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Input and Output Coefficients of Various Cropping and Livestock Systems in the European Communities

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The results of this study can also be obtained from disquette. Those who are interested are requested to contact the Centre for Agrobiological Research in Wageningen.

De resultaten van deze studie zijn ook verkrijgbaar op diskette. Geïnteresseerden kunnen daarvoor contact opnemen met het Centrum voor Agrobiologisch Onderzoek te Wageningen.

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PREFACE

The Netherlands Scientific Council for Government Policy (WRR) has undertaken a study on the options for land use in the rural areas of the European Community. The major arguments for its initiation were the increase in productivity per unit area, the surplus production of the major agricultural products, the need for re-orientation of the Common Agricultural Policy, the negative environmental effects of current agricultural developments and the increased importance of socio-economic considerations. In this study socio-economic objectives and constraints are confronted with agro-technical possibilities and aims. The WRR study comprises several background studies that are synthesized in a framework designed by a WRR-working group.
Some of the background studies were carried out by Agricultural Research Institutes.

At the Centre for Agrobiological Research in Wageningen (CABO-DLO), a study was carried out to assess the inputs and outputs of cropping systems in the European Communities in technical terms, based on results of a physical land evaluation study by the Winand Staring Centre (SC-DLO) in Wageningen. WRR implements the technical coefficients of the cropping systems in the GOAL (General Optimal Allocation of Land use) model to evaluate future land use possibilities.

During execution of the study, many methodological and practical problems are encountered. We would like to thank the members of the WRR working group "Rural Areas within the European Communities". During our meetings, the approach and the results of the study were intensively discussed until they reached their final shape.
For the execution we depended to a large extent on the knowledge of various experts.
We are indebted for their invaluable contributions.

Wageningen, December 1991

Free de Koning
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SUMMARY

The project "Rural Areas within the European Communities" has been initiated by the Netherlands Scientific Council for Government Policy (WRR) to explore the possible developments of the rural areas within the EC. Different land use scenarios are evaluated with respect to their impact on rural development, taking into account agricultural, socio-economic, environmental and physical planning aspects. WRR uses a method known as Interactive Multiple Goal Linear Programming (MGLP). For this method technical information is required on the relation between inputs and outputs of cropping and livestock systems in the EC.
For the NUTS-1 regions in the EC-12, the Centre for Agrobiological Research (CABO-DLO) has calculated inputs and outputs for grass and selected rotations of arable crop activities, on the basis of simulated yields and soil and climatic characteristics. Basic data were available from a study performed by the Winand Staring Centre (SC-DLO). Inputs comprise pesticides, irrigation water, nitrogen, labour and machinery. Outputs are crop yields and emissions to the environment of nitrogen and pesticides. Two categories of agricultural production techniques have been distinguished: (i) yield-oriented agriculture, with emphasis on attaining the highest possible yields under the given physical conditions; (ii) environment-oriented agriculture, with emphasis on limited negative effects on the environment (e.g. restricted use of fertilizers and pesticides). Within each of these categories, two production levels have been defined: potential production, attainable under optimum soil moisture conditions, and water-limited production, attainable under natural moisture supply.
For a number of fruit crop activities technical coefficients have also been defined, but less detailed than for grass and arable crops.
Animal production activities comprise milk and meat production by cattle, and meat and wool production by sheep. These activities are linked to crop production activities through feed supply and demand and through the nitrogen balance, as animal manure is used as nutrient input in crop production activities.
For all production activities the technical coefficients are based on application of the "best technical means", i.e. both available knowledge and available means of production are optimally applied.
The results of this study turned out to be very useful for inplementation of the MGLP-model of WRR. In future research, more efforts should be directed towards identification and quantification of elements necessary for a complete definition of agricultural production activities.

Glossary

A.I.	Active Ingredient
ANR	Apparent Nitrogen Recovery
CA	Current Agriculture
CABO-DLO	Centre for Agrobiological Research
CNp, CNr	Concentration of nitrogen in the marketable product and crop residues, respectively
CPP	Crop Production Potential of the Rural Areas within the European Communities
DCP	Digestible Crude Protein
EC	European Communities
EOA	Environment-Oriented Agriculture
EOP	Environment-Oriented Potential production
EOW	Environment-Oriented Water-limited production
ETL	Economic Threshold Level
Fe	Field application efficiency
GIS	Geographical Information System
GOAL	General Optimal Allocation of Land use
Ie	Effective irrigation requirement
It	Total irrigation requirement of a water source at the field
LEU	Land Evaluation Unit
N	Nitrogen
Nc	Nitrogen Concentration in the Crop
Ni	Nitrogen Input
Nm	Mineral Nitrogen at Harvest
Nu	Nitrogen Uptake
NUTS-1	Nomenclature des Unités Territoriales Statistiques, level 1
SC-DLO	Winand Staring Centre
YOA	Yield-Oriented Agriculture
YOP	Yield-Oriented Potential production
YOW	Yield-Oriented Water-limited production
WOFOST	crop growth simulation model
Wp, Wr	dry weight at harvest of marketable product and crop residues, respectively
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 like wheat, sugar, milk and wine have become structural. In areas favourable for agriculture, farm size increased, narrow crop rotations were introduced and large amounts of relatively cheap agro-chemicals and feedstuffs 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 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 (Van Latesteijn, 1990). The aim is 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 will develop and apply 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 development of this model technical information is required on cropping and livestock systems in the EC, i.e. the relation between inputs of means of production and outputs, both desired (economic product) and undesired (emissions to the environment).

As a first step, the Winand Staring Centre (SC-DLO) has investigated the physical crop production potentials for rural areas in the EC. This resulted in quantitative estimates of the yield potential of grass and major arable crops, grown on major land units suitable for agricultural use, based on the use of a crop growth simulation model in combination with a Geographical Information System (GIS). For a number of fruit crops and forest, suitability of land was assessed qualitatively, using GIS and an automated land evaluation system. This study "Crop Production Potential of the Rural Areas within the European Communities" will in this report be referred to as CPP. CPP has been documented extensively in a series of working documents and scientific papers (Appendix 1).

As a next step, the Centre for Agrobiological Research (CABO-DLO) was approached to define, on the basis of the results of CPP, the required inputs of various means of production for different production techniques, for 58 of the 64 NUTS-1 regions in the EC-12 (6 very small regions were omitted). The selection of the means of production to be considered should be based on the goals defined in the GOAL model. For grass and selected rotations of arable crop activities, inputs and outputs have been calculated on the basis of simulated yields and soil and climatic characteristics. Inputs comprise pesticides, irrigation water, nitrogen, labour and machinery. Outputs are crop yields and nitrogen losses. Two categories of agricultural production techniques have been distinguished: (i) yield-oriented agriculture (YOA) with emphasis on attaining the highest possible yields under the given physical conditions; (ii) environment-oriented agriculture (EOA) with emphasis on limited negative effects on the environment (e.g. restricted use of fertilizers and pesticides). Within each of the two agricultural production techniques, two production levels have been defined: 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.

For a number of fruit crop activities technical coefficients have also been defined, but less detailed than for grass and arable crops, because no simulated yields were available from CPP and data were scarce.

Animal production activities comprise milk and meat production by cattle, and meat and wool production by sheep. These activities are linked to crop production activities through feed supply and demand and through the nitrogen balance, as animal manure is used as nutrient input in crop production activities.

For all production activities the technical coefficients are based on application of the "best technical means", i.e. both available knowledge and available means of production are optimally applied.

2 DESCRIPTION OF CROPPING SYSTEMS OF GRASS AND ARABLE CROPS

2.1 Introduction

In this chapter general descriptions are given for cropping systems of grass and a number of individual arable crops mainly based on the Dutch situation. The effect of different rotations on yields and cultivation practices of individual crops are treated. The basis for the quantitative description of the cropping systems is application of "the best technical means". That implies that both the available knowledge and the available means of production are optimally applied, which precludes any waste or inefficient use of resources. Current economic conditions, nor farm infrastructure present constraints to farming practices.
A detailed description of the calculation of inputs and outputs for crop rotations in each of the NUTS-1 regions within the EC is given in Chapter 3. These calculations are based on cropping systems and production activities as described in Section 2.3, in combination with the specific characteristics of soil and climate in each region. The calculations have been performed for 4 production situations, which are described in Section 2.2.

2.2 Production situations

Production techniques in this study are differentiated on the basis of the main goal pursued in the agricultural activity. Two different categories of production techniques have been distinguished. Yield-oriented agriculture (YOA) aims at attaining the highest possible yields under given physical conditions. Starting point for the definition of this agricultural production technique has been common management practices in current agriculture (CA). For the Dutch situation these practices have been described by research stations like the Research Station for Arable Farming and Field Production of Vegetables (PAGV, 1990) and extension services (CAD, 1989). For each crop these current practices have been modified if more efficient methods of weed, disease and pest control were judged feasible without a reduction in yield. The second category of agricultural production techniques, designated environment-oriented agriculture (EOA), primarily aims at minimizing negative effects on the environment for example by restricted use of fertilizers and pesticides. The latter can partly be compensated by mechanical and guided control, adequate crop rotation and proper variety selection

(Vereijken, 1989). This leads to a shift towards the application of labour and machines. Below-maximum yields are accepted. For this category of production techniques, technical coefficients were defined for each crop on the basis of information from literature and expert knowledge on pest, weed and disease control.
Both categories of production techniques are assumed to be practiced applying the best technical means, i.e. tradition, level of knowledge, available farm equipment and layout and size of parcels are no limitation. Differences in inputs and outputs among regions are based on climatic conditions and soil properties only.
For both categories of production techniques, two production levels were distinguished: potential production, attainable under optimum soil moisture conditions, created through appropriate application of irrigation and/or drainage, and water-limited production, attainable under natural moisture supply. Yields for these production levels are based on the simulated potential and water-limited yields, respectively.

Hence 4 production situations are distinguished:
- Yield-Oriented, Potential (YOP)
- Yield-Oriented, Water-limited (YOW)
- Environment-Oriented, Potential (EOP)
- Environment-Oriented, Water-limited (EOW)

2.3 Crop cultivation

For both YOA and EOA, cropping practices under Dutch conditions for each crop are summarized in Tables 1-7. Especially the assumptions on weed, disease and pest control need some further elaboration, as they form the basis for the definition of EOA. Possibilities for reduced pesticide use for each crop have been based on the expected developments in the near future with respect to pesticide use and on the yield loss that is accepted. Yield reductions in EOA depend on climate, soil type and yield level. In this section, only indicative values for these yield reductions under average Dutch conditions are given. More detailed information is given in Section 3.7.
A list of diseases, weeds and pests, both in Latin and Dutch, is given in Appendix 2.

2.3.1 Wheat

Herbicide use in CA can be considerably reduced without loss of yield through the best combination of practices, such as accurate seedbed preparation, improved timing and

methods of herbicide application, definition of economic threshold levels (ETL's) and the use of highly competitive wheat cultivars. The Netherlands Grain Centre estimates this reduction at 35% (Anonymous, 1989b), while Vereijken and Wijnands (1990) suggest even 70%. Based on these figures we set herbicide use in YOA at a rate 60% lower than in CA (Table 1). That requires alternative control measures such as mechanical control. In EOA herbicide use is still substantially lower. This may lead to problems with weeds that interfere with harvesting operations (e.g. *Galium asparine*) and affect the quality of the harvested grain (e.g. *Alopecurus myosuroides, Avena fatua*). In the absence of chemical weed control, yield reductions are negligible in some years, but may be as high as 35-40% in others (Lotz et al., 1990). This may be partly compensated by mechanical control (Hoogerkamp, 1989), but on average reductions of up to 10% have to be accepted.
Fungal diseases may be effectively controlled, using the EPIPRE pest management system (Reinink, 1986; Drenth and Stol, 1990). Applying that system for tactical, within season decisions, an average reduction in the use of fungicides of 20% seems possible without yield reductions. In EOA, limited curative fungicide applications may restrict yield reductions due to fungal diseases like *Puccinia striiformis, Erysiphe graminis* and *Lepthosphaeria nodorum* under Dutch climatic conditions without preventing them (Daamen et al., 1989; Daamen and Jorritsma, 1990; Daamen, 1990). Average long-term yield reductions may be estimated at 15% (Daamen, pers. comm.).
Insecticides are mainly used for the control of aphids. In EOA higher threshold levels for intervention are applied than in YOA (Rabbinge and Zadoks, 1989). This reduced use of insecticides will lead to yield reductions of up to 5%. Guided control requires additional observations. In EOA no growth regulators are applied. Only at potentially high yield levels this results in small losses.

2.3.2 Maize

In YOA herbicides are applied in the rows while between the rows mechanical control is practised by hoeing a number of times. This practice allows a reduction in herbicide use to about 40% of that in CA (Schröder, pers. comm.). In EOA herbicide use may be still further reduced (Table 2). This can be partly compensated by additional mechanical weeding (Van Der Werf et al., 1983). Later sowing facilitates maintenance of weedfree conditions during early growth (Anonymous, 1989c). Nevertheless, average yield reductions of about 10% are unavoidable (Van Der Werf et al., 1983). Fungicides are only used for seed disinfection; insecticide use is insignificant.

For silage maize, labour for conservation has been taken into account. Where climatic conditions are suitable for cultivation of grain maize, the crop may either be used for silage or grain.

2.3.3 Oilseed rape

In CA the use of herbicides varies widely, but is estimated at 2.5 kg a.i./ha on average (Anonymous, 1989d). This can to some extent be reduced in YOA by mechanical control, depending on soil type (Table 3). Possibilities for mechanical weed control in oilseed rape are limited, however, due to the narrow row distance. In EOA row spacing is wider to facilitate mechanical weeding though this results in harvest losses due to irregular ripening. In EOA the use of herbicides is 40% of that in YOA, resulting in average yield losses of 10% (Meijer, pers. comm.).
The main fungi affecting oilseed rape are *Sclerotinia sclerotiorum* and *Verticillium dahliae* (Hornig, 1990). In YOA the same fungicide rates are applied as in CA. Reducing fungicide use in EOA to 55% of that in YOA would lead to a yield reduction of about 10% (Hornig, 1990; Meijer, pers. comm.).
Insecticides are used to control *Meligethes aeneus, Ceuthorhynchus assimilis* and *Dasineura brassicae.* Improved application techniques and tactical decisions allow a reduction in insecticide use in YOA of 20% compared to CA. In EOA yield reductions of up to 15% must be accepted, at a 40-60% reduced application level of insecticides, depending on soil type (Daebeler and Lucke, 1990; Meijer, pers. comm.).
In some cases (Hornig, 1990) growth regulators are applied, but their effect seems insignificant (Habekotté, 1985).

2.3.4 Potato

In this study, cultivation of potatoes only refers to ware potatoes. Potato cultivation under the narrow rotations, common in CA, requires large amounts of pesticides (Table 4). Especially soil fumigation for the control of nematodes (e.g. *Globodera rostochiensis, Globodera pallida*) involves large amounts of a.i.. However, by using resistant cultivars, nematicide application can be avoided, if the frequency of potato cultivation does not exceed once in 4 years. In shorter rotations nematode control is necessary in YOA. In EOA, such rotations are not considered.
According to the Dutch Potato Association (Anonymous, 1989e), a reduction in herbicide use of 30-40% is possible in YOA, compared to CA, through substitution by

mechanical control. On sandy soils weed problems are more serious than on clay soils (Haverkort, pers. comm.). Vereijken and Van Loon (1991) suggest that potato cultivation without herbicides is feasible. To account for the increased risk of crop damage in unfavourable years when optimal mechanical control is impossible, low herbices rates are applied in EOA, and average yield reductions amount to 5%.
Fungi are a major threat for potatoes. Planting material is often disinfected against *Rhizoctonia solani,* and several field applications are necessary for the control of *Phytophthora infestans.* A reduction of 20% in fungicide use is possible according to the Dutch Potato Association (1989e) and, by selecting resistant varieties, 60% reduction is possible according to Vereijken and Van Loon (1991). Based on these figures the reduction in fungicide use in YOA compared to CA was in this study set at 40%. In EOA, fungicides are applied in a curative way only, resulting in average yield reductions of 20%.
Aphids, especially *Myzus persicae,* have to be controlled, as they are the vectors of potato Y and X virus. Insecticides are also used against *Leptinotarsa decemlineata.* However, insecticide use in ware potato cultivation is low compared to that in seed potato cultivation. In EOA no insecticides are applied, leading to average yield reductions of 5-10%.
Haulms are destroyed mechanically, both in YOA and EOA.

