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Formulation and characteristics of goal

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FORMULATION AND CHARACTERISTICS OF GOAL

PREFACE

In its Report to the Government "Ground for Choices", the Netherlands Scientific Council for Government Policy presents several options to the use of land in the European Community. The modes of land-use offer a common factor that is linked to a set of policy goals. These policy goals comprise socio-economic objectives, environmental objectives and rural objectives.
The employment that is related to the use of land, the environmental pollution as a result of land-use, and the costs of land-use that the society has to bear, are all determined by both the destination of land-use, i.e. for arable farming, for dairy or drystock farming, for forestry or for nature conservation, and the technology that is applied, i.e. yield-oriented technology, environmental oriented technology or land-use oriented technology.
The goals that are set for such policy variables can to some extent be conflicting. Therefore, it is necessary to balance the policy goals. This may be done by defining the policy goals in their own dimension and by explicitly stating the technical production options and the quantitative production potentials.
A multi-objective programming model may serve to carry out the calculations. In this Working Document the multiple goal programming model GOAL is described. All assumptions and working hypotheses are discussed and several input and output characteristics are described.

A sensitivity analysis has been carried out to evaluate the robustness of the model and to explore which factors and relations are most pertinent to the model results. It is remarkable how sensitive the model results are to slight changes in the costs of production and it is also remarkable that the model results are far less sensitive to changes in environmental parameters. The sensitivity of the model results concerns the regional allocation of land-use over the regions of the European Community. However, the aggregate model results for the European Community, such as the agriculturally used area, the level of employment, nutrients and biocides application are far less sensitive to changes in parameters.

The Council would like to suggest that the development of the GOAL model contributes to the set of research instruments that may be used for long term explorations.

The author of this document, the Councils' staff-member Drs. D. Scheele, has insightfully presented the formulation of and the background to the GOAL model. This may be of advantage to new users of this model.

The chairman of the workinggroup
'Rural areas in Europe',

Prof.dr.ir. R. Rabbinge

1. INTRODUCTION

GOAL is a multi-objective linear programming model that has been used to construct several scenarios as described in the Netherlands Scientific Council for Government Policy's report 'Ground for choices'[1]. The acronym GOAL stands for general optimal allocation of land-use. The focus of the model is on land-use not only by agriculture but also by the other rural land using sectors such as forestry and nature conservation. The aim of this document is to give a technical description of the model and to make it accessible to all those interested into the backgrounds of the Council's scenarios.

The technical description of GOAL comprises a complete formulation of the model. Several choices have been made during the model building and most of these will be discussed here. This description offers the reader access to all the details of GOAL, but also gives an impression of the broad lines along which the model has been built. Moreover, it highlights some characteristics of the model, starting from a few conclusions on the quantitative structure of the model data.

The following document consists of two parts. In the first part the structure of the GOAL model will be described. In the second part a few characteristics of GOAL will be discussed.

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1 WRR, Ground for choices. Four perspectives for the rural areas in the European Community; Reports to the government nr. 42, 's-Gravenhage, Staatsuitgeverij, 1992.

2. A FORMAL PRESENTATION OF THE MODEL GOAL

2.1 What is the purpose of the GOAL model: An introduction

Technical progress is at the core of the present imbalances in the agricultural markets. Steady increases in physical yields have caused the European Community to change from a net food importer into a net food exporter. Because in the other major agricultural areas outside Europe technical progress also results in expanding exports, the Community's increasing supplies of agricultural products are not matched by an adequate demand, neither on the home market nor on the world market. Many of the agricultural exports from moderate zones are now in some way subsidized. Without a significant breakthrough in the process of restructuring agricultural policies, among which the Common Agricultural Policy, the burden of public transfers to agriculture will not diminish.

European farmers are to a large extent protected from uncontrolled market pressures. Yet, employment in European agriculture has continued to shrink over the last decades. Those who stayed in business have often raised agricultural productivity often by intensification of agricultural land-use. As a side-effect of this process agricultural pollution has become a serious threat to the state of the rural environment.

