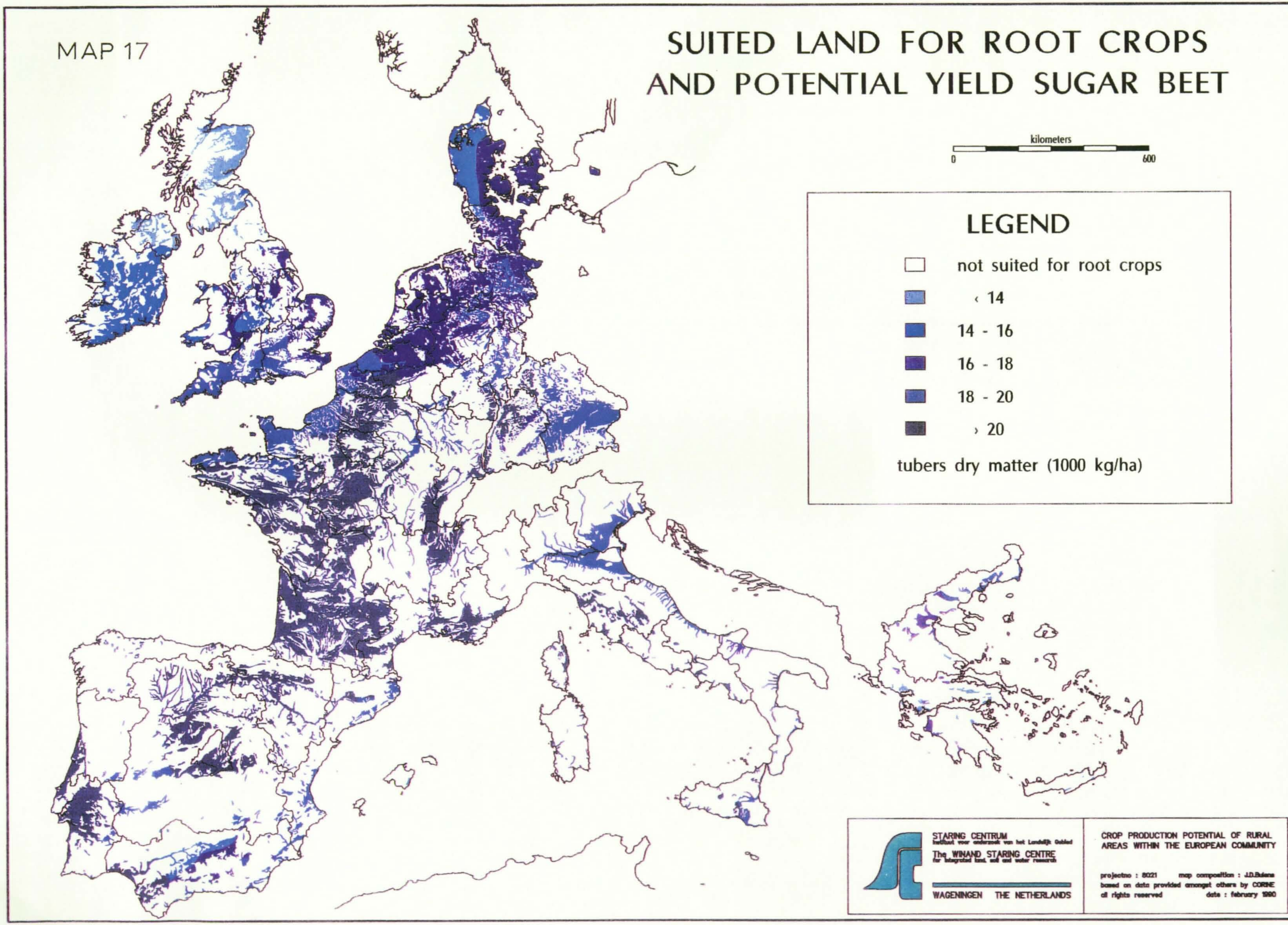
MAP 17
SUITED LAND FOR ROOT CROPS AND POTENTIAL YIELD SUGAR BEET
kilometers
0
600
LEGEND
not suited for root crops
‹ 14
14 - 16
16 - 18
18 - 20
› 20
tubers dry matter (1000 kg/ha)
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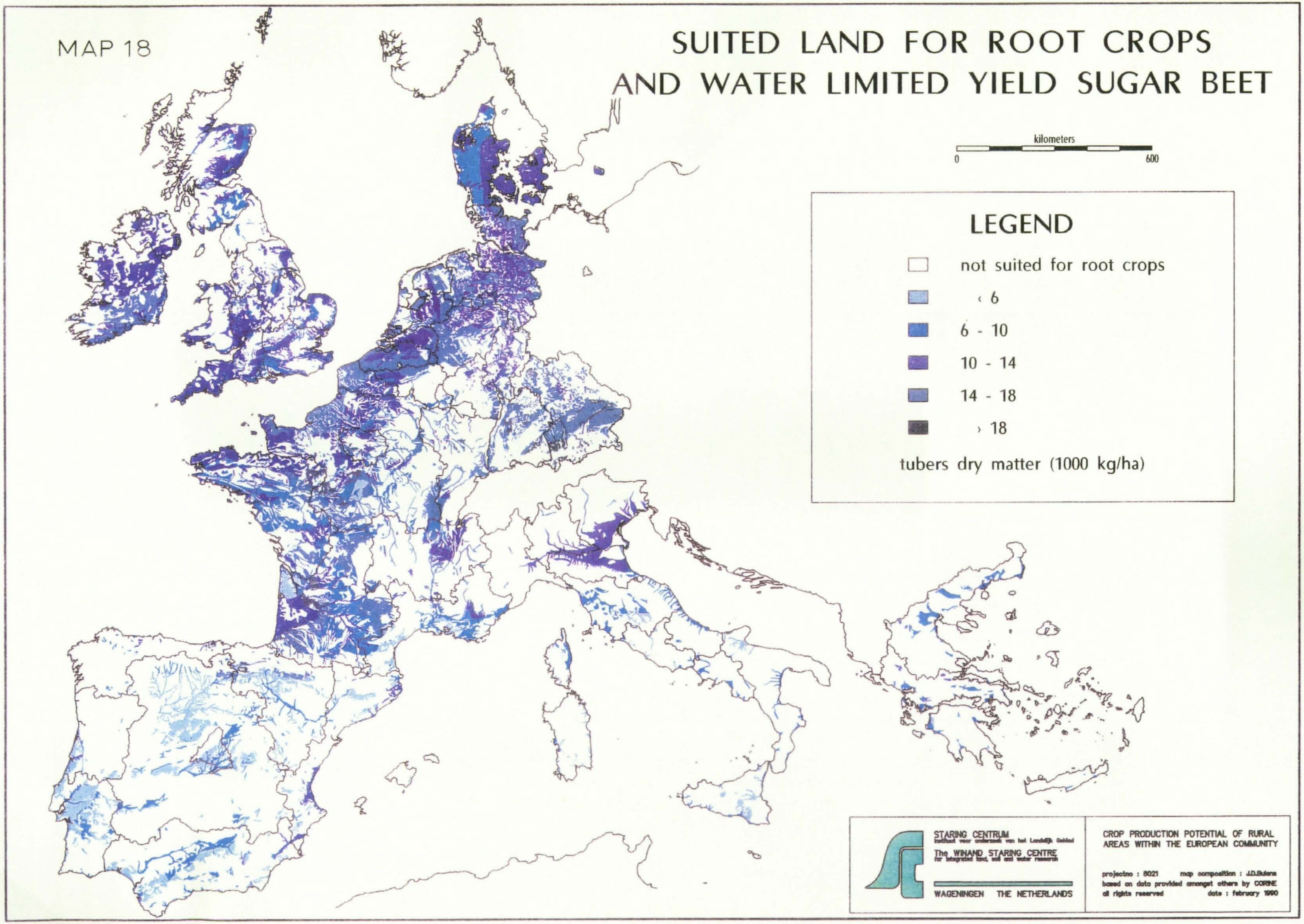
MAP 18
SUITED LAND FOR ROOT CROPS