2.3.5 Sugar beet

For nematodes (*Heterodera schachtii, Heterodera trifolii*) the reasoning for sugar beet is identical to that for potato (Table 5).
Based on information from Aarts and Dekkers (1985), Smith (1990), Wijnands (1990) and Pals (1990), herbicide use in YOA can be reduced to 40% of that in CA by low volume application in rows, combined with mechanical control. As for potato, weed problems are more serious on sandy soils than on clay soils (Smit, pers. comm.). In EOA, herbicide use is substituted by intensive mechanical control. *Matricaria chamomilla* is hard to control and average yield losses of 5% due to weeds are assumed.
Fungicides are used only for seed disinfection. In narrow rotations *Aphanomyces cochlioides* and *Rhizoctonia* can cause some damage (Lamers and Hoekstra, 1989).
Aphids are vectors of virus diseases. The use of insecticides can in YOA be reduced with 30% compared to CA, through the use of warning systems and appropriate application methods (Westerdijk, pers. comm.). In EOA insecticide rates are further

reduced, leading to average yield reductions of 10% (Westerdijk, pers. comm.).

2.3.6 Field bean

Weeds in field bean that are difficult to control are *Galium asparine, Polygonum aviculare* and *Chenopodium album.* Chemical control can partly be substituted by mechanical control, but field bean is rather sensitive to weed competition (van Heemst, 1985). In EOA reduced use of herbicides leads to yield reductions of 20% on average.
The main fungal diseases that have to be controlled are *Botrytis cinerea, Uromyces fabae* and *Peronospora viviae.* Possibilities for reduction in fungicide use are limited (Anonymous, 1989a). In EOA restricted fungicide use leads to an average yield reduction of 10%.
In CA, insecticides are used for control of *Aphis fabae* and *Sitona lineatus.* Restricted insecticide use in EOA leads to yield reductions of 10%.

2.3.7 Grass

Grass in this study refers to permanent grassland. This section only applies to intensively managed grassland. Extensive grassland is assumed to be only used for sheep production (Sub-section 5.2.2). Two types of exploitation of intensive grassland are distinguished: mowing and grazing (Table 7). Every 4 years the grass is re-sown but without ploughing. Under the mowing regime the animals are kept indoors year-round. Hence, organic manure has to be applied mechanically twice as often as under the grazing regime, where animals are grazing during half of the year. Under the mowing regime less labour is required for maintenance of the sward, but harvesting and conservation are much more labour-intensive. Use of biocides in YOA is low (F Aarts, pers. comm.; PR, 1988). Insecticides are used against *Tipula paludosa* and *Dilophus febrilis.* In EOA no pesticides are used at all. Additional mowing or harrowing can control some of the weeds. Total average yield reduction in EOA was estimated at 10-15% (Baan Hofman and Van Der Meer, 1986).

2.4 Crop rotations

Crop performance and cultivation practices in a specific year are often affected by the preceding crops. Successive crops can influence each other via weed problems, soil-borne pests and diseases, soil structure, soil nutrient status and timing of farm operations. Rotation especially is an important management tool to control occurrence of crop-specific pests and diseases (Vereijken and Wijnands, 1990). Hence, the required crop protection input is rotation-specific rather than crop-specific.

A limited number of crop rotations has been defined for arable crops (Appendix 3). Some narrow rotations with profitable crops can be selected in YOA only, because of the high incidence of soil-borne pests and diseases and the associated high need for pesticides. This applies particularly to the use of nematicides in short rotations of potatoes or sugar beets (Haverkort et al., 1989; Lamers and Hoekstra, 1989).

For all arable crop rotations, crop cultivation practices and yields of individual crops have been adapted to account for specific rotation effects, based on literature data and expert knowledge. The example of nematicide application in potato and sugar beet cultivation has already been given. Oilseed rape can serve as a host for sugar beet nematodes. Nematodes can also cause problems in short rotations of wheat, where *Meloidogyne naasi* causes yield reductions (Olsen, 1984; Lamers and Hoekstra, 1989), and field bean.

Oilseed rape can only be grown after grain maize or wheat because it has to be sown early to ensure proper establishment before winter. The yield of the crop following sugar beet on clay soils may be reduced due to poor soil structure (Lamers and Hoekstra, 1989). Germination of residual potato tubers requires additional weed control in the following year. Germination of wheat may cause serious weed problems in oilseed rape.

When crops are grown in short rotations, soil-borne diseases may cause yield reductions. To counteract these effects high fungicide applications are necessary. Some examples are *Verticillium dahliae* in field bean and potatoes (De Jaeger, 1989), *Fusarium* spp. and *Pythium* spp. in maize (Scholte, 1987), *Aphanomyces cochlioides* in sugar beet (Lamers and Hoekstra, 1989) and *Gaeumannomyces graminis* in wheat (Dijst, 1989; Vereijken and Wijnands, 1990).

Residual mineral nitrogen in the soil after crop harvest is taken into account when calculating the nutrient requirements for the subsequent crop.

Silage maize and grass, both forage crops, are considered to be grown in continuous cultivation.

For the rotations listed in Appendix 3a, specific rotation effects that have been taken into account in defining the technical coefficients, are given in Appendix 3b. Figures are based on literature cited in this section.

3 CALCULATION OF INPUTS AND OUTPUTS OF GRASS AND ARABLE CROP ROTATIONS IN THE EC

3.1 General procedure

General cropping practices as described in Chapter 2, have been translated into region-specific activities by relating inputs and outputs to soil and climate characteristics and crop yields. Basic data were available for each of the 4200 Land Evaluation Units (LEU's), comprising a unique combination of soil unit, climatic zone and administrative region, as distinguished in CPP (Van Lanen et al., 1991b). For all LEU's, suitable for crop cultivation, potential and water-limited yields were available from CPP, as well as the water use of the crops.

Soil characteristics such as texture, slope and salinity level, were in CPP derived from the EC soil map (CEC, 1985), (Reinds and Van Lanen, 1991).

Climatic characteristics used in this study, were annual precipitation surplus and annual precipitation deficit. These were calculated in CPP (Reinds et al., 1991), by adding separately the monthly values for months with a positive difference between rainfall and potential evapotranspiration and those with a negative difference, the latter also expressed as a positive value (Mohrmann and Kessler, 1959).

The LEU-characteristics, used for modification of inputs and outputs are given in Table 8.

A FORTRAN computer program (ROTAT) was developed to perform all calculations at LEU-level for any interactively specified rotation. The crop in the rotation having the highest crop- and management-specific soil requirements determines which LEU's are suitable for the total crop rotation (Reinds and Van Lanen, 1991). For rotations including grain maize, the suitable area is also limited by climatic conditions, because only in southerly agro-climatic zones the temperature regime allows ripening of the grains (De Koning et al., 1991).

Applying general rules, the program first computes for each crop in a rotation the input of pesticides, irrigation water, nitrogen and labour, on the basis of LEU-characteristics and crop yields. For each crop the preceding crops are screened to derive rotation-specific adaptations. At first, crop yields for YOA have been set at the simulated potential (YOP) and water-limited values (YOW). For EOA, the simulated yields have been multiplied by reduction factors to account for yield losses due to weed, pest and disease damage as a result of limited pesticide use. In some cases yields in YOA have been reduced as well, due to unavoidable rotation problems or harvest losses (grass).

The results for the individual crops are subsequently averaged for the total rotation and aggregated to NUTS-1 level by calculating the weighted mean of all its suitable LEU's.

3.2 Pesticides

Quantitative treatment of pesticide use (which includes here all chemical means applied in crop protection, i.e. herbicides, insecticides, fungicides and nematicides) is hampered by the fact that hundreds of different products are on the market, and that even under reasonably well-regulated conditions, dozens are permitted and actually applied.
In the framework of the present study the most preferable common denominator would be a measure of environmental impact of the various products. However, such a measure has, to our knowledge, not been developed sofar, and an additional constraint is that not only the primary agent has to be taken into account, but also the many metabolites that are formed during its decomposition. Insufficient knowledge is available for such a treatment.
Therefore, the amount of "active ingredient" expressed in kg/ha has been applied, irrespective of toxicity, persistency, mobility, etc.. A further refinement of the present study would have to pay more attention to these aspects.

The amount of herbicides applied in YOA depends on climate, soil texture and rotation. The effect of soil texture has been derived from the data in Tables 1-7. For wheat, maize and oilseed rape higher rates are required on clay soils than on sandy soils, while for root crops the opposite applies. Figures for sand were applied to EC texture class 1 and those for clay to texture class 4, while for the intermediate classes 2 and 3 linear interpolation with class number was applied.
In humid climates more intensive control of weeds is needed than in dry climates, as the range of adapted species is wider. Herbicide application rates were therefore linearly related to precipitation deficit with an identical relation for all crops. In the driest, Mediterranean, regions the required rates were set at about 70% of those in humid regions like the Netherlands. The combined effect of soil texture and precipitation deficit on herbicide rates in YOA is illustrated for wheat in Appendix 4.
In EOA, the herbicide rates were not related to climate or soil conditions, but fixed at a low, environmentally acceptable, rate (Tables 1-7). Herbicide use can partly be substituted by mechanical weed control. Depending on the crop, a certain amount of a.i. can be substituted by a number (maximally 4) of labour hours for weeding. The

remaining difference in herbicide application rates between YOA and EOA leads to yield reductions in EOA that are proportional to this difference.
Specific weed problems may occur in both YOA and EOA in certain types of rotations. This applies for example to crops following potato because of the germination of residual tubers and to oilseed rape following wheat because of germinating grains. In YOA these problems can increase the need for herbicides by up to 25%, depending on the crop type and in EOA it results in higher demands for mechanical control and higher yield reductions.

The use of fungicides is negligible in maize, sugar beet and grass. For the other crops, fungicide rates in YOA depend on yield level, climate and rotation. Application rates of fungicides have been positively and linearly related to yield level, because yield is related to crop density, which affects micro-climate and rate of disease development. In humid climates, due to the longer periods of wetness, fungal diseases develop more easily than in dry climates. Therefore, fungicide rates have been linearly and negatively related to the precipitation deficit. The combined effect of yield and precipitation deficit on fungicide rates in YOA is illustrated for wheat in Appendix 4.
In EOA no fungicides are applied when the (simulated) yield level is low. Above this critical yield level, a crop-specific fixed limited amount of fungicides is applied (Tables 1-7). This leads to yield reductions in EOA that are proportional to the difference in application rates between YOA and EOA.
Specific problems with fungal diseases may occur in narrow rotations (Section 2.4). This has been accounted for by defining increased fungicide rates and yield reductions in YOA and additional yield reductions in EOA.

In maize cultivation no insecticides are applied and in grass cultivation only a fixed small amount. All other crops are assumed to require insecticides only above a certain critical yield level. For some crops (oilseed rape, potato and sugar beet) the level of insecticide application depends on soil type, hence insecticide rates have been linearly related to soil texture class based on the data in Tables 3, 4 and 5.
In sugar beet, oilseed rape and field bean, more insecticides (up to 50%) are needed in warm dry climates than in cool wet climates. Therefore insecticide rates have been linearly and positively related to precipitation deficit.

Nematicides are applied in potato and sugar beet cultivation. It has been assumed that resistant cultivars are used and that no nematicides are needed when the frequency of

potato and sugar beet cultivation is below once every 4 years. Shorter rotations are considered only in YOA and require a fixed high input of nematicides.
In narrow rotations of wheat and field bean, nematodes may lead to yield reductions in both YOA and EOA (Section 2.4).

Growth regulators (like chloormequat) were assumed to be applied only in wheat in YOA. When high yields are attained in EOA, omitting growth regulators leads to small yield reductions.

3.3 Irrigation

Crop water use in both the potential and water-limited production situation was in CPP calculated with the WOFOST crop growth simulation model. Water use is defined in this study as the amount of water transpired by the crop, assuming no interference of pests, weeds and diseases. When target yields in YOA or EOA did not attain the simulated values due to weeds, pests, and diseases, water use of the crop was reduced proportionally, neglecting possible interactions. This is rather arbitrary, especially for pests and diseases. The difference in water use between the potential and water-limited production situations, is the amount of water that a crop must take up from sources other than rain, to attain potential yield. This additional amount of water is referred to as the effective irrigation requirement, Ie, in m^3/ha/year

Ie = It * Fe, in which:

It : total irrigation requirement at the field inlet (m^3/ha/year)
Fe : field application efficiency

Field application efficiency, i.e. the ratio of crop water use and total application, depends on various factors (Driessen, 1986). For the irrigation system in this study a sprinkler system was selected, having a higher Fe than surface irrigation systems. In hot dry climates Fe for a sprinkler system is on average 0.6, compared to 0.8 in humid and cool climates (Doorenbos and Pruitt, 1977, cited by Driessen, 1986).
On steep slopes water will be lost by surface runoff. Fe is higher for loamy soils than for clay and sandy soils.
Fe has been calculated for each LEU as a function of precipitation deficit, soil texture class and slope (Appendix 5) and subsequently Ie was divided by this value to arrive at

the total irrigation requirement.
For the GOAL model, It is relevant rather than Ie because It determines the total need for irrigation water in a certain region to obtain potential yields.

3.4 Nitrogen

3.4.1 Nitrogen balance

As this study deals with long term effects, it was assumed that under continuous invariable management soil organic matter content reaches a steady state condition, where inputs of organic matter (crop residues, biological fixation) balance losses due to decomposition. It may take 30-50 years before such an equilibrium is reached (Van Keulen and Van Heemst, 1982; De Willigen, 1986).
Since in this study not only nitrogen uptake by the crop is of interest, but equally the losses of the element to the environment, especially by leaching, calculation of the nitrogen balance is not restricted to the growing period of each crop but covers the calendar year. Inputs of nitrogen (N) are chemical fertilizer, organic manure (only for grass and silage maize), and atmospheric deposition. Crop residues are only taken into account for field bean and sugar beet. The roots of all crops are supposed to be in equilibrium and are therefore not included in the calculations. Outputs of nitrogen are volatilization, leaching, denitrification and removal of crop products.
The N-balance during the growing period is schematized as follows:

Ni = Nu/ANR , in which:

Ni : nitrogen input into the system (kg/ha)
Nu : total nitrogen uptake by all plant parts except roots (kg/ha)
ANR : apparent nitrogen recovery (kg/kg)

Nu = Wp • CNp + Wr • CNr , in which:

CNp, CNr : concentration of nitrogen in the dry matter of marketable product and crop residues (excluding roots), respectively (kg/kg)
Wp, Wr : dry weight at harvest of marketable product and crop residues (excluding roots), respectively (kg/ha)

In the equilibrium situation, the fraction of the input not taken up by the crop, is left in the soil as mineral N after harvesting the crop:

Nm = Ni • (1-ANR), in which:

Nm : mineral nitrogen in soil at harvest (kg/ha)

Mineral nitrogen refers to the total amount of N that can be taken up by the crop, i.e. nitrate (NO_3^-) and ammonium (NH_4^+). During the fallow period after harvest, part of Nm will be lost (Nlost) by leaching and denitrification (Section 3.2). The remainder of Nm (Nrest) is available for uptake by the subsequent crop:

Nrest = Nm - Nlost

CNp and CNr were assumed to be crop-specific constants, high enough to allow non-constrained yields. The average concentrations used, based on literature (Nijhof, 1987; Van Keulen and Van Heemst, 1982, Groot et al., 1989), are given in Appendix 6.

3.4.2 Sources of N

For arable crops the most important source of N is chemical fertilizer. Furthermore, at present, atmospheric deposition can supply a considerable amount of N, depending on the intensity of traffic, industrial activity and prevailing animal husbandry practices. In the Netherlands, annual deposition can amount to 50 kg/ha (Aarts and Middelkoop, 1990). For the whole of the EC an average deposition of 30 kg/ha has been assumed, as application of region-specific values would suggest unwarranted accuracy.
The nitrogen requirements of field bean are covered by symbiotic fixation and it therefore needs no additional fertilizer. The crop residues of field bean and sugar beet were assumed to supply 30 kg/ha N to the subsequent crop (PAGV, 1990).
Animal manure is used for the fodder crops silage maize and grass only. Manure, collected in stables, is mechanically applied using methods minimizing losses (injection) and its mineral N was treated as chemical fertilizer-N (Chapter 5). Manure of grazing animals is not considered a significant N-source for grass because of the low N availability and its irregular distribution. Nitrogen from urine of grazing animals does, however, contribute to leaching losses.

3.4.3 Recovery

The recovery of chemical fertilizer nitrogen by a crop is determined experimentally by comparing uptake in fertilized plots with uptake in unfertilized control plots. Thus, ANR is defined as:

ANR = (Nu fertilized - Nu unfertilized)/fertilizer rate

ANR, first of all, is crop-specific because rooting systems differ in their efficiency of N-uptake. Average recoveries based on literature data are given in Appendix 7 for wheat (Prins et al., 1988), maize (Schröder, 1990), potato (Neeteson, 1989), sugar beet (Prins et al., 1988) and grass (Prins et al., 1988; Van Der Meer and Uum-van Lohuyzen, 1986). The recovery for oilseed rape is set equal to that for wheat.