European agriculture has arrived at a turning point. The scope for output growth is limited. Trade relations, the employment situation and the rural environment are all under pressure. The growth in demand for agricultural products is lagging behind the growth in soil productivity. For a long time it has been acknowledged that the Common Agricultural Policy needs reform. However, not many policy proposals on this matter did materialize so far. Recently, the European Commission has launched a set of proposals that seem to mark a new attitude. It is clear that the debate on the reform of the Common Agricultural Policy has just begun. ***A clear view of the directions in which European agriculture could develop has not been presented.*** The effects of the Commission's proposals on the agricultural economy are uncertain. It can also be argued that these proposals will have to be supplemented with further reaching policies after some time.

Instead of investigating the adjustments European agriculture will go through, the Netherlands Scientific Council for Government Policy has concentrated on long term policy goals for agriculture in the setting of the rural areas. It investigated *the long term potentials for agriculture* in the rural areas of the European Community *under the condition that certain policy goals be met*. These long term potentials were defined from *an agro-technical perspective*.
The study deals with the employment situation, the environmental burden and the use of the rural space. It also considers the possibilities for nature development and forestry. With respect to all these fields policy goals can be defined. The Council has used four different views on the development of the rural areas to derive the policy goals that were used as the guiding conditions in scenarios of agricultural potentials in the rural areas. In each of these views figure different priorities on development goals for the rural areas.

In this section the formulation of the GOAL model, that was devised as a tool for the study of the Council will be presented. The modelling technique that has been used is known as interactive multiple goal programming.

It is recognized that there are several interests at stake in designing an agricultural policy. It is also acknowledged that an agricultural policy has effects upon the well-being of the rural areas. In many respects *the way in which the land* in the rural areas *is used is a crucial variable*. The GOAL model focuses on the extent to which different and possibly conflicting interests are affected by various forms of land use. These interests range from agricultural productivity to employment and environmental issues.

In the agricultural market the growth of demand is lagging behind the growth of productivity, whether total factor productivity or soil productivity. Such mature markets are characterised by cost competition. In the agricultural market competition induces marked changes in existing agricultural structures and patterns of land-use. Competition can be seen within regions and between regions.

Cost advantages of certain regions stem from many factors, most notably the level of technical advancement and the existence of dynamic scale effects. In the long run advantages stemming from such factors can in principle diminish or disappear altogether. Whether this is a plausible assumption or not will not further be discussed here.

In the modelling work the focus will not be on the description of a plausible future development of European agriculture, but on the exploration of agricultural potentials as seen from an agro-technical perspective. From such a perspective cost advantages may arise in regions well endowed with fertile grounds and favoured by climatological conditions. Soil and climate are conditions not at all likely to change as fast as factors such as the relative level of technical advancement and the existence of dynamic scale effects. The ultimate level of soil productivity, however, is bounded by soil and climate. Therefore, if the opportunities to policy goals are assessed in their relation to technological potentials, in the long term it makes sense to abstract from the variant technical conditions and to recur to relatively invariant natural conditions.
A cost optimal allocation generated by GOAL is thus an allocation of land-use over regions that results in lowest cost production. Such production in GOAL is achieved through comparative advantages that stem from natural endowments. To know whether or not a robust allocation with respect to production costs exists is significant information for policy-makers. It may be sensible to seek a robust allocation even when dynamic factors interplay.
The aim of GOAL is thus the search for robust allocations and not the search for plausible paths of future development. The allocations may be robust and optimal with respect to costs or to other goal variables or even with respect to combinations of goal variables.

The long term potentials of agriculture are the subject of the study of the Council. Therefore an ultimate level of technical performance is incorporated in the model. The implications of this level of performance, only constrained by physical conditions, will be investigated.

The agro-technical perspective of the study has implications for the definition of the land-use forms that are distinguished in the model. Agricultural and forestry activities only take place on suited grounds. They make use of the best technical means available. This implies mechanisation and a high level of expertise. In the model no drawbacks on the efficiency of land-use activities are allowed. Therefore, agriculture in GOAL is assumed to make use of the best technical means.
Efficiency is a multidimensional notion. Overall efficiency trade-off of the agricultural system can be related to the relevant policy goals and originates in the definition of the land-use activities. Two land-use activities that produce the same bundle of commodities but combine inputs in different quantities may belong to the activity set if both vectors of inputs are 'efficient'. As certain inputs are more or less related to specific policy goals, some activities contribute more to one policy objective and less to another, while for other activities the reverse is true.