AND WATER LIMITED YIELD SUGAR BEET
kilometers
0
600
LEGEND
not suited for root crops
‹ 6
6 - 10
10 - 14
14 - 18
› 18
tubers dry matter (1000 kg/ha)
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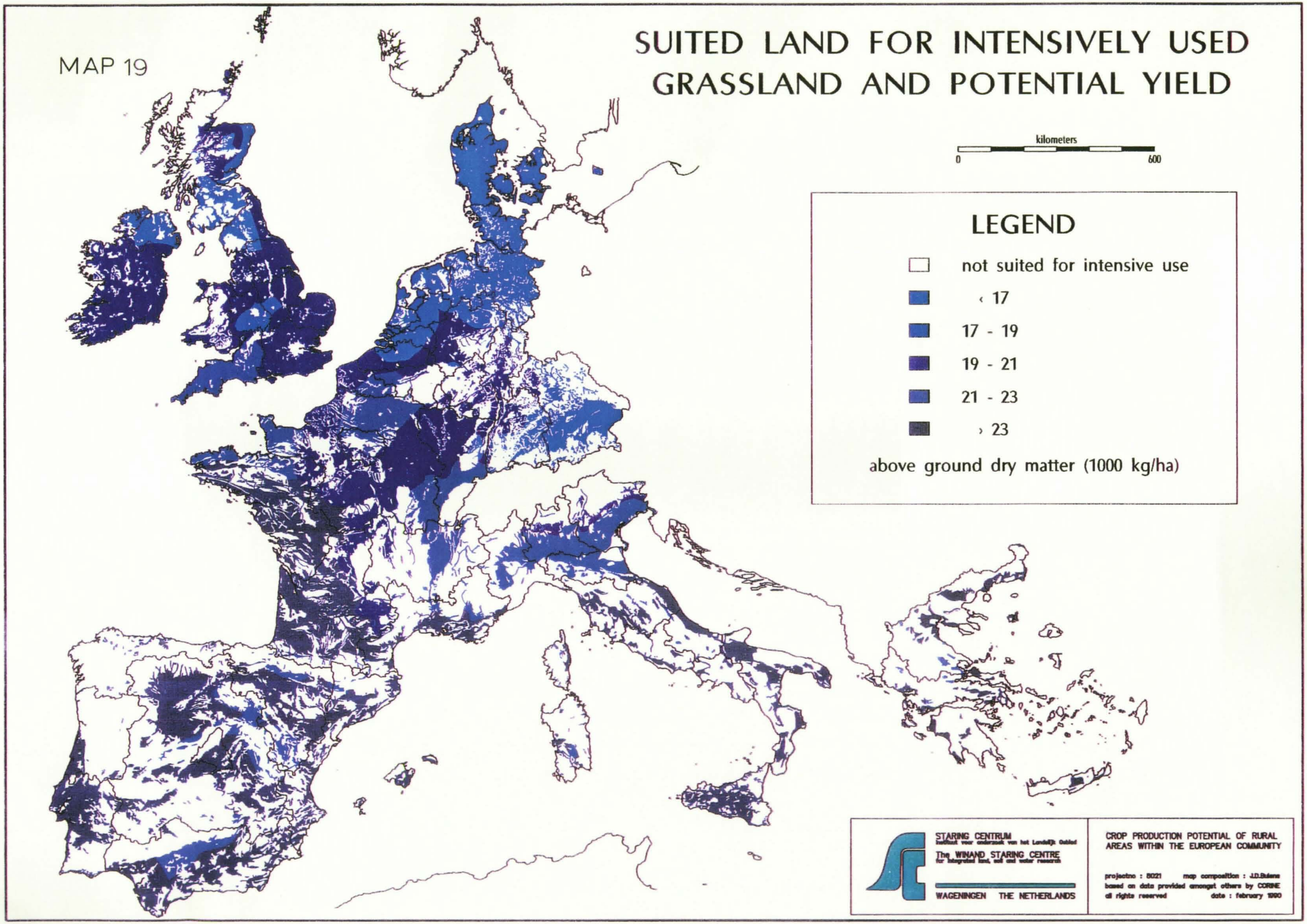
MAP 19
SUITED LAND FOR INTENSIVELY USED GRASSLAND AND POTENTIAL YIELD
kilometers
0
600
LEGEND