At very high chemical fertilizer application rates ANR decreases because the concentration of N in the crop reaches a maximum level and uptake is not limited by N but by another growth factor in short supply (Van Keulen and Van Heemst, 1982). In this study it has been assumed that nitrogen is optimally applied according to the expected yield level ('best technical means'), and that both CNp and CNr are constant (Sub-section 3.4.1).

In the potential production situation, soil water status is optimal for N-uptake throughout. However, ANR may be lower in the water-limited production situation, as under dry conditions uptake of N may be hampered (Buresh et al., 1990). At very high soil moisture contents ANR also tends to be lower, as losses due to leaching and denitrification are higher (De Wit, 1991).
Soil water status is determined by climate and soil type. For each crop a range of ANR values was defined as a function of precipitation deficit and soil texture, based on expert knowledge. The values have been derived from experiments conducted under favourable conditions and, as much as possible, optimum management ('best technical means'). Recovery increases with decreasing precipitation deficit, as the intensity of the major processes causing losses, leaching and denitrification, decreases with lower rainfall. In sandy soils, leaching plays a more important role, hence recoveries are lower than in heavier soils. An example is given for wheat and potato in Appendix 7.

Temperature also affects ANR, for example by its influence on root growth and ammonia volatilization. Because of the many uncertainties involved, however, temperature was not taken into account. Identical values for ANR are applied in EOA and YOA, neglecting possible effects of pests, weeds and diseases on N-uptake efficiency.

3.4.4 Losses

As chemical fertilizer and manure are applied using the best technical means, form of fertilizer, and rate, timing and method of application are such that volatilization is negligible. However, mineral N in the soil profile is subject to leaching and denitrification, especially during the winter period with a precipitation surplus and no growing crop in the field (Neeteson, 1985). These processes are still poorly understood and have inadequately been quantified, both theoretically and experimentally. Some preliminary, but still inconclusive, data are available for Dutch conditions, but for the Mediterranean situation no relevant information was obtained within the time-frame of this study. Models for the prediction of N-leaching at the regional scale like RENLEM (Kragt et al., 1990) have not yet been calibrated for South-European conditions (Hack, pers. comm.).
Therefore, losses have been calculated on the basis of a number of very general assumptions, and further research is necessary for a more accurate quantification of leaching and denitrification in regional studies.
According to the N-balance in Sub-section 3.4.1, Nm at harvest equals Ni * (1-ANR). The Nm-values calculated according to this equation are often higher than measured Nm-values (Neeteson et al., 1989, Prins et al., 1988, Groot et al., 1989). This is due to losses during the growing season and/or (temporary) immobilization in the organic matter store. Based on figures of Groot et al. (1989) and Goossensen and Meeuwissen (1990) the calculated Nm-values have been multiplied by a reduction factor (1-FIX) to arrive at Nm that is subject to leaching and denitrification. The value of FIX is crop-specific and is about 0.3 (Appendix 8). The remainder of Nm is temporarily immobilized and available for the subsequent crop.
The magnitude of leaching and denitrification depends on precipitation surplus and soil type (Aarts and Middelkoop, 1990). According to Lammers (1984), 85% of Nm is lost during winter, partitioned on sand in 68% leaching and 17% denitrification. For clay soils these figures are 47% and 38%, respectively. On well-drained sandy soils in the Netherlands, complete leaching of Nm during winter following a maize crop has been

measured (Goossensen and Meeuwissen, 1990). In a grassland experiment, leaching of about 50% was observed. In situations with high groundwater tables relatively more N is lost through denitrification. Goossensen and Meeuwissen (1990) assume that under Dutch conditions on sandy soils all losses may be ascribed to denitrification if the groundwater table is very shallow (less than 50 cm) and that denitrification gradually declines with increasing groundwater depth and is negligible in very deeply drained soils. The only information available in this study on groundwater in the EC is whether there is probable groundwater influence (Table 8).

The procedure to calculate N losses and the proportion of leaching are illustrated in Appendix 8.

The calculated loss fractions only apply to chemical fertilizer(-like)-N. On grazed grassland additional leaching originates from excreted urine-N. This contribution is calculated separately (Chapter 5).

Losses of N from crop residues of field bean and sugar beet were not taken into account.

Leaching of nitrate not only implies loss of valuable plant nutrients, but it also contributes to the nitrate load of the groundwater. Groundwater is in many cases the source of drinking water, for which the EC has set a maximum permitted concentration of 11.3 g N per m^3 (Prins et al., 1988). In EOA this norm should not be exceeded. Assuming that the annual precipitation surplus fully contributes to recharge of the groundwater, under Dutch conditions with an annual precipitation surplus of 360 mm (3600 m^3/ha), the upper limit to leaching is 40 kg/ha. Following the same reasoning, the upper limit to the amount of leached N can be specified per climatic region. This results for example for the region of Zaragoza, in an upper limit of only about 4 kg/ha. However, it is questionable whether the drinking water norm should be applied here, as in Mediterranean regions drinking water resources are often recharged by lateral supply from high-elevation, non-agricultural areas. Therefore, considering also the many assumptions that have to be made to calculate N-leaching, it is not justified to reduce N-input (and consequently yields) in EOA to meet the drinking water quality standard. In EOA, yields are lower than in YOA as a result of the effects of weeds, pests and diseases. Therefore N-input and consequently losses are lower in EOA than in YOA.

3.5 Labour requirements

In this study, only task times for field operations have been taken into account. General tasks like administration and the maintenance of ditches, paths, drains, machinery and buildings have not been considered. Required field operations for each crop are included in Tables 1-7. For each operation an indication of the task time is given (PAGV, 1990). The task time is the time required to carry out an operation under standard conditions by a skilled male adult working at normal pace with standard equipment and with maximum efficiency. The task time includes :

- the time required for the actual work
- the time required for smooth operation, e.g. switching on and off the filling mechanism of a sowing machine
- the time required to repair minor breakdowns
- the time required to install the implements, transport them between farm buildings and the field and perform the necessary maintenance.

Labour requirements from Tables 1-7 for soil tillage on sandy soils were assumed to apply to EC texture class 1 and those on clay soils to texture class 4. For texture classes 2 and 3 labour requirements were obtained by linear interpolation. Additional labour requirements were assumed for tillage on slopes between 8-15% and on soils with a gravelly or concretionary phase (40 and 15% more time, respectively).
Task times for pesticide application were linearly related to the amount applied, while harvest and transport times were assumed to be proportional to the calculated yield. For the fodder crops grass and silage maize, conservation of the harvested product has been included in the labour requirements. At each irrigation operation with a sprinkler system, 15 mm of water was supposed to be applied, requiring for arable crops 1.8 hours and for grass 0.4 hours. The number of irrigation operations is determined by the calculated irrigation requirement during the growing period from which the total labour demand for irrigation in the potential production situation is derived.

3.6 Machinery

Machinery requirements for arable cropping systems and grass have been assessed in a more simplified way than the other inputs, due to lack of pertinent information. The coefficients defined have been based entirely on the Dutch situation and no attempt has been made to relate the requirements to crop yields or soil and climate characteristics. No distinction has been made between on-farm activities and contract-work.

The calendar year has been divided in two-weekly periods, each consisting of 80 labour hours. The time needed per hectare to perform an operation with a machine, for example plowing, and the time period available for that operation, determine how many hectares a farmer can handle with that implement. Task times and periods of execution have been derived from PAGV (1990). The reported task times have been increased by 20% to account for limited exchange possibilities. For all machines that are not self-powered, an equal number of tractor hours is needed. The required power of the tractor depends on the demands of the operation. Machine requirements have been expressed as machine- equivalents per (100) ha, to facilitate addition of requirements for the same implement for the various crops in a rotation. The calculation procedure was carried out for all crops separately and for each machine that is used. The results are listed in Appendix 9. For a specific crop rotation, the requirements are a combination of those of the separate crops.

The moment of and the time available for plowing depends on soil type. Under Dutch conditions, clay soils are generally plowed in autumn and sandy soils in spring. In this study, it was assumed that all plowing takes place in autumn.

For grass, very broad periods have been defined for all operations, because timing is rather diffuse.

Because of its high costs, wheat harvesting has been analyzed in more detail. At harvest, a wheat crop must be mature and the moisture content of the kernels sufficiently low. Within the EC, the length of the wheat harvesting period hardly differs, because a mature crop must be harvested before yield losses or loss of quality occur due to kernel shedding, sprouting in the ear or bird attack. However, large regional variation exists in workable combine hours within the harvesting period, due to local weather conditions. A wet crop cannot be harvested because of problems with straw processing and threshing of the kernels. Furthermore, the moisture content of the kernels must be below 19%, to avoid the necessity of drying in special drying barns. Wetness may be caused by precipitation or dew.

To account for regional variation, the NUTS-1 regions were divided into 3 groups on the basis of their precipitation deficit (Appendix 10). The most humid regions, with a precipitation deficit below 175 mm, are classified as group 1, precipitation deficits in group 3 exceed 450 mm, while group 2 consists of the intermediate climates. The common month of harvesting is August, July and June for group 1, 2 and 3, respectively and the average number of rainy days in the harvesting month amounts to

11, 7 and 4, respectively. Rainy days with heavy showers can also render the following dry day unsuitable for combining (Glasbey and McGechan, 1986), but this is compensated by rainy days with rain only falling in the evening or in negligible amounts. Because no information was available on the daily rainfall pattern, the recorded number of rainy days in the harvesting month was considered as the total number of days unsuitable for harvesting. The number of workable hours for harvesting on a dry day depends on the dew conditions. Based on information from PAGV (van de Zande, pers. comm.), the Department of Agrotechnics and Physics of the Agricultural University Wageningen (Goense, pers. comm.) and the Servicio Investigacion Agraria Zaragoza (Pedes Marco, pers. comm.), the maximum number of available hours for harvesting on a day without rain was set at 9, 12 and 15 for group 1, 2 and 3, respectively.

The harvesting period for each group was set at 30 days (one month, including saturdays and sundays). To calculate the total number of workable combine hours, the rainy days are subtracted from the harvesting period and the resulting number of days multiplied with the number of workable hours per dry day. This results in 172, 276 and 390 combine hours for group 1, 2 and 3, respectively. For Dutch conditions (group 1), Portiek (1975) has estimated the number of combine hours in August at 148.

3.7 Yields

For all crops except field bean, simulated potential and water-limited dry matter yields were available. Field bean yields were derived from the simulated wheat dry matter production. In the potential production situation field bean yields were assumed to be 10% lower than wheat yields and in the water-limited situation, linearly related to the precipitation deficit, 15 - 80% lower (Grashoff, 1990; Grashoff, pers. comm.).

Crop yields in both YOA and EOA have been derived from the simulated (or in case of field bean, estimated) yields. For EOA, reduction factors were calculated to account for losses due to weeds, pests and diseases. No distinction has been made between the potential and water-limited production situation, assuming no interaction between water supply and incidence of weeds, pests and diseases. For each of the yield-reducing factors yield loss was expressed as a fraction of the simulated yield. Final yield was calculated by multiplying the relative yields associated with each yield-reducing factor. Yield losses due to for example weeds have been derived from the indicative yield reductions discussed in Chapter 2, taking into account the specific environmental conditions for each LEU. In YOA these conditions are reflected in the level of herbicide

use which can be considered a measure of weed pressure. For pests and diseases a similar procedure was applied.
In some cases yield reductions occur in YOA also, due to specific rotation problems (Appendix 3b).
Under grazing, grass yields were reduced by 25% to account for grazing losses (PR, 1988). In silage grass production, mowing losses amount to 5%, and 15% is respired during conservation (PR, 1988). Losses during silage maize conservation amount to 8%.
Dry matter yields were converted into fresh matter by dividing by average dry matter contents as given in Table 9.

3.8 Results

In appendices 11a and 11b an example of output of the computer program ROTAT is given. It refers to a 5-year rotation in the order: field bean, potato, wheat, oilseed rape and sugar beet. In Appendix 11a marketable crop yield of each of these crops is given for all NUTS-1 regions and 4 production situations. In Appendix 11b average annual inputs for the rotation are given, and the proportion of the area of each NUTS-1 region suitable for the rotation. For this rotation the suitable area is determined by the land use requirements of the root crops potato and sugar beet. Regional suitability can be as low as 1% (Saarland, Germany). At country level suitability ranges from 89% in Denmark to only 8% in Greece (De Koning et al., 1991). The amounts of active ingredient of herbicides, fungicides, insecticides and growth regulators have been added to obtain the total quantities of pesticides. Nematicides are not applied in this rotation. Labour requirements are expressed as the total time needed for all field operations. When irrigation requirements are high, labour demands for operating the sprinkler system comprise a major part of the total labour requirements. Water input refers to the potential production situation. As no fodder crops are included in the rotation, nitrogen fertilization only consists of chemical fertilizer. Losses of nitrogen relate to the total of denitrification and leaching.

4 INPUTS AND OUTPUTS OF FRUIT CROPS

In CPP, fruit crop yields have not been simulated because of lack of understanding of the underlying processes. For those crops only a qualitative land evaluation was carried out (Van Lanen et al., 1991a). Therefore, inputs and outputs of fruit cropping systems have been described in far less detail than those for grass and arable crops.

4.1 Olives

Olive trees easily recover from drought stress and need little care. The trees are in full production about 8 years after planting and may remain productive for 50 to more than 100 years, depending on conditions (Abdel-Razik et al., 1987). Bearing fruit can exhaust the reserves in the tree to such an extent, that it does not produce olives the following year. This leads to biennial bearing. This common phenomenon is associated with lack of pruning, water and/or nutrients.

Two management intensities, designated extensive and intensive, have been distinguished, both for the production of olive oil (Van Lanen et al., 1991a). Another production target, that of table olives, has not been taken into account. Quantitative descriptions of both olive tree management systems as given in Table 10, have been derived from Abdel-Razik et al. (1987). In the low intensity management system animal traction is used because of conditions restricting mechanization, for example on steep slopes which are unsuitable for the high intensity management system (Van Lanen et al., 1991a). Trees in the low intensity management system are not pruned and no chemical pest control is practised. Soil tillage and mechanical weeding take place to a limited extent. In the high intensity management system, additional operations are application of pesticides and pruning of the trees. Pruning is essential to improve light use efficiency and to optimize the leaf/wood ratio, as an excessive amount of wood leads to increased biennial bearing.

The major part of the labour time is used for pruning and harvest, which, in combination with pest and disease control, causes the higher labour demand in the high intensity management system. Irrigation is not applied in either system. Yields in the high intensity management system are twice those in the low management system. Oil content of the olives is 20% on a fresh weight basis.

4.2 Citrus

Citrus comprises among others oranges, lemons, mandarins and grapefruit. A system with irrigation (potential production) and a rainfed system (water-limited production) have been distinguished (Van Lanen et al., 1991a). Technical coefficients for citrus (Table 10) are mainly based on information from the "Volcani Centre" (Bet Dagan, Israel; unpublished) and on Samson (1980). In the irrigated system, weeds, pests and diseases are optimally controlled and the trees are pruned annually. Irrigation requirements depend on climate, soil type and slope. In the rainfed system, labour requirements are lower, because weed, pest and disease control are less intensive, no irrigation is applied and harvesting takes less time due to the lower yields. Nitrogen demand is estimated as a function of the yield level.

4.3 Apple

For apple, a potential and a water-limited system have been defined (Van Lanen et al., 1991a). The trees are supposed to be grown in the Northern part of the EC, were it is too cold for peaches or citrus. Here, irrigation requirements are lower than in the Mediterranean zone were citrus is grown. Technical coefficients for apple (Table 10) are based on information from "IKC-AT-fruitteelt" in Wilhelminadorp, the Netherlands (Joosse, pers. comm.). In the irrigated system a density of 4500 trees/ha is assumed, in the rainfed system of 1125 trees/ha, resulting in lower labour requirements for pruning. In the rainfed system, the absence of irrigation reduces labour requirements, but this is partly compensated by additional fertilizer application, because normally N is applied in combination with the irrigation water (fertigation). Intensity of control of weeds, pests and diseases is similar in both systems.

5 ANIMAL PRODUCTION

5.1 Dairy farming

For milk production, two grassland management systems have been defined. In the summer grazing system, continuous grazing is assumed during half of the year. In the zero grazing system, cows are inside year-round and all grass is mechanically harvested and conserved. Two levels of milk production per cow were considered: 5000 kg/yr and 8000 kg/yr. The diet of the low-productivity cow consists of grass and maize only, while the diet of the high-productivity cow contains the maximum possible proportion (from an animal nutrition point of view) of concentrates. The proportion of concentrate in the diet is limited by the requirements of a cow for fibrous material (roughage). The high-productivity cows have only been defined in combination with the zero grazing system. For each of the resulting three milk production systems, technical coefficients (Table 11) have been derived from the GRASMOD grassland management model (Van De Ven, in prep.). All figures are given per lactating cow and include the requirements of non-lactating young animals. According to Bakker (1985), each year 100 milk cows give birth to 90 calves of which 63 are sold for fattening. The remaining 27 are reared for replacement, calving for the first time at the age of 2 years. The productive period of a cow is slightly over 4 years. Obsolete cows are slaughtered for consumption.

Feed requirements have been defined in terms of energy, protein and fibre. Protein requirements are expressed in digestible crude protein (DCP). The non-digestible protein does not enter the metabolic system and is excreted with faeces. To prevent digestion problems, one third of the total dry matter intake should consist of fibrous material. Feeding values of a number of products are given in Appendix 12. In the summer grazing system, half of the annual energy requirements originates from fresh grass during grazing. No silage maize is fed in this period. Due to the relatively high protein content of grass, DCP intake exceeds the requirements. For animals indoors, a diet can be selected that exactly meets both the energy and protein requirements.

Uptake of N in the metabolic system of a cow can be calculated by dividing digestible protein intake by 6.25, the average ratio of protein to nitrogen. Part of this N is incorporated in milk and meat and the remainder is excreted in urine, either in the stable or during grazing. Urine-N in slurry from stables is as effective as chemical fertilizer-N, provided an appropriate application method is used. It can thus substitute chemical fertilizer-N in the grass and silage maize production systems (Sub-section

3.4.2). In the zero grazing system, all urine-N produced is applied as slurry. In the summer grazing system, half of the manure is produced during the grazing period. Urine of grazing cows is very unevenly distributed over the field. Moreover, in and under the urine patches volatilization, denitrification and leaching take place. According to the results of the GRASMOD model, about 25% of the urine-N excreted during grazing is lost through leaching and denitrification. The remainder volatilizes, is immobilized or is taken up by the crop as luxury consumption. Hence, nitrogen from urine patches in the field can not substitute fertilizer-N. The losses per cow must be multiplied by the stocking rate to obtain losses per ha. The stocking rate is determined in the GOAL-model. The N-losses during grazing have to be added to the losses of chemical fertilizer-N in the grass production system (Sub-section 3.4.4), to arrive at the total losses of N per ha.

The organic N in the non-digested proteins in faeces is very stable and decomposes very slowly, hence the nitrogen is hardly available for uptake by the crop and is therefore neglected.

Labour requirements, given in Table 11, are based on information from PR (1988).

5.2 Meat

5.2.1 Bovine livestock

An intensive and an extensive beef production system have been defined. In the intensive system, calves from dairy farms, starting from one week of age, are fattened in stables for about 500 days. On dairy farms part of the cows may be crossed with meat breeds to produce calves that are better suited for meat production. After initial feeding with 50 kg of milk powder, the animals are fed silage maize and concentrates. Their final weight is 525 kg of which 310 kg is carcass (meat, fat and bone). Feed requirements for the 500 day fattening period are given in Table 12, based on information from PR (1985, 1988). For the system as a whole these can be considered as annual requirements per animal because each spring new animals are bought while at the same time animals from last year are still kept for another 4-5 months. About 20% of the total dry matter intake should consist of fibrous material. N-flows are calculated similar to the milk production systems. No grazing takes place.

Labour requirements (Table 12) are based on information from PR (1988).

The extensive system is based on sucklers, as widely practised in France, Scotland and Ireland, described by Hermans (1990) for the Charolais breed. The cows are

grazing continuously during half of the year. After birth in spring, the calves remain with their mothers for about 7 months, feeding on milk and grass. They have then reached a liveweight of about 250 kg. From the young animals, 25% is used for replacement of obsolete animals. The remainder is kept inside during the next 12 months and fattened on silage maize and grass, reaching a liveweight of 520 kg and a carcass weight of 338 kg. The total annual feed requirements per cow and its offspring (including the 12 months fattening period) are given in Table 12 (Hermans, 1990). Mother milk has not been included in the requirements of the calf because that is included in the requirements of the mother animal. Of the total annual energy intake, 32% is consumed during grazing. As for dairy cows, intake of protein during grazing exceeds the requirements to meet the energy requirements. N-flows were calculated similar to the milk production systems. It is assumed that meat of obsolete cows can be sold as well, thus compensating for the young animals needed for replacement.
Labour requirements (Table 13) are based on data from Hermans (1990).

5.2.2 Sheep

In CPP, yields of grass were simulated for intensive production systems. However, also less favourable areas, for example on steep slopes, have been identified where extensive grassland is feasible. Dry matter yields of these extensive pastures vary, after conversion to grass with a feeding value comparable to that of intensively managed grass, between 500 and 2000 kg/ha, depending on local conditions of soil and climate (Lee, 1984).
In this study sheep are supposed to be kept on extensive grassland only. In winter they are in stables, in summer they graze continuously. The technical coefficients for the sheep production system are based on the Dutch Texelaar breed (PR, 1990). The net lambing rate of ewes is, on average, 1.6 lambs each year. The lambs remain with the ewe for 7 months and are then slaughtered at a liveweight of 40 kg, 50% of which is carcass. Each year 13% of the lambs are needed for replacement of old ewes. Meat of these ewes cannot be marketed. Ewes produce 3 kg of washed wool annually. Annual feed requirements per ewe and its offspring are given in Table 13 (De Boer, pers. comm.). Of the total annual energy intake, 62% is consumed during the grazing period. As for suckler cows, mother milk is not included in the feed requirements of the lambs. N-flows are calculated similar to the milk production systems.
Labour requirements (Table 13) are based on figures from Hermans (1990).

6 DISCUSSION

In this study, inputs and outputs for arable cropping systems and grass have been assessed, based on data from a physical land evaluation study (CPP), in combination with a general definition of cropping systems. For fruit cropping systems and livestock systems, inputs and outputs have also been defined, but in less detail.

The land evaluation units identified in CPP, characterized by specific soil and climate conditions, and their associated simulated yield levels for each crop, appeared a useful basis for definition of technical coefficients, despite its limitations, as extensively discussed in the reports originating from CPP (Appendix 1).

Cropping and livestock systems in this study have been defined largely on the basis of information relevant to the Dutch situation. For arable cropping systems and grass, inputs and outputs have been related to simulated crop yields and soil and climate characteristics, to extrapolate technical coefficients of these activities to other EC-regions. Considering the basic assumptions underlying this study, i.e. the description of agricultural production techniques carried out with the best technical means, this appears an acceptable starting point. Detailed information on agricultural production systems from EC-regions outside the Netherlands would have been valuable for a more accurate calibration and verification of technical coefficients derived in the present study. Collecting such data is, however, very elaborate and time-consuming, hence impossible within the time-frame of this study.

Moreover, information on current cropping systems is less relevant for this study, as the the concept of "best technical means" implies that constraints related to tradition, level of knowledge, available farm equipment and layout of the parcels are assumed to have been removed. For this type of farming, the Dutch situation appears a good proto-type.

Two categories of production techniques have been distinguished, one yield-oriented and the other environment-oriented. Starting point for the definition of yield-oriented agriculture has been common management practices in current intensive agriculture. For environment-oriented agriculture, weed, pest and disease control were defined on the basis of aims to reduce negative effects on the environment. For each crop, different combinations of management practices are feasible within each category of production techniques, but for reasons of simplicity only one combination of practices was considered.

Some specific questions, derived from this study, will be treated in more detail.

The relations between yield level, soil and climate characteristics, and the incidence of weeds, pests and diseases have still been poorly described. Yield losses depend to a large extent on the specific weather conditions in a certain year, as these determine the population dynamics. In environment-oriented agriculture much skill is required from the farmer. Therefore, the magnitude of yield loss under conditions of reduced pesticide input is subject to strong debate, resulting in the use of rather subjective estimates. Therefore, experimental work on the effects of the introduction of integrated cropping systems is an absolute necessity for improved quantitative description of alternative cropping systems.

A large number of different pesticides is on the market, but hardly any information is available on the quantity and type of products actually used. At present important changes are taking place due to increasing concern about environmental problems, resulting in a ban on certain pesticides and the development of new products that are applied in low doses. A common European legislation, however, has not yet been developed. As indicated in Section 3.2, the most preferable common denominator for pesticides and their metabolites, would be some measure of environmental impact. Due to lack of such a measure, the rather crude criterion of "active ingredient" expressed in kg/ha has been applied, irrespective of toxicity, persistence and mobility. For a more refined assessment of the inputs of pesticides, more attention should be paid to these aspects.

The production factor nitrogen was, for arable cropping systems and grass, quantified in relation to crop yields and soil and climate characteristics. Two aspects have been emphasized in this study: the amount of nitrogen fertilizer that must be applied to realize the simulated yields, and the losses of N through leaching that potentially contribute to pollution of groundwater. For calculation of the nitrogen requirements of crops, fixed nitrogen concentrations in economic product and crop residues have been assumed, irrespective of yield level. For some crops (e.g. maize) that is close to reality while for others (sugar beet) it is an oversimplification. Results of many nitrogen fertilizer experiments are available, from which uptake of nitrogen in relation to crop yield can be derived. However, the relation between uptake and fertilizer application appears to be highly variable, as a function of soil type, weather conditions, fertilizer type and method and time of application (Van Keulen and Van Heemst, 1982). Generally applicable quantitative descriptions of this relation as a function of soil characteristics or climate conditions can therefore not be formulated. In this study, the recovery fraction (the proportion of applied fertilizer taken up by the crop), has been estimated on the basis of available experimental evidence. However, not for all the relevant combinations of land and management practices sufficient data were available. The fate of the fertilizer nitrogen not taken up by the crop is even more difficult to assess, as that not only depends on processes taking place during the growing season, but also on those that take place during the period that no crop is in the field.

Estimation of N-losses, important for their environmental impact, remains speculative, as quantitative information is scarce and insights in the underlying processes is at best fragmentary. For Dutch conditions some experimental data on leaching are available for a limited number of sites. Regional models for calculation of N-losses, calibrated for the Dutch situation, are not yet suitable for South-European conditions. A possible criterion for determining the maximum permitted fertilizer rate in environment-oriented agriculture (and hence the yield) would be the EC-norm for nitrate concentration in the drinking water, provided leaching can be calculated on the basis of precipitation surplus. However, because of the many uncertainties in calculating leaching, this procedure was not followed.

Nitrogen cycling is even more complicated when animal production systems are included. Manure can be collected in stables and applied to the field through slurry injection. Volatilization, either during storage or after application, has been neglected, assuming optimal management. Denitrification and leaching of N, from urine and faeces excreted by grazing animals was estimated as a fixed fraction of total excretion, irrespective of soil and climate conditions. The amount of N excreted by the animals depends on their diet, which is determined in the GOAL model, on the basis of the feed requirements and forage availability from the various cropping systems. In this way the cropping and livestock systems are coupled. For reasons of simplicity dairy cows in the zero grazing system were only fed conserved grass, though in reality in summer often fresh grass is fed.

Yields of fruit crops were not simulated due to lack of insight in the underlying processes. Technical coefficients for these crops were defined in rather broad terms.

It may be concluded that much scattered information is available on processes in agricultural systems. However this partial knowledge appears difficult to integrate for consistent quantitative descriptions of agricultural production systems as a whole, because often essential elements are lacking. Therefore more efforts should be directed towards identification and quantification of elements necessary for a complete definition of agricultural production systems. An urgent need exists for such information, especially for application at a regional scale, for example in land use planning. The methodology applied in the present study seems a promising starting point for such analyses.

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Table 1a. Description of yield-oriented wheat cultivation systems under Dutch conditions on clay and sandy soils.

activity	no. of operations		labour requirements (h/ha)		active ingredient (kg/ha)	
	clay	sand	clay	sand	clay	sand
plowing	1	1	2.8	1.8		
harrowing	1	1	0.5	0.5		
seedbed preparation	1	1	0.8	0.8		
sowing	1	1	1.1	1.1		
fertilizer application	4	4	2.4	2.4		
weeding	2	2	1.0	1.0		
herbicide application	1.5	0.5	0.8	0.25	2.3	1.0
fungicide application	2.0	2.0	1.0	1.0	2.7	2.7
insecticide application	1	1	0.5	0.5	0.1	0.1
growth regulators	1	0	0.5	0	0.6	0
harvesting	1	1	1.6	1.6		
transport of grain	1	1	1.6	1.6		
straw baling	1	1	1.1	1.1		
straw transport	1	1	1.7	1.7		
plowing of stubble	1	1	1.0	1.0		
cultivating	2	2	1.8	1.8		

Table 1b. Description of pest, disease and weed control in environment-oriented wheat cultivation systems under Dutch conditions on clay and sandy soils.

activity	no. of operations		labour requirements (h/ha)		active ingredient (kg/ha)	
	clay	sand	clay	sand	clay	sand
herbicide application	0.4	0.2	0.25	0.1	0.35	0.35
fungicide application	1	1	0.5	0.5	0.8	0.8
insecticide application	1	1	0.5	0.5	0.03	0.03
weeding			maximally 4.0			
observations	1	1	0.5	0.5		

Table 2a. Description of yield-oriented maize cultivation systems under Dutch conditions on clay and sandy soils.

activity	no. of operations		labour requirements (h/ha)		active ingredient (kg/ha)	
	clay	sand	clay	sand	clay	sand
plowing	1	1	2.8	1.8		
seedbed preparation	1	1	1.1	0.8		
sowing	1	1	1.2	1.2		
fertilizer application	2	2	1.2	1.2		
herbicide application	1	1	0.5	0.5	2.1	1.6
fungicide application (seed disinfection)	0	0	0	0	0.2	0.2
hoeing	2.5	2.5	7.5	6.2		
cutting	1	1	1.5	1.5		
transport	1	1	1.5	1.5		
cultivating	1	1	1.0	0.9		
conservation			0.5**	0.5**		

Table 2b. Description of pest, disease and weed control in environment-oriented maize cultivation systems under Dutch conditions on clay and sandy soils.

activity	no. of operations		labour requirements (h/ha)		active ingredient (kg/ha)	
	clay	sand	clay	sand	clay	sand
herbicide application	0.5	0.5	0.2	0.2	0.4	0.4
fungicide application	0	0	0	0	0.2	0.2
weeding			maximally 4.0			
harrowing,earthing up	3	3	7	5.5		

** : for each 1000 kg fresh weight

Table 3a. Description of yield-oriented oilseed rape cultivation systems under Dutch conditions on clay and sandy soils.

activity	no. of operations		labour requirements (h/ha)		active ingredient (kg/ha)	
	clay	sand	clay	sand	clay	sand
plowing	1	1	2.8	1.8		
seedbed preparation	2	2	2.2	1.6		
sowing	1	1	1.0	1.0		
fertilizer application	2	4	1.2	2.4		
herbicide application	1.5	1	0.75	0.5	1.9	1.0
fungicide application	1	1	0.5	0.5	0.4	0.4
insecticide application	3	2.5	1.5	1.25	0.6	0.4
swath mowing	1	1	1.4	1.4		
threshing	1	1	1.4	1.4		
straw-cutting	1	1	1.3	1.3		
levelling	1	1	0.5	0.5		
transport	1	1	0.5	0.5		
stubble plowing	1	1	1.3	1.3		
cultivating	2	2	2.0	1.8		

Table 3b. Description of pest, disease and weed control in environment-oriented oilseed rape cultivation systems under Dutch conditions on clay and sandy soils.

activity	no. of operations		labour requirements (h/ha)		active ingredient (kg/ha)	
	clay	sand	clay	sand	clay	sand
herbicide application	1	1	0.5	0.5	0.6	0.6
fungicide application	1	1	0.5	0.5	0.25	0.25
insecticide application	2	2	1.0	1.0	0.35	0.35
weeding			maximally 4.0			

Table 4a. Description of yield-oriented ware potato cultivation systems under Dutch conditions on clay and sandy soils.

activity	no. of operations		labour requirements (h/ha)		active ingredient (kg/ha)	
	clay	sand	clay	sand	clay	sand
plowing	1	1	2.8	1.8		
seedbed preparation	2	2	3.6	1.6		
planting	1	1	2.5	2.5		
ridging	3	3	6.0	3.0		
fertilizer application	2	3	1.2	1.8		
herbicide application	1	1	0.5	0.5	0.6	1.1
fungicide application	7	7	3.5	3.5	8.4	8.4
insecticide application	1	1	0.5	0.5	0.22	0.45
nematicide application (only in short rotation)	1	1	2.0	2.0	100	100
haulm destruction	1	1	1.0	1.0		
harvesting	1	1	6.4	6.4		
transport			6.4	6.4		
cultivating	1	2	0.9	1.8		