not suited for intensive use
‹ 17
17 - 19
19 - 21
21 - 23
› 23
above ground dry matter (1000 kg/ha)
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for integrated land, soil and water research
WAGENINGEN THE NETHERLANDS
CROP PRODUCTION POTENTIAL OF RURAL AREAS WITHIN THE EUROPEAN COMMUNITY
projectno : 8021 map composition : J.D.Bulens
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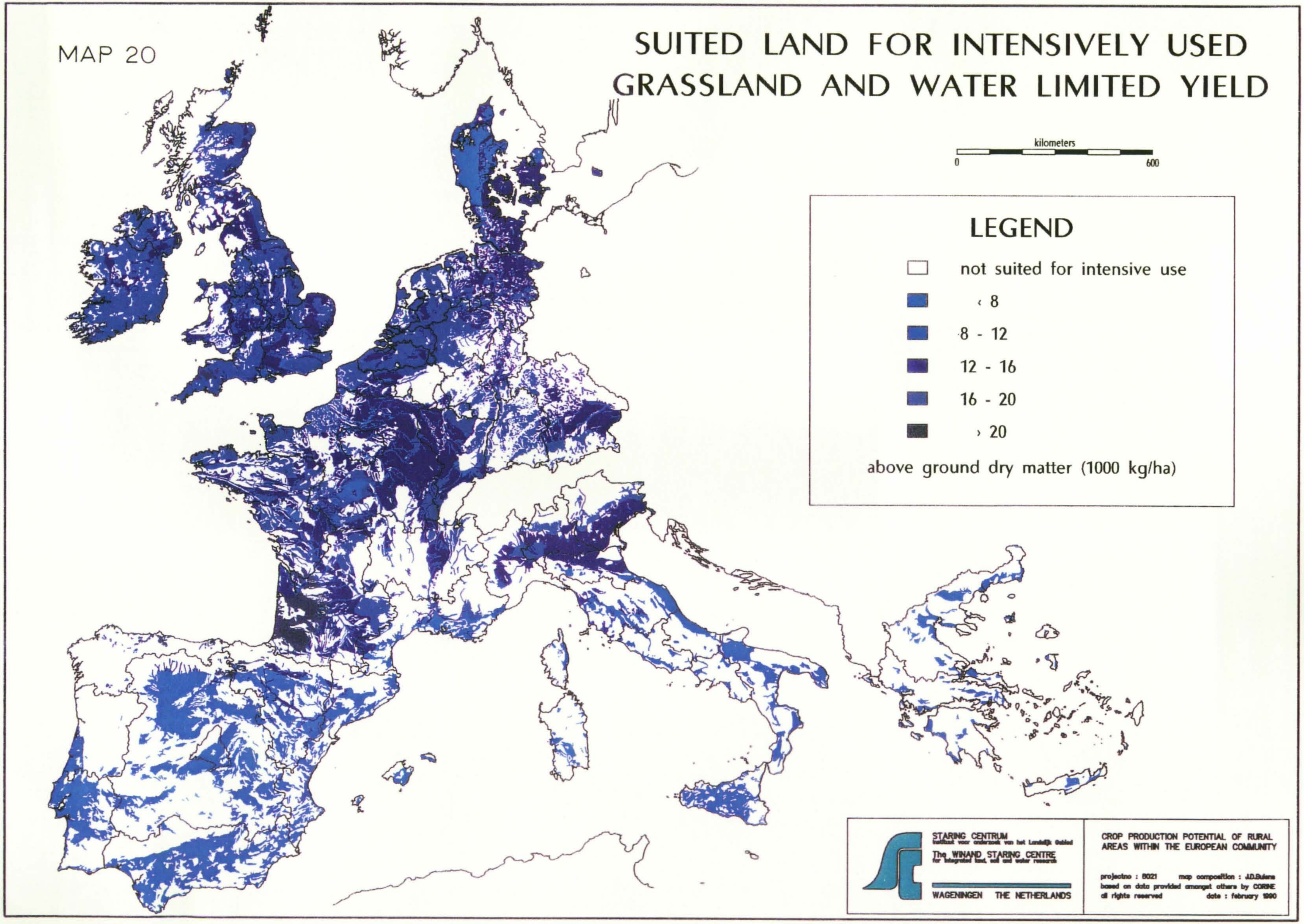
MAP 20
SUITED LAND FOR INTENSIVELY USED GRASSLAND AND WATER LIMITED YIELD
kilometers
0
600
LEGEND
not suited for intensive use
‹ 8
8 - 12
12 - 16
16 - 20
› 20
above ground dry matter (1000 kg/ha)
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