Table 4b. Description of pest, disease and weed control in environment-oriented ware potato cultivation systems under Dutch conditions on clay and sandy soils.

activity	no. of operations		labour requirements (h/ha)		active ingredient (kg/ha)	
	clay	sand	clay	sand	clay	sand
seedbed preparation	3	3	5.4	2.4		
herbicide application	0.1	0.1	0.1	0.1	0.18	0.18
fungicide application	3	3	1.5	1.5	3.4	3.4
insecticide application					0	0
weeding			maximally 4.0			

Table 5a. Description of yield-oriented sugar beet cultivation systems under Dutch conditions on clay and sandy soils.

activity	no. of operations		labour requirements (h/ha)		active ingredient (kg/ha)	
	clay	sand	clay	sand	clay	sand
plowing	1	1	2.8	1.8		
seedbed preparation	1	1	1.1	0.8		
sowing	1	1	1.1	1.1		
fertilizer application	3	4	1.8	2.4		
herbicide application	2.5	3.5	1.3	1.8	1.5	2.1
insecticide application	2	1	1.0	0.5	0.23	0.18
fungicide application (seed disinfection)	0	0	0	0	0.2	0.2
nematicides (only in narrow rotation)	1	1	2.0	2.0	100	100
hoeing	4	4	6.0	5.0		
weeding	2	2	17.5	17.5		
harvesting	1	1	5.2	5.2		
transport	1	1	2.6	2.6		
cultivating	1	1	1.0	0.9		

Table 5b. Description of pest, disease and weed control in environment-oriented sugar beet cultivation systems under Dutch conditions on clay and sandy soils.

activity	no. of operations		labour requirements (h/ha)		active ingredient (kg/ha)	
	clay	sand	clay	sand	clay	sand
seedbed preparation	3	3	3.3	2.4		
herbicide application	1	1	0.5	0.5	0.45	0.45
insecticide application	1	1	0.5	0.5	0.12	0.12
fungicide application	0	0	0	0	0.2	0.2
extra weeding			maximally 4.0			

Table 6a. Description of yield-oriented field bean cultivation systems under Dutch conditions on clay and sandy soils.

activity	no. of operations		labour requirements (h/ha)		active ingredient (kg/ha)	
	clay	sand	clay	sand	clay	sand
plowing	1	1	2.8	1.8		
seedbed preparation	1	1	1.1	0.8		
sowing	1	1	1.1	1.1		
herbicide application	2	2	1.0	1.0	1.6	1.6
fungicide application	1	1	0.5	0.5	0.45	0.45
insecticide application	2	2	1.0	1.0	0.37	0.37
hoeing	1	1	1.3	1.3		
harvesting	1	1	1.6	1.6		
transport	1	1	1.6	1.6		
ploughing stubble	1	1	1.3	1.3		
cultivating	2	2	2.0	1.8		

Table 6b. Description of pest, disease and weed control in environment-oriented field bean cultivation systems under Dutch conditions on clay and sandy soils.

activity	no. of operations		labour requirements (h/ha)		active ingredient (kg/ha)	
	clay	sand	clay	sand	clay	sand
seedbed preparation	2	2	2.2	1.6		
herbicide application	1	2	0.5	1.0	0.8	0.8
fungicide application	1	1	0.5	0.5	0.35	0.35
insecticide application	1	1	0.5	0.5	0.25	0.25
weeding			maximally 4.0			
hoeing	3	3	3.9	3.9		

Table 7a. Description of yield-oriented grass cultivation systems under a mowing regime under Dutch conditions.

activity	no. of operations	labour requirements (h/ha)	active ingredient (kg/ha)
sowing through	0.25	0.4	
fertilizer application	3	1.8	
manure application	4	10	
mole control	0.5	0.75	
herbicide application	0.25	0.15	0.6
insecticide application	0.25	0.15	0.1
mowing		1.5*	
turning,shaking	3*	1.8*	
silage		0.5**	

Table 7b. Description of yield-oriented grass cultivation systems under a grazing regime under Dutch conditions.

activity	no. of operations	labour requirements (h/ha)	active ingredient (kg/ha)
sowing through	0.25	0.4	
fertilizer application	4	2.4	
manure application	2	5.0	
mole control	0.5	0.75	
harrowing	1	0.6	
mowing of tussocks	2	2.0	
herbicide application	0.25	0.15	0.6
insecticide application	0.25	0.15	0.1

Table 7c. Description of pest, disease and weed control in environment-oriented grass cultivation systems under Dutch conditions.

activity	no. of operations	labour requirements (h/ha)	active ingredient (kg/ha)
herbicide application	0	0	0
insecticide application	0	0	0

* : for each harvest
** : for each 1000 kg fresh weight

Table 8. Available data for each suitable Land Evaluation Unit and for each crop.

- Name of the NUTS-1 region

- Surface of the LEU, m^2

- Climatic zone:
  precipitation deficit, mm/year
  precipitation surplus, mm/year

- Soil texture:
  coarse: more than 65% sand and less than 18% clay
  medium: more than 15% sand and less than 35% clay
  medium fine: less than 15% sand and less than 35% clay
  fine: more than 35% clay but less than 60% clay

- Slope:
  level: major slopes between 0 and 8%
  sloping: major slopes between 8 and 15%

- Groundwater influence : yes or no.

- Phase:
  no phase
  gravelly phase
  concretionary phase

- Crop yield:
  dry matter stems, potential production (kg/ha)
  dry matter leaves, potential production (kg/ha)
  dry matter storage organs, potential production (kg/ha)
  dry matter stems, water-limited production (kg/ha)
  dry matter leaves, water-limited production (kg/ha)
  dry matter storage organs, water-limited production (kg/ha)

- Water use, m^3/year

Table 9. Dry matter contents (%)

Wheat	84
Grain maize	86
Silage maize	29
Oilseed rape	91
Potato	22
Sugar beet	20
Field bean	86
Fresh grass	16
Silage grass	50

Table 10. Input/output coefficients for fruit crops

Olive (for oil production)

A: Low management intensity		
N-fertilizer	50	kg/ha
Pesticides	0	kg/ha
Irrigation	0	m^3/ha
Labour	250	h/ha
Yield	1500	kg/ha (20% oil)
B: High management intensity		
N-fertilizer	100	kg/ha
Pesticides	2	kg/ha
Irrigation	0	m^3/ha
Labour	400	h/ha
Yield	3000	kg/ha (20% oil)

Citrus

A : Rainfed		
N-fertilizer	100	kg/ha
Pesticides	2	kg/ha
Irrigation	0	m^3/ha
Labour	300	h/ha
Yield	15000	kg/ha
B : Irrigated		
N-fertilizer	200	kg/ha
Pesticides	7	kg/ha
Irrigation	2000-7000	m^3/ha
Labour	500	h/ha
Yield	40000	kg/ha

Apple

A : Rainfed		
N-fertilizer	75	kg/ha
Pesticides	15	kg/ha
Irrigation	0	m^3/ha
Labour	175	h/ha
Yield	30000	kg/ha
B : Irrigated		
N-fertilizer	100	kg/ha
Pesticides	15	kg/ha
Irrigation	300-1500	m^3/ha
Labour	240	h/ha
Yield	48000	kg/ha

Table 11. Input/output coefficients for dairy farming systems; coefficients expressed on annual basis

	summer grazing	zero grazing		
production:				
milk	5000	5000	8000	kg *
meat	75	75	75	kg
calves	0.63	0.63	0.63	
feed requirements:				
energy	34700	33550	44770	Mj
protein (DCP)	500	500	700	kg
fibrous material	+	+	+	
nitrogen:				
N-uptake grazing	56	0	0	kg
N-uptake stable	40	80	112	kg
removed N	28	28	45	kg
urine-N grazing	42	0	0	kg
urine-N slurry	26	52	67	kg
leaching + denitrification of urine-N grazing	10	0	0	kg
labour:				
milking	16	16	16	hour
transport cows	4.8			hour
hygiene	6	6	6	hour
feeding grass	0.9	1.8	1.8	hour
feeding maize	1.1	2.2	2.2	hour
cleaning stable	2.0	4.0	4.0	hour
attending young cattle	8	8	8	hour

* All coefficients are expressed per lactating cow, including requirements of non-lactating young animals.

Table 12. Input/output coefficients for bovine meat production systems, expressed on an annual basis.

	intensive	extensive	
production:			
live weight	525	520	kg
meat (carcass)	310	338	kg
feed requirements:			
energy	18855	47865	MJ
protein (DCP)	256	650	kg
fibrous material	+	+	
nitrogen:			
N-uptake grazing	0	49	kg
N-uptake stable	41	71	kg
removed N	12	12	kg
urine-N grazing	0	45	kg
urine-N slurry	29	63	kg
leaching + denitrification of urine-N grazing	0	11	kg
labour:			
attending cattle	10	25	hour

* All coefficients are expressed per slaughtered animal. In the extensive system, the annual requirements of mother cows are included.

Table 13. Input/output coefficients for a mutton production system, expressed on an annual basis.

	extensive	
production:		
live weight	56	kg
meat (carcass)	28	kg
feed requirements:		
energy	4586	MJ
protein (DCP)	69	kg
nitrogen:		
N-uptake grazing	9.2	kg
N-uptake stable	4.0	kg
removed N	1.7	kg
urine-N grazing	8.2	kg
urine-N slurry	3.3	kg
leaching + denitrification of urine-N grazing	2.1	kg
labour:		
attending cattle	15	hour

* All coefficients are expressed per ewe and its 1.6 lambs. Meat production is reduced by 13% in order to account for replacement.

Appendix 1. Publications project "Crop Production Potential of the Rural Areas in the European Communities"

Bulens, J.D., A.K. Bregt, 1991. Crop production potential of the rural areas within the European Communities. I: GIS and datamodel. Technical Working Document, Netherlands Scientific Council for Government Policy, The Hague.

Reinds, G.J., H.A.J. Van Lanen, 1991. Crop production potential of the rural areas within the European Communities. II: A physical land evaluation procedure for annual crops and grass. Technical Working Document, Netherlands Scientific Council for Government Policy, The Hague, 28 pp.

Reinds, G.J., G.H.J. De Koning, J.D. Bulens, 1991. Crop production potential of the rural areas within the European Communities. III: Soils, climate and administrative regions. Technical Working Document, Netherlands Scientific Council for Government Policy, The Hague, 39 pp.

De Koning, G.H.J, C.A. Van Diepen, G.J. Reinds, J.D. Bulens, H.A.J. Van Lanen, in prep. Crop production potential of the rural areas within the European Communities. IV: Potential, water-limited and actual crop production. Technical Working Document, Netherlands Scientific Council for Government Policy, The Hague.

Van Lanen, H.A.J., C.M.A. Hendriks, J.D. Bulens, in prep. Crop production potential of the rural areas within the European Communities. V: Qualitative suitability assessment for forestry and perennial crops. Technical Working Document, Netherlands Scientific Council for Government Policy, The Hague.

Bulens, J.D., A.K. Bregt, G.H.J. De Koning, G.J. Reinds, C.A. Van Diepen, H.A.J. Van Lanen, 1990. GIS supporting crop production potential research for the European Communities. In: Harts, J., H.F.L. Ottens, H.J. Scholten, D.A. Ondaatje (Eds.), EGIS'90, First European Conference on Geographical Information Systems, EGIS Foundation, Utrecht, Vol. 1, pp 117-125.

C.A. Van Diepen, G.H.J. De Koning, G.J. Reinds, J.D. Bulens, H.A.J. Van Lanen, 1990. Regional analysis of physical potential of crop production in the European Communities. In : Goudriaan, J., H. Van Keulen, H.H. Van Laar (Eds.), The greenhouse effect and primary productivity in European agro-ecosystems.

Van Lanen, H.A.J., C.A. Van Diepen, G.J. Reinds, G.H.J. De Koning, J.D. Bulens, A.K. Bregt, 1991. Physical land evaluation methods and GIS to explore the crop growth potential and its effects within the European Communities. Submitted for publication in Agricultural Systems.

Van Lanen, H.A.J., C.A. Van Diepen, G.J. Reinds, G.H.J. de Koning, 1991. Comparing qualitative and quantitative physical land evaluations using the assessment of the growing potential for sugar beet in the European Communities. Submitted for publication in Soil Use and Management.

Appendix 2. Crop pests (Latin, Dutch)

Insects

Dilophus febrilis (L.)	Rouwvlieglarven
Tipula paludosa Meig.	Langpootmuggen (emelten)
Meligethes aeneus (F.)	Koolzaadglanskever
Ceuthorhynchus assimilis (Payk.)	Koolzaadsnuitkever
Dasineura brassicae (Winn.)	Koolzaadhauwgalmug
Myzus persicae (Sulz.)	Groene perzikluis
Leptinotarsa decemlineata (Say)	Coloradokever
Aphis fabae (Scop)	Zwarte boneluis
Sitona lineatus (L.)	Bladrandkever

Fungi	Disease
Puccinia striiformis	Gele roest
Leptospaeria nodorum E. Mull.	Kafjesbruin
Erysiphe graminis DC.	Meeldauw
Sclerotinia sclerotiorum (Lib.)	Sclerotiënrot
Verticillium dahliae	Verwelkingsziekte
Phytophthora infestans (Mont.)	Aardappelziekte
Rhizoctonia solani	Lakschurft
Aphanomyces cochlioides	Afdraaiers
Botrytis cinerea	Chocoladevlekkenziekte
Uromyces fabae	Bonenroest
Peronospora viviae	Valse meeldauw
Pythium spp.	Kiemplanteziekte
Fusarium spp.	Stengelrot, kolfsteelrot
Gaeumannomyces graminis	Halmdoder

Weeds

Galium asparine L.	Kleefkruid
Alopecurus myosuroides Huds.	Duist
Avena fatua	Wilde haver
Matricaria chamomilla L.	Kamille
Polygonum aviculare L.	Varkensgras
Chenopodium album L.	Melganzevoet

Nematodes

Globodera rostochiensis	Geel aardappelcysteaaltje
Globodera pallida	Wit aardappelcysteaaltje
Heterodera schachtii	Wit bietecysteaaltje
Heterodera trifolii	Geel bietecysteaaltje
Meloidogyne naasi	Graswortelknobbelaaltje

Appendix 3a. Selected crop rotations.

Arable crop rotations that can be selected in YOA only:

W
G
W P
W S
P W S
W O P
G S P
G O P
G S W
O S W
G S W S
P S P W
G W S W F S
W S W F S P

Arable crop rotations that can be selected in both YOA and EOA:

G W
G O
W W O
P W O W
G S W P
G W O F
F P W O S
W O W F S
G W F W O
W P W O F S
W O W F W P
W O W O P F
W S W F W P
W O
G O W
P W S W
P F S W
G P W O
G O P S
G S F P W
W O W W P
G O S F W P
W W W W W S
W O W F S P
G W O W F S

Forage crops, grass and silage maize, are grown in continuous cropping.

W = Wheat
G = Grain maize
P = Potato
S = Sugar beet
O = Oilseed rape
F = Field bean

Appendix 3b. Rotation specific effects.

Crop	Rotation	Effect	Cause
potato	after sugar beet	8% yield reduction *	soil structure
potato	after field bean	5% yield reduction	*Verticillium dahliae*
potato	1 in 4	10% yield reduction	nematodes
potato	1 in 3	nematicide application	nematodes
potato	1 in 2	nematicide application	nematodes
sugar beet	after potato	25% more herbicides in YOA	residual tubers
		10% more herbicides in EOA + 1.5 labour	residual tubers
sugar beet	1 in 4	10% yield reduction	nematodes
sugar beet	1 in 3	5% yield red. on sand + nematicide application **	*Aphanomyces cochlioides* nematodes
wheat	after potato	as sugar beet after potato	residual tubers
wheat	after sugar beet	5% yield red. on clay	soil structure
wheat	after wheat	20% yield reduction	diseases
wheat	continuous	15% yield reduction	diseases
oilseed rape	after potato	as sugar beet after potato	residual tubers
oilseed rape	after wheat	30% more herbicides in YOA	weed problems
		20% more herbicides in EOA + 1.5 labour	weed problems
maize	after potato	as sugar beet after potato	residual tubers
maize	1 in 2	5% yield reduction	*Phythium, Fusarium*
maize	3 in 4	10% yield reduction	*Phythium, Fusarium*
maize	continuous	15% yield reduction	*Phythium, Fusarium*
field bean	after potato	as sugar beet after potato	residual tubers
field bean	1 in 5	5% yield reduction	diseases
field bean	1 in 4	10% yield reduction	diseases

* : if not specified, yield reductions apply to both YOA and EOA

** : if nematicides are applied for potatoes in the same rotation, no extra application is necessary

Appendix 4. Use of herbicides and fungicides for wheat cultivation in YOA.

Herbicide rate (a.i., kg/ha) for wheat in YOA in dependence of soil type and climate type:

SOIL*	1	2	3	4
CLIMATE **				
1	0.70	1.01	1.32	1.62
2	0.78	1.12	1.46	1.80
3	0.85	1.22	1.60	1.97
4	0.93	1.33	1.74	2.15
5	1.00	1.44	1.88	2.32

Fungicide rate (a.i., kg/ha) for wheat in YOA in dependence of dry matter yield (1000 kg/ha) and climate type:

YIELD	2.5	5.0	7.5	10.0
CLIMATE **				
1	1.66	1.86	2.26	2.67
2	1.83	2.06	2.50	2.95
3	2.01	2.26	2.75	3.24
4	2.19	2.45	2.99	3.52
5	2.37	2.37	3.23	3.81

* Soil : texture classes 1-4 (see Table 8)

** Climate type	annual precipitation deficit (mm)
1	800
2	600
3	400
4	200
5	0

(Annual precipitation deficit in De Bilt (climate type 4.7) amounts to 66 mm)

Appendix 5. Field application efficiency

Field application efficiency of a sprinkler system as a function of climate type, soil type and slope.

	major slopes 0-8%				major slopes 8-15%			
SOIL*	1	2	3	4	1	2	3	4
CLIMATE **								
1	0.51	0.51	0.57	0.54	0.43	0.43	0.48	0.45
2	0.51	0.51	0.57	0.54	0.43	0.43	0.48	0.45
3	0.60	0.60	0.67	0.63	0.50	0.50	0.56	0.53
4	0.60	0.60	0.67	0.63	0.50	0.50	0.56	0.53
5	0.68	0.68	0.76	0.72	0.57	0.57	0.63	0.60

* soil : texture classes 1-4 (see Table 8)
** climate : see Appendix 4

Appendix 6. Nitrogen concentration in residues and storage organs of various crops (% N of dry matter).

	Residues	Storage organs
Wheat	0.4	2.2
Maize	1.0	1.5
Oilseed rape	0.8	2.7
Potato	2.5	1.5
Sugar beet	2.0	1.0
Field bean	1.0	4.0
Grass	3.0	

Appendix 7. Apparent nitrogen recoveries for various crops

Average recoveries for crops under favourable conditions:

Wheat	0.7
Maize	0.5
Oilseed rape	0.7
Potato	0.5
Sugar beet	0.7
Grass	0.85

Recovery of wheat in potential production situation : 0.75
Recovery of wheat in water-limited production situation in dependence of soil type and climate type:

SOIL *	1	2	3	4
CLIMATE **				
1	0.50	0.55	0.55	0.55
2	0.54	0.60	0.60	0.60
3	0.59	0.65	0.65	0.65
4	0.63	0.70	0.70	0.70
5	0.68	0.75	0.75	0.68

Recovery of potato in potential production situation : 0.75
Recovery of potato in water-limited production situation in dependence of soil type and climate type.

SOIL *	1	2	3	4
CLIMATE **				
1	0.36	0.40	0.40	0.40
2	0.41	0.45	0.45	0.45
3	0.45	0.50	0.50	0.50
4	0.50	0.55	0.55	0.55
5	0.54	0.60	0.60	0.54

* Soil : texture classes 1-4 (see Table 8)
** Climate : based on annual precipitation deficit (see Appendix 5

Appendix 8. Nitrogen losses.

Values of FIX, the fraction of residual N in the soil profile not subject to losses:

Wheat	0.3
Maize	0.25
Oilseed rape	0.3
Potato	0.2
Sugar beet	0.3
Grass	0.3

Nitrogen losses are calculated with the equation:

Nlost = Nm * (1-FIX) * SOICLI, in which :

SOICLI is a factor depending on soil type and climate type.

SOICLI for various soil/climate combinations:

SOIL *	1	2	3	4
CLIMATE **				
1	0.56	0.42	0.42	0.56
2	0.88	0.66	0.66	0.88
3	1.00	0.75	0.75	1.00
4	1.00	0.75	0.75	1.00
5	1.00	0.75	0.75	1.00

The fraction of Nlost that is denitrified depends on soil type, groundwater influence and climate type.

Fraction of Nlost that is denitrified for various soil/climate combinations:

	no groundwater				groundwater			
SOIL *	1	2	3	4	1	2	3	4
CLIMATE **								
1	0.00	0.10	0.19	0.29	0.11	0.22	0.34	0.45
2	0.00	0.15	0.30	0.46	0.17	0.34	0.51	0.68
3	0.00	0.21	0.42	0.64	0.23	0.46	0.69	0.91
4	0.00	0.25	0.50	0.75	0.25	0.50	0.75	1.00
5	0.00	0.25	0.50	0.75	0.25	0.50	0.75	1.00

* Soil : texture classes 1-4 (see table *)

** Climate type	annual precipitation surplus
1	50
2	300
3	550
4	800
5	1050

(The precipitation surplus in The Bilt amounts to 362 mm)

Appendix 9 Machines. YOA : yield-oriented agriculture, EOA : environment-oriented agriculture. In first column the number of the month of the year is indicated (a and b are the first two weeks and the last two weeks of the month, respectively). Machine input is given as machines per 100 ha (after the stroke, the code for the machine is given, explanation at end of appendix).

	potato YOA	potato EOA	sugar beet YOA	sugar beet EOA	field bean YOA	field bean EOA
2b	0.94-1	0.94-1				
3a	0.94-1, 2.78-7	0.94-1, 4.55-7	0.94-1	0.94-1, 0.78-6	1.72-7, 1.72-8	1.72-7
3b	2.78-7	4.55-7		0.78-6	0.78-2	0.78-2, 1.72-7, 1.72-8
4a	3.13-17 0.78-10	3.13-17 0.78-10	1.72-7, 1.72-8, 2.32-4, 0.78-3	1.72-7, 1.78-8, 2.32-4		2.04-4
4b	3.13-18, 0.78-2	3.13-18, 0.078-2		2.32-4	0.78-2	
5a		3.13-18	0.78-3, 2.32-4	0.78-3, 2.32-4		2.04-4
5b	3.13-18	3.13-18	0.94-1, 6.67-21, 2.32-4, 0.78-3	0.94-1, 6.67-21, 2.32-4,	2.04-4	2.04-4
6a	0.91-2	0.39-2	6.67-21	6.67-21		2.04-4
6b	0.91-2	0.39-2	6.67-21, 0.78-2	6.67-21, 0.78-2	0.78-2	0.78-2
7a	1.69-2	0.39-2	6.67-21	6.67-21	0.78-2	
7b	0.91-2	0.39-2			0.78-2	0.78-2
8a	0.91-2	0.39-2				
8b	0.91-2, 0.78-19	0.39-2, 0.78-19	0.94-1	0.94-1	2.50-15, 2.50-10	2.50-15, 2.50-10
9a	0.78-19, 2.50-20, 2.50-10	0.78-19, 2.50-20, 2.50-10				
9b	2.50-20, 2.50-10	2.50-20, 2.50-10	1.37-22, 1.37-10	1.37-22, 1.37-10		
10a	1.45-5, 0.52-7	1.45-5, 0.52-7	1.37-22, 1.37-10, 1.45-5, 0.52-7	1.37-22, 1.37-10, 1.45-5, 0.52-7	1.45-5, 0.52-7	1.45-5, 0.52-7
10b	1.45-5, 0.52-7	1.45-5, 0.52-7	1.37-22, 1.37-10, 1.45-5, 0.52-7	1.37-22, 1.37-10, 1.45-5, 0.52-7	1.45-5, 0.52-7	1.45-5, 0.52-7
11a	1.45-5, 0.52-7	1.45-5, 0.52-7	1.45-5, 0.52-7	1.45-5, 0.52-7	1.45-5, 0.52-7	1.45-5, 0.52-7

Appendix 9.(continued).

	wheat YOA	wheat EOA	silage maize* YOA	silage maize* EOA	oilseed rape YOA	oilseed rape EOA
2a	0.94-1	0.94-1				
2b						
3a		2.32-4			0.47-1	0.47-1
3b					0.47-1	0.47-1, 2.32-4
4a	0.94-1, 0.39-2	0.94-1	0.94-1	0.94-1		
4b	0.39-2	0.39-2	1.72-7, 1.89-8	1.72-7		
5a				1.72-7, 1.89-8	0.78-2	0.78-2
5b	0.94-1, 0.52-2	0.94-1, 0.26-2	0.78-3, 2.32-4	0.39-3, 2.32-4	0.78-2	
6a	0.52-2	0.26-2	2.32-4	2.32-4,	0.78-2	0.78-2
6b	0.52-2	0.26-2		2.32-4		
7a	0.78-2	0.78-2				
7b					2.17-14	2.17-14
8a	1.25-15, 1.25-10	1.25-15, 1.25-10			2.17-5, 1.72-7, 2.17-15, 2.17-10	2.17-5, 1.72-7, 2.17-15, 2.17-10
8b	1.25-15, 1.25-10, 1.72-11, 2.63-12 2.63-9	1.25-15, 1.25-10, 1.72-11, 2.63-12 2.63-9	0.94-1	0.94-1	2.17-5, 1.72-7, 1.89-8	2.17-5, 1.72-7, 1.89-8
9a					0.47-1, 0.78-2	0.47-1, 0.78-2
9b			0.33-13, 0.33-10	0.33-13, 0.33-10	0.47-1	0.47-1
10a	1.45-5, 0.42-7, 0.26-6, 0.57-8	1.45-5, 0.42-7, 0.26-6, 0.57-8	0.33-13, 0.33-10, 1.45-5, 0.52-7	0.33-13, 0.33-10, 1.45-5, 0.52-7	0.78-2	0.78-2
10b	1.45-5, 0.42-7, 0.26-6, 0.57-8,	1.45-5, 0.42-7, 0.26-6, 0.57-8,	0.33-13, 0.33-10, 1.45-5, 0.52-7	0.33-13, 0.33-10, 1.45-5, 0.52-7		
11a	1.45-5, 0.42-7, 0.26-6, 0.57-8	1.45-5, 0.42-7, 0.26-6, 0.57-8	1.45-5, 0.52-7	1.45-5, 0.52-7		

* grain maize : for harvesting operations 0.83-15 and 0.83-10 are required instead of 0.33-13 and 0.33-10

Appendix 9 (continued). Machines. Machine input for two gras management systems. On each line are indicated: period of the year (number indicates month, a and b are the first two weeks and the last two weeks of the month, respectively), number of machines per ha and type of machine, respectively). For both management systems a tractor is required (40-60 kW).

Mowing system:
3a - 8b, 0.23 chemical fertilizer distributor
1a - 12b, 0.02 field sprayer
3a - 8b, 1.30 manure injector
8a - 9a, 0.21 resowing machine
4a - 9b, 1.17 mower
4a - 9b, 0.94 hay tedder
4a - 9b, 0.47 side rake
4a - 9b, 0.47 pick-up machine
Grazing system:
3a - 8b, 0.31 chemical fertilizer distributor
1a - 12b, 0.02 field sprayer
3a - 8b, 0.65 manure injector
8a - 9a, 0.21 resowing machine
4a - 9b, 0.26 mower
4a - 9b, 0.08 weed harrow
4a - 9b, 0.08 flat roller
4a - 9b, 0.08 leveller

Codes of arable crop machines (behind machines that are towed by a tractor, the required tractor is indicated with a, b or c):
a tractor (25-40 kW)
b tractor (40-60 kW)
c tractor (60-90 kW)
1 chemical fertilizer distributor, capacity 1000 l (b)
2 field sprayer (b)
3 row sprayer (a)
4 hoeing machine (a)
5 plough (c)
6 weed harrow (b)
7 cultivator + crumbler (c)
8 seed drill (crop specific) (b)
9 trailer (b)
10 big trailer (b)
11 straw press (b)
12 hay lifter (combined with straw press)
13 maize chopper (self-riding)
14 swath mower (b)
15 combine harvester (self-riding)
17 potato-planter (b)
18 rowmiller + ridger (c)
19 leaf cutter (a)
20 potato lifter (c)
21 hoe
22 sugar beet lifter (c)

Appendix 10. Division of NUTS-1 regions in groups according to climatic characteristics.

Group 1	Group 2	Group 3
Schleswig-Holstein (Ge)	Ile-de-France (Fr)	Méditerranée (Fr)
Niedersachsen (Ge)	Bassin-Parisien (Fr)	Lazio (It)
Nordrhein-Westfalen (Ge)	Ouest (Fr)	Campania (It)
Hessen (Ge)	Sud-Ouest (Fr)	Sud (It)
Rheinland-Pfalz (Ge)	Centre-Est (Fr)	Sicilia (It)
Baden-Wurttemberg (Ge)	Nord-Ovest (It)	Sardegna (It)
Bayern (Ge)	Lombardia (It)	North (Gr)
Saarland (Ge)	Nord-Est (It)	Central (Gr)
Nord-Pas-de-Calais (Fr)	Emilia-Romagna (It)	East (Gr)
Est (Fr)	Centro (It)	Noreste (Sp)
Noord-Nederland (Nl)	Abruzzi-Molise (It)	Madrid (Sp)
Oost-Nederland (Nl)	Este (Sp)	Centro (Sp)
West-Nederland (Nl)	Norte d. Co. (Po)	Sur (Sp)
Zuid-Nederland (Nl)		Sul d. Co. (Po)
Vlaams gewest (Nl)		
Région Wallonne (B)		
Luxembourg		
North (UK)		
Yorkshire-Humberside (UK)		
East-Midlands (UK)		
East-Anglia (UK)		
South-East (UK)		
South-West (UK)		
West-Midlands (UK)		
North-West (UK)		
Wales (UK)		
Scotland (UK)		
Northern-Ireland (UK)		
Ireland		
Danmark		
Noroeste (Sp)		

B : Belgium
Fr : France
Ge : Germany
Gr : Greece
It : Italy
Nl : Netherlands
Po : Portugal
Sp : Spain
UK : United Kingdom

Appendix 11a. Results. Yields (kg/ha fresh weight) for rotation:
field bean - potato - wheat - oilseed rape - sugar beet
YOP : yield-oriented potential production
YOW : yield-oriented water-limited production
EOP : environment-oriented potential production
EOW : environment-oriented water-limited production

	WHEAT	POTAT	SBEET	OILS	BEAN
YOP.SCHLEWIG-H	10.0	69.0	83.3	4.9	8.4
YOW.SCHLEWIG-H	7.9	51.8	68.4	3.7	5.8
EOP.SCHLEWIG-H	7.5	50.0	73.3	3.7	5.5
EOW.SCHLEWIG-H	6.3	38.8	60.2	2.9	4.0
YOP.NIEDERSACH	9.8	67.5	87.3	4.5	8.1
YOW.NIEDERSACH	7.7	51.3	70.6	3.6	5.6
EOP.NIEDERSACH	7.4	48.9	76.8	3.5	5.4
EOW.NIEDERSACH	6.3	38.4	62.1	3.0	3.9
YOP.NORDRHN-WF	9.5	65.3	88.4	4.2	7.9
YOW.NORDRHN-WF	8.6	55.2	77.9	4.0	6.5
EOP.NORDRHN-WF	7.3	47.6	77.9	3.3	5.3
EOW.NORDRHN-WF	6.8	41.1	68.6	3.1	4.4
YOP.HESSEN	9.5	65.3	96.1	4.1	7.9
YOW.HESSEN	8.2	48.0	81.5	4.0	5.4
EOP.HESSEN	7.3	49.6	84.9	3.1	5.4
EOW.HESSEN	6.5	37.6	72.0	3.0	3.9
YOP.RHEIN-PFLZ	9.5	65.8	100.2	4.0	7.9
YOW.RHEIN-PFLZ	8.2	48.3	84.0	3.8	5.5
EOP.RHEIN-PFLZ	7.3	49.5	88.4	3.1	5.4
EOW.RHEIN-PFLZ	6.5	37.5	74.1	3.0	4.0
YOP.BADEN-WURT	10.1	67.5	95.2	4.4	8.4
YOW.BADEN-WURT	9.8	58.3	87.5	4.4	7.3
EOP.BADEN-WURT	7.3	49.5	83.9	3.3	5.5
EOW.BADEN-WURT	7.3	43.4	77.2	3.2	4.9
YOP.BAYERN	9.6	67.0	98.8	4.0	8.1
YOW.BAYERN	8.9	53.3	87.5	3.9	6.3
EOP.BAYERN	7.1	49.7	87.1	3.1	5.4
EOW.BAYERN	6.9	40.6	77.2	3.0	4.4
YOP.SAARLAND	9.5	66.4	102.5	4.0	7.9
YOW.SAARLAND	8.9	58.1	93.9	3.8	6.2
EOP.SAARLAND	7.4	49.1	91.1	3.1	5.4
EOW.SAARLAND	7.0	43.6	83.4	3.0	4.4
YOP.ILEDEFRNCE	10.6	68.4	103.6	4.3	8.8
YOW.ILEDEFRNCE	8.2	42.7	71.1	3.9	5.1
EOP.ILEDEFRNCE	7.7	52.2	91.5	3.2	6.1
EOW.ILEDEFRNCE	6.3	34.1	62.8	2.9	3.7
YOP.BASSIN-PAR	10.6	67.5	101.5	4.3	8.8
YOW.BASSIN-PAR	8.7	44.5	72.7	3.9	5.6
EOP.BASSIN-PAR	7.7	51.1	89.6	3.2	6.0
EOW.BASSIN-PAR	6.6	35.0	64.2	3.0	4.0
YOP.NORD-PDCAL	10.2	66.1	96.4	4.3	8.5
YOW.NORD-PDCAL	8.8	47.4	75.9	4.1	6.1
EOP.NORD-PDCAL	7.4	49.7	85.1	3.2	5.7
EOW.NORD-PDCAL	6.8	36.7	67.0	3.1	4.3
YOP.EST	9.9	66.7	104.4	4.2	8.3
YOW.EST	8.7	51.4	85.1	4.0	5.7

EOP.EST	7.3	50.5	92.2	3.2	5.7
EOW.EST	6.8	39.9	75.2	3.0	4.1
YOP.OUEST	11.1	67.4	105.0	4.4	9.3
YOW.OUEST	10.3	40.1	70.3	4.2	6.5
EOP.OUEST	7.9	51.5	92.8	3.2	6.4
EOW.OUEST	7.5	32.1	62.1	3.1	4.6
YOP.SUD-OUEST	10.8	66.8	109.4	4.0	9.0
YOW.SUD-OUEST	9.2	42.2	67.0	3.6	6.1
EOP.SUD-OUEST	7.8	50.2	96.5	3.1	6.1
EOW.SUD-OUEST	7.0	33.0	59.2	2.8	4.3
YOP.CENTRE-EST	10.2	68.1	110.7	4.2	8.5
YOW.CENTRE-EST	7.7	39.8	67.1	4.0	5.0
EOP.CENTRE-EST	7.6	51.4	97.7	3.2	5.9
EOW.CENTRE-EST	6.2	31.6	59.3	3.1	3.6
YOP.MEDITERRAN	10.2	65.6	106.6	3.7	8.5
YOW.MEDITERRAN	7.0	31.6	44.3	2.8	3.4
EOP.MEDITERRAN	7.7	52.7	94.4	2.9	6.4
EOW.MEDITERRAN	5.7	26.5	39.5	2.3	2.6
YOP.NORD-OVEST	8.6	60.9	98.2	3.5	7.2
YOW.NORD-OVEST	7.5	39.7	59.5	3.3	5.0
EOP.NORD-OVEST	6.8	46.0	86.6	2.8	5.0
EOW.NORD-OVEST	6.0	31.2	52.5	2.7	3.6
YOP.LOMBARDIA	8.4	60.0	94.6	3.3	7.0
YOW.LOMBARDIA	7.4	40.2	59.1	3.2	4.9
EOP.LOMBARDIA	6.8	45.4	83.4	2.7	4.9
EOW.LOMBARDIA	6.0	31.6	52.2	2.6	3.6
YOP.NORD-EST	8.4	60.0	94.5	3.3	7.1
YOW.NORD-EST	7.4	40.8	59.9	3.1	4.9
EOP.NORD-EST	6.8	45.5	83.3	2.7	4.9
EOW.NORD-EST	6.1	32.0	52.8	2.6	3.6
YOP.EMILIA-ROM	8.5	60.0	94.3	3.3	7.1
YOW.EMILIA-ROM	7.3	38.6	56.3	3.1	4.7
EOP.EMILIA-ROM	6.8	45.8	83.2	2.7	5.0
EOW.EMILIA-ROM	6.0	30.6	49.7	2.6	3.5
YOP.CENTRO-IT	9.8	63.7	102.1	3.5	8.2
YOW.CENTRO-IT	7.6	29.1	37.3	3.0	4.0
EOP.CENTRO-IT	7.6	50.1	90.2	2.9	6.0
EOW.CENTRO-IT	6.1	24.2	33.2	2.5	3.0
YOP.LAZIO	10.1	63.2	101.8	3.3	8.4
YOW.LAZIO	7.7	22.0	30.0	2.7	3.4
EOP.LAZIO	7.7	51.0	90.1	2.8	6.4
EOW.LAZIO	6.4	18.9	26.8	2.3	2.7
YOP.CAMPANIA	9.9	63.7	103.7	3.4	8.2
YOW.CAMPANIA	7.9	26.6	34.3	3.0	3.9
EOP.CAMPANIA	7.5	50.5	91.7	2.8	6.1
EOW.CAMPANIA	6.5	22.3	30.8	2.5	3.0
YOP.ABRUZ-MOLI	9.2	62.0	97.3	3.3	7.7
YOW.ABRUZ-MOLI	6.3	25.6	35.4	2.7	3.2
EOP.ABRUZ-MOLI	7.4	49.4	86.1	2.7	5.7
EOW.ABRUZ-MOLI	5.3	21.7	31.7	2.3	2.5
YOP.SUD	9.7	63.0	95.5	3.2	8.1
YOW.SUD	6.9	24.5	31.8	2.5	2.4
EOP.SUD	7.7	52.2	84.6	2.7	6.4
EOW.SUD	5.8	21.4	28.4	2.2	2.0

YOP.SICILIA	10.1	65.0	99.9	3.1	8.4
YOW.SICILIA	7.3	24.6	33.4	2.2	2.4
EOP.SICILIA	7.8	54.1	88.5	2.6	6.7
EOW.SICILIA	6.2	21.5	29.8	2.0	1.9
YOP.SARDEGNA	10.7	64.9	104.7	3.5	9.0
YOW.SARDEGNA	8.1	22.9	29.7	2.8	2.8
EOP.SARDEGNA	8.3	53.5	92.8	2.9	7.0
EOW.SARDEGNA	6.6	19.9	26.7	2.4	2.3
YOP.NOORD-NL	9.9	67.0	84.9	4.6	8.2
YOW.NOORD-NL	8.0	59.1	74.1	3.8	5.9
EOP.NOORD-NL	7.5	48.2	74.6	3.6	5.5
EOW.NOORD-NL	6.5	43.2	65.1	3.1	4.1
YOP.OOST-NL	9.8	66.2	84.3	4.4	8.2
YOW.OOST-NL	8.0	56.5	72.7	3.7	6.0
EOP.OOST-NL	7.4	47.7	74.1	3.5	5.4
EOW.OOST-NL	6.5	41.5	63.8	3.1	4.1
YOP.ZUID-NL	9.7	65.7	85.0	4.3	8.1
YOW.ZUID-NL	7.9	55.6	72.6	3.7	6.0
EOP.ZUID-NL	7.4	47.2	74.7	3.5	5.4
EOW.ZUID-NL	6.5	40.8	63.8	3.0	4.1
YOP.WEST-NL	9.8	65.6	83.2	4.4	8.2
YOW.WEST-NL	8.4	57.9	73.4	3.9	6.2
EOP.WEST-NL	7.3	47.7	73.2	3.4	5.4
EOW.WEST-NL	6.6	42.8	64.6	3.1	4.3
YOP.VLAAMSGWST	9.7	65.2	87.3	4.3	8.1
YOW.VLAAMSGWST	8.4	53.2	74.0	3.7	6.3
EOP.VLAAMSGWST	7.3	47.3	76.8	3.3	5.4
EOW.VLAAMSGWST	6.7	39.5	65.1	3.0	4.3
YOP.REG-WALLON	10.0	66.2	95.4	4.3	8.3
YOW.REG-WALLON	8.6	47.7	74.2	4.0	6.1
EOP.REG-WALLON	7.3	49.7	84.3	3.2	5.6
EOW.REG-WALLON	6.6	36.8	65.5	3.0	4.2
YOP.LUXEMBOURG	9.8	67.4	100.1	4.1	8.2
YOW.LUXEMBOURG	5.9	41.0	63.8	2.9	4.1
EOP.LUXEMBOURG	7.4	49.4	88.2	3.3	5.5
EOW.LUXEMBOURG	4.9	31.6	56.3	2.4	3.0
YOP.NORTH	9.8	62.7	55.4	4.7	8.2
YOW.NORTH	9.1	56.5	52.6	4.4	7.0
EOP.NORTH	7.6	45.2	48.7	3.6	5.4
EOW.NORTH	7.2	41.2	46.3	3.5	4.7
YOP.YORKSH-HUM	10.5	66.9	80.2	4.8	8.8
YOW.YORKSH-HUM	7.9	47.4	65.8	4.0	5.6
EOP.YORKSH-HUM	7.7	49.2	70.7	3.6	5.8
EOW.YORKSH-HUM	6.2	36.3	58.0	3.1	3.9
YOP.EAST-MIDL	10.5	66.9	81.6	4.8	8.7
YOW.EAST-MIDL	8.1	47.8	66.4	4.0	5.6
EOP.EAST-MIDL	7.8	49.2	71.9	3.6	5.8
EOW.EAST-MIDL	6.3	36.5	58.5	3.1	4.0
YOP.EAST-ANGL	10.6	67.5	82.3	4.8	8.9
YOW.EAST-ANGL	8.1	43.9	64.0	3.7	5.7
EOP.EAST-ANGL	7.9	49.3	72.4	3.7	5.9
EOW.EAST-ANGL	6.4	33.6	56.3	2.9	4.0
YOP.SOUTH-EAST	11.2	68.7	88.5	4.9	9.3
YOW.SOUTH-EAST	8.1	41.4	64.6	4.0	5.5

EOP.SOUTH-EAST	8.0	51.1	78.0	3.6	6.2
EOW.SOUTH-EAST	6.2	32.4	57.0	3.0	3.9
YOP.SOUTH-WEST	12.3	69.7	91.4	4.9	10.2
YOW.SOUTH-WEST	9.3	44.9	68.9	4.1	6.5
EOP.SOUTH-WEST	8.6	51.1	80.6	3.6	6.7
EOW.SOUTH-WEST	7.0	34.6	60.7	3.1	4.5
YOP.WEST-MIDL	10.0	65.1	79.4	4.6	8.3
YOW.WEST-MIDL	8.4	47.0	67.8	4.1	5.9
EOP.WEST-MIDL	7.5	48.4	70.0	3.4	5.6
EOW.WEST-MIDL	6.5	36.2	59.8	3.1	4.1
YOP.NORTH-WEST	10.7	67.0	81.3	4.7	8.9
YOW.NORTH-WEST	6.9	47.1	63.2	3.3	4.7
EOP.NORTH-WEST	8.0	49.1	71.6	3.7	6.0
EOW.NORTH-WEST	5.7	35.8	55.7	2.7	3.4
YOP.WALES	11.4	67.7	82.2	4.9	9.5
YOW.WALES	9.2	46.6	69.6	4.4	6.5
EOP.WALES	8.2	49.6	72.3	3.7	6.3
EOW.WALES	7.0	35.6	61.3	3.3	4.5
YOP.SCOTLAND	10.7	63.2	58.9	5.1	8.9
YOW.SCOTLAND	9.3	55.3	55.4	4.3	7.0
EOP.SCOTLAND	7.9	45.9	51.8	3.8	5.8
EOW.SCOTLAND	7.1	40.7	48.7	3.3	4.7
YOP.NRTH-IRLND	10.6	64.3	70.9	4.8	8.8
YOW.NRTH-IRLND	9.4	51.4	65.4	4.4	6.8
EOP.NRTH-IRLND	7.8	47.0	62.4	3.6	5.8
EOW.NRTH-IRLND	7.1	38.5	57.5	3.4	4.7
YOP.IRELAND	11.2	65.4	76.4	4.8	9.4
YOW.IRELAND	10.1	51.2	69.7	4.5	7.4
EOP.IRELAND	8.1	47.7	67.2	3.6	6.1
EOW.IRELAND	7.5	38.4	61.4	3.4	5.0
YOP.DANMARK	9.8	70.0	82.9	4.9	8.2
YOW.DANMARK	6.9	41.4	61.5	3.2	4.7
EOP.DANMARK	7.5	51.2	73.0	3.8	5.5
EOW.DANMARK	5.7	32.0	54.2	2.6	3.4
YOP.VOR-ELLADA	8.2	55.7	87.0	3.2	6.9
YOW.VOR-ELLADA	6.5	35.1	44.7	3.0	2.0
EOP.VOR-ELLADA	6.9	47.1	77.1	2.7	5.6
EOW.VOR-ELLADA	5.6	30.3	39.7	2.5	1.7
YOP.KENTR-ELLA	7.8	52.9	70.3	2.4	6.5
YOW.KENTR-ELLA	6.7	31.0	37.9	2.2	1.6
EOP.KENTR-ELLA	6.7	45.6	62.4	2.2	5.5
EOW.KENTR-ELLA	5.8	27.3	33.9	2.0	1.3
YOP.NISIA	7.4	56.0	62.9	2.4	6.2
YOW.NISIA	6.4	21.9	29.8	2.1	1.2
EOP.NISIA	6.5	48.6	55.8	2.1	5.2
EOW.NISIA	5.7	19.9	27.2	1.9	1.0
YOP.NOROESTE	11.5	71.5	118.2	3.9	9.6
YOW.NOROESTE	9.3	51.1	69.4	3.2	6.2
EOP.NOROESTE	8.3	53.4	104.3	3.1	6.5
EOW.NOROESTE	7.0	38.8	61.2	2.6	4.3
YOP.NORESTE	10.3	65.2	106.2	3.7	8.6
YOW.NORESTE	5.5	33.9	46.6	2.5	2.2
EOP.NORESTE	8.0	53.9	94.0	3.0	6.8
EOW.NORESTE	4.6	28.7	41.3	2.1	1.7

YOP.MADRID	10.0	62.1	100.8	3.8	8.4
YOW.MADRID	4.3	26.4	31.2	2.3	1.0
EOP.MADRID	7.9	53.3	89.4	3.0	7.0
EOW.MADRID	3.9	23.5	27.7	2.1	0.8
YOP.CENTRO-ESP	10.5	64.9	107.7	4.2	8.8
YOW.CENTRO-ESP	4.8	25.9	30.8	3.0	1.3
EOP.CENTRO-ESP	8.3	55.0	95.5	3.3	7.2
EOW.CENTRO-ESP	4.2	22.9	27.6	2.5	1.0
YOP.ESTE	10.3	63.6	99.1	3.3	8.6
YOW.ESTE	8.0	39.6	52.7	2.7	3.3
EOP.ESTE	7.9	52.1	87.7	2.8	6.6
EOW.ESTE	6.4	33.3	46.7	2.3	2.5
YOP.SUR	9.7	60.7	92.6	3.0	8.1
YOW.SUR	6.3	26.9	32.8	2.1	1.1
EOP.SUR	7.9	52.7	82.2	2.6	6.9
EOW.SUR	5.5	24.1	29.6	1.8	0.9
YOP.NORTE-CONT	11.4	69.0	122.0	3.7	9.6
YOW.NORTE-CONT	6.2	21.6	24.7	2.0	2.2
EOP.NORTE-CONT	8.8	56.2	108.0	3.1	7.4
EOW.NORTE-CONT	5.3	18.6	22.5	1.8	1.8
YOP.SUL-CONT	10.8	67.1	114.4	3.4	9.1
YOW.SUL-CONT	5.8	16.4	21.4	1.8	1.2
EOP.SUL-CONT	8.6	57.6	101.5	3.0	7.6
EOW.SUL-CONT	4.9	15.0	19.4	1.6	1.0

Appendix 11b. Results. Average annual inputs for rotation:
field bean - potato - wheat - oilseed rape - sugar beet

YOP : yield-oriented potential production
YOW : yield-oriented water-limited production
EOP : environment-oriented potential production
EOW : environment-oriented water-limited production
SUIT : percentage of the area of the NUTS-1 region that is suitable for this rotation
A.I. : active ingredient of pesticides (kg/ha)
LABOUR : labour (hours/ha)
WATER : water input (m^3/ha)
N-INP : chemical nitrogen (N) fertilizer (kg/ha)
LOSS : nitrogen (N) loss through leaching and denitrification (kg/ha)

	SUIT	A.I.	LABOUR	WATER	N-INP	LOSS
YOP.SCHLEWIG-H	73.5	4.9	43	796	245	59
YOW.SCHLEWIG-H	73.5	4.4	31	0	203	59
EOP.SCHLEWIG-H	73.5	1.6	39	520	182	45
EOW.SCHLEWIG-H	73.5	1.6	32	0	157	48
YOP.NIEDERSACH	66.2	4.8	39	679	235	55
YOW.NIEDERSACH	66.2	4.4	29	0	202	60
EOP.NIEDERSACH	66.2	1.6	37	445	177	43
EOW.NIEDERSACH	66.2	1.6	30	0	157	48
YOP.NORDRHN-WF	55.9	4.9	34	288	226	51
YOW.NORDRHN-WF	55.9	4.7	30	0	211	55
EOP.NORDRHN-WF	55.9	1.6	33	196	171	40
EOW.NORDRHN-WF	55.9	1.6	31	0	161	44
YOP.HESSEN	26.7	4.7	36	351	213	37
YOW.HESSEN	26.7	4.4	30	0	191	40
EOP.HESSEN	26.7	1.6	35	246	163	29
EOW.HESSEN	26.7	1.6	31	0	148	32
YOP.RHEIN-PFLZ	16.2	4.7	37	392	214	36
YOW.RHEIN-PFLZ	16.2	4.4	30	0	189	38
EOP.RHEIN-PFLZ	16.2	1.6	36	275	164	29
EOW.RHEIN-PFLZ	16.2	1.6	31	0	147	31
YOP.BADEN-WURT	26.1	5.0	34	172	229	44
YOW.BADEN-WURT	26.1	4.8	31	0	218	45
EOP.BADEN-WURT	26.1	1.6	34	113	169	34
EOW.BADEN-WURT	26.1	1.6	32	0	163	35
YOP.BAYERN	37.2	4.8	36	311	217	40
YOW.BAYERN	37.2	4.6	30	0	199	42
EOP.BAYERN	37.2	1.6	35	203	163	31
EOW.BAYERN	37.2	1.6	31	0	153	34
YOP.SAARLAND	1.2	4.7	32	182	216	38
YOW.SAARLAND	1.2	4.6	29	0	208	44
EOP.SAARLAND	1.2	1.6	32	123	166	30
EOW.SAARLAND	1.2	1.6	30	0	162	36
YOP.ILEDEFRNCE	43.1	4.7	51	958	238	45
YOW.ILEDEFRNCE	43.1	4.3	33	0	191	45
EOP.ILEDEFRNCE	43.1	1.6	47	682	180	35
EOW.ILEDEFRNCE	43.1	1.6	35	0	148	37
YOP.BASSIN-PAR	42.8	4.8	49	866	239	48

YOW.BASSIN-PAR	42.8	4.4	33	0	197	48
EOP.BASSIN-PAR	42.8	1.6	45	618	180	37
EOW.BASSIN-PAR	42.8	1.6	34	0	152	39
YOP.NORD-PDCAL	69.9	4.8	45	575	232	46
YOW.NORD-PDCAL	69.9	4.5	34	0	201	46
EOP.NORD-PDCAL	69.9	1.6	43	394	173	36
EOW.NORD-PDCAL	69.9	1.6	35	0	154	37
YOP.EST	12.9	4.7	40	481	230	46
YOW.EST	12.9	4.5	31	0	207	50
EOP.EST	12.9	1.6	38	333	175	36
EOW.EST	12.9	1.6	33	0	160	40
YOP.OUEST	54.5	4.8	46	719	254	52
YOW.OUEST	54.5	4.4	33	0	215	53
EOP.OUEST	54.5	1.6	43	527	191	41
EOW.OUEST	54.5	1.6	34	0	162	42
YOP.SUD-OUEST	48.7	4.8	51	962	251	54
YOW.SUD-OUEST	48.7	4.4	34	0	202	54
EOP.SUD-OUEST	48.7	1.6	48	707	191	42
EOW.SUD-OUEST	48.7	1.6	35	0	157	43
YOP.CENTRE-EST	24.5	4.7	54	1126	239	47
YOW.CENTRE-EST	24.5	4.2	33	0	185	46
EOP.CENTRE-EST	24.5	1.6	50	819	183	37
EOW.CENTRE-EST	24.5	1.6	35	0	145	37
YOP.MEDITERRAN	24.3	4.2	64	1996	235	42
YOW.MEDITERRAN	24.3	3.6	30	0	164	46
EOP.MEDITERRAN	24.3	1.6	59	1574	185	34
EOW.MEDITERRAN	24.3	1.6	33	0	134	39
YOP.NORD-OVEST	2.2	4.6	36	719	223	54
YOW.NORD-OVEST	2.2	4.1	26	0	185	55
EOP.NORD-OVEST	2.2	1.6	35	547	175	43
EOW.NORD-OVEST	2.2	1.6	27	0	147	46
YOP.LOMBARDIA	9.2	4.5	34	637	212	47
YOW.LOMBARDIA	9.2	4.2	25	0	177	50
EOP.LOMBARDIA	9.2	1.6	33	479	166	38
EOW.LOMBARDIA	9.2	1.6	27	0	141	41
YOP.NORD-EST	15.8	4.5	34	628	210	46
YOW.NORD-EST	15.8	4.2	25	0	177	49
EOP.NORD-EST	15.8	1.6	33	471	165	37
EOW.NORD-EST	15.8	1.6	27	0	141	40
YOP.EMILIA-ROM	26.1	4.5	37	729	210	45
YOW.EMILIA-ROM	26.1	4.1	26	0	173	48
EOP.EMILIA-ROM	26.1	1.6	35	551	166	37
EOW.EMILIA-ROM	26.1	1.6	28	0	138	40
YOP.CENTRO-IT	15.6	4.3	53	1553	237	53
YOW.CENTRO-IT	15.6	3.7	28	0	171	55
EOP.CENTRO-IT	15.6	1.6	50	1219	188	43
EOW.CENTRO-IT	15.6	1.6	30	0	140	47
YOP.LAZIO	6.5	4.1	57	1853	243	53
YOW.LAZIO	6.5	3.5	28	0	167	56
EOP.LAZIO	6.5	1.6	53	1478	195	44
EOW.LAZIO	6.5	1.6	30	0	139	49
YOP.CAMPANIA	7.7	4.2	49	1601	246	57
YOW.CAMPANIA	7.7	3.7	26	0	178	60
EOP.CAMPANIA	7.7	1.6	45	1252	196	47

EOW.CAMPANIA	7.7	1.6	28	0	146	52
YOP.ABRUZ-MOLI	8.7	4.2	58	1705	223	44
YOW.ABRUZ-MOLI	8.7	3.6	29	0	151	45
EOP.ABRUZ-MOLI	8.7	1.6	54	1353	179	37
EOW.ABRUZ-MOLI	8.7	1.6	32	0	125	39
YOP.SUD	8.1	3.9	58	1933	224	43
YOW.SUD	8.1	3.3	28	0	160	53
EOP.SUD	8.1	1.6	54	1573	182	36
EOW.SUD	8.1	1.6	30	0	135	46
YOP.SICILIA	18.0	3.8	66	2065	222	39
YOW.SICILIA	18.0	3.3	30	0	153	48
EOP.SICILIA	18.0	1.6	61	1675	180	33
EOW.SICILIA	18.0	1.6	33	0	131	42
YOP.SARDEGNA	6.2	3.9	58	2061	242	47
YOW.SARDEGNA	6.2	3.3	27	0	170	57
EOP.SARDEGNA	6.2	1.6	53	1666	196	39
EOW.SARDEGNA	6.2	1.6	29	0	142	50
YOP.NOORD-NL	50.6	4.8	33	432	240	61
YOW.NOORD-NL	50.6	4.5	26	0	229	74
EOP.NOORD-NL	50.6	1.6	31	269	181	47
EOW.NOORD-NL	50.6	1.6	27	0	177	59
YOP.OOST-NL	75.9	4.8	34	474	236	60
YOW.OOST-NL	75.9	4.5	27	0	219	70
EOP.OOST-NL	75.9	1.6	32	304	177	46
EOW.OOST-NL	75.9	1.6	28	0	170	56
YOP.ZUID-NL	86.1	4.8	35	483	235	61
YOW.ZUID-NL	86.1	4.5	27	0	220	72
EOP.ZUID-NL	86.1	1.6	33	310	178	47
EOW.ZUID-NL	86.1	1.6	28	0	171	57
YOP.WEST-NL	39.3	4.9	34	356	229	55
YOW.WEST-NL	39.3	4.6	28	0	213	61
EOP.WEST-NL	39.3	1.6	32	233	171	42
EOW.WEST-NL	39.3	1.6	28	0	163	48
YOP.VLAAMSGWST	88.1	4.9	38	457	232	56
YOW.VLAAMSGWST	88.1	4.6	30	0	209	60
EOP.VLAAMSGWST	88.1	1.6	36	296	174	43
EOW.VLAAMSGWST	88.1	1.6	31	0	161	48
YOP.REG-WALLON	35.1	4.9	47	608	232	47
YOW.REG-WALLON	35.1	4.6	35	0	199	46
EOP.REG-WALLON	35.1	1.6	45	427	173	37
EOW.REG-WALLON	35.1	1.6	37	0	152	37
YOP.LUXEMBOURG	15.1	4.7	57	1302	232	54
YOW.LUXEMBOURG	15.1	4.1	33	0	163	50
EOP.LUXEMBOURG	15.1	1.6	51	920	177	42
EOW.LUXEMBOURG	15.1	1.6	34	0	130	41
YOP.NORTH	8.9	4.8	35	176	219	55
YOW.NORTH	8.9	4.7	32	0	218	65
EOP.NORTH	8.9	1.6	35	111	163	42
EOW.NORTH	8.9	1.6	33	0	165	50
YOP.YORKSH-HUM	21.7	4.9	43	593	233	45
YOW.YORKSH-HUM	21.7	4.4	32	0	195	45
EOP.YORKSH-HUM	21.7	1.6	40	389	173	35
EOW.YORKSH-HUM	21.7	1.6	33	0	150	36
YOP.EAST-MIDL	27.6	4.8	43	629	237	49

YOW.EAST-MIDL	27.6	4.4	31	0	203	52
EOP.EAST-MIDL	27.6	1.6	40	419	177	38
EOW.EAST-MIDL	27.6	1.6	33	0	156	42
YOP.EAST-ANGL	41.1	4.8	43	791	240	50
YOW.EAST-ANGL	41.1	4.3	30	0	192	50
EOP.EAST-ANGL	41.1	1.6	39	533	179	39
EOW.EAST-ANGL	41.1	1.6	31	0	149	40
YOP.SOUTH-EAST	41.9	4.9	49	876	255	57
YOW.SOUTH-EAST	41.9	4.3	33	0	201	54
EOP.SOUTH-EAST	41.9	1.6	45	601	189	44
EOW.SOUTH-EAST	41.9	1.6	34	0	154	43
YOP.SOUTH-WEST	45.5	5.0	50	798	275	63
YOW.SOUTH-WEST	45.5	4.4	34	0	224	60
EOP.SOUTH-WEST	45.5	1.6	46	535	202	48
EOW.SOUTH-WEST	45.5	1.6	36	0	172	48
YOP.WEST-MIDL	46.7	4.8	42	532	233	51
YOW.WEST-MIDL	46.7	4.5	33	0	204	52
EOP.WEST-MIDL	46.7	1.6	40	364	174	39
EOW.WEST-MIDL	46.7	1.6	34	0	156	42
YOP.NORTH-WEST	14.5	4.7	44	1058	246	59
YOW.NORTH-WEST	14.5	4.1	27	0	201	65
EOP.NORTH-WEST	14.5	1.6	39	717	186	46
EOW.NORTH-WEST	14.5	1.6	29	0	160	53
YOP.WALES	30.9	4.9	46	606	259	60
YOW.WALES	30.9	4.5	35	0	225	62
EOP.WALES	30.9	1.6	43	405	192	46
EOW.WALES	30.9	1.6	36	0	172	49
YOP.SCOTLAND	18.9	4.9	42	377	238	57
YOW.SCOTLAND	18.9	4.7	35	0	224	62
EOP.SCOTLAND	18.9	1.6	40	230	175	43
EOW.SCOTLAND	18.9	1.6	36	0	169	49
YOP.NRTH-IRLND	28.5	4.9	42	347	236	54
YOW.NRTH-IRLND	28.5	4.6	36	0	219	58
EOP.NRTH-IRLND	28.5	1.6	41	222	174	42
EOW.NRTH-IRLND	28.5	1.6	36	0	166	45
YOP.IRELAND	46.5	4.9	43	353	246	57
YOW.IRELAND	46.5	4.7	36	0	229	60
EOP.IRELAND	46.5	1.6	41	229	181	43
EOW.IRELAND	46.5	1.6	36	0	173	47
YOP.DANMARK	89.1	4.7	49	1174	241	55
YOW.DANMARK	89.1	4.1	30	0	174	52
EOP.DANMARK	89.1	1.6	44	794	181	42
EOW.DANMARK	89.1	1.6	32	0	138	43
YOP.VOR-ELLADA	9.5	3.6	49	1466	195	33
YOW.VOR-ELLADA	9.5	3.3	27	0	168	49
EOP.VOR-ELLADA	9.5	1.6	48	1217	162	28
EOW.VOR-ELLADA	9.5	1.6	29	0	141	43
YOP.KENTR-ELLA	7.2	3.3	49	1353	171	34
YOW.KENTR-ELLA	7.2	3.1	27	0	154	55
EOP.KENTR-ELLA	7.2	1.6	48	1138	145	29
EOW.KENTR-ELLA	7.2	1.6	30	0	133	49
YOP.NISIA	6.4	3.2	58	1585	152	27
YOW.NISIA	6.4	2.8	30	0	121	41
EOP.NISIA	6.4	1.6	56	1316	129	23

EOW.NISIA	6.4	1.6	33	0	106	37
YOP.NOROESTE	1.9	4.8	56	1314	264	55
YOW.NOROESTE	1.9	4.4	32	0	206	52
EOP.NOROESTE	1.9	1.6	51	1005	202	43
EOW.NOROESTE	1.9	1.6	33	0	161	42
YOP.NORESTE	12.3	3.9	66	2231	229	33
YOW.NORESTE	12.3	3.3	29	0	157	39
EOP.NORESTE	12.3	1.6	61	1811	183	27
EOW.NORESTE	12.3	1.6	32	0	130	34
YOP.MADRID	31.8	3.6	77	3063	230	34
YOW.MADRID	31.8	2.8	28	0	149	45
EOP.MADRID	31.8	1.6	71	2508	187	29
EOW.MADRID	31.8	1.6	31	0	129	40
YOP.CENTRO-ESP	12.0	3.7	82	3451	234	37
YOW.CENTRO-ESP	12.0	2.9	27	0	142	43
EOP.CENTRO-ESP	12.0	1.6	74	2817	190	31
EOW.CENTRO-ESP	12.0	1.6	30	0	120	38
YOP.ESTE	12.0	4.0	53	1578	217	32
YOW.ESTE	12.0	3.6	28	0	175	41
EOP.ESTE	12.0	1.6	50	1265	175	26
EOW.ESTE	12.0	1.6	30	0	144	35
YOP.SUR	13.4	3.4	79	3007	208	34
YOW.SUR	13.4	2.8	29	0	146	48
EOP.SUR	13.4	1.6	73	2515	174	29
EOW.SUR	13.4	1.6	32	0	127	43
YOP.NORTE-CONT	6.0	3.9	98	3864	273	63
YOW.NORTE-CONT	6.0	3.0	30	0	147	60
EOP.NORTE-CONT	6.0	1.6	87	3116	221	52
EOW.NORTE-CONT	6.0	1.6	33	0	127	54
YOP.SUL-CONT	25.3	3.5	107	4366	246	52
YOW.SUL-CONT	25.3	2.7	30	0	126	53
EOP.SUL-CONT	25.3	1.6	99	3662	205	44
EOW.SUL-CONT	25.3	1.6	36	0	111	48

Appendix 12 : Feeding value of a number of products
(per kg fresh weight)

	Energy MJ	DCP g	Fibrous fraction
fresh grass	1.043	21	0.55
silage grass	2.680	58	0.9
silage maize	1.823	15	0.6
wheat	7.378	82	
grain maize	7.274	54	
potato	1.596	13	
bean	6.556	195	
beetroot pulp	6.438	64	
maize glutenfeed	6.970	149	
oat husk meal	3.468	22	
rapeseed meal	5.609	299	
cassave starch	6.342	0	
skimmilk powder	7.854	327	
wholemilk powder	12.075	238	
whey	0.449	7	
soybean meal	6.984	410	