The way in which land in the rural areas is used can be considered as a central variable. In the analysis of agricultural potentials, the whole area of the European Community will be covered. This is motivated as follows. It is the aim of the study to confront demand for agricultural products with potential production. The existence of the Common Agricultural Market is the reason to consider the total area of the Community and not only a part of it. Technological progress in agriculture manifests itself amongst others as land saving. The potentials of yield increases have been studied in depth[2]. Except for land, all other production inputs such as labour, capital, irrigation water and chemicals can be related to land-use. Therefore, it makes sense to take land-use as the central variable in the model.

As has already been noted, it is assumed that in the long run agricultural structures are flexible, that agro-industrial relations adapt and that human capital is mobile. It is again explicitly stated that it is not the aim of the model to explore the distributional effects of these

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2 Crop production potential of rural areas within the European Communities, part I to V, Working Documents W65 to W69, The Hague, WRR, 1992

factors. The model scenarios should therefore neither be regarded as predictive nor as most plausible. They rather explore the extent of conflict between policy goals and the existence of robust regional allocations with respect to these policy goals. The scenarios are conditional with respect to the option of a high level of technical performance and the predominance of agronomic factors.

2.2 The formulation of the model

The model focuses on land-use in the rural areas of the European Community. Major users of land are agriculture and forestry. Yet, some areas in the Community are barren lands, either nominated 'nature' or in very extensive use, for example by livestock. So, a distinction in land-use can be made between commercial uses and other (dis)uses. Again the focus of GOAL is on the commercial uses. Commercial land-use serves to generate income primarily by meeting the demand for agricultural products and forestry products.

There are many ways in which the demand for agricultural and forestry products can be met. Current agricultural practice varies considerably among and even within regions. Moreover, production is concentrated in some parts of the European Community. Even if the activity set is bounded to efficient techniques that make use of best technical means, the variation between regions persists. Therefore, in GOAL attention has been paid to where and how agricultural production can take place. The spatial disaggregation level chosen in GOAL is the EC's NUTS-I classification, because on this level independent regional policies have been formulated.

Most of the agricultural activities are directly connected to the use of land. But horticulture in glass houses and modern pig and poultry raising do not use land as a biological production factor, but merely as a location factor. Agriculture of this kind does not play a major role in GOAL. Pig and poultry raising in GOAL are treated as industrial processes with an agricultural input. Horticulture is not considered at all. So only those agricultural activities that require the use of land as a production factor are specified by region. The raising of grazing cattle is included in these activities.

In GOAL no regional distinction has been made between imports, exports and agricultural demand, either human or industrial. Moreover, transport costs are introduced in a very limited sense only. Two groups of products are discerned with either free transport or no transport between regions. Of course this imposes limitations on the model's ability to explore cost optimal regional allocations of production. The computational burden of including detailed transport costs and interregional trade flows would be great[3]. Considering that the aim of this modelling exercise is in the first place to assess the consequences of technological progress in agriculture for the rural areas within the Community, it will be taken for granted that more specified transport costs might lead to different regional allocations.

GOAL can be qualified as a programming model for exploration of system boundaries. These system boundaries are of a predominantly agro-technical nature. According to policy objectives forestry or agricultural land-use is allocated to the regions of the European Community. The allocation follows the opportunities that are set by the physical endowments of the regions. Thus, soil fertility, water availability and climate direct the implementation of land-use and determine the boundaries between which objective variables can vary in interaction.

The model consists of two types of relations. *The first type* of relation is the balance equation. These balance equations account for limited availabilities of physical units. They define the limits between which European agriculture can develop. A given demand of agricultural products has to be satisfied with available resources, such as land and water. The only limits that are taken into consideration are those of a technical or physical nature.
The second type of relation links the programming objectives to exploited resources. The programming objectives represent the policy goals that have been set.

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3 Heady,E.O., "Models for agricultural policy: The CARD example"; European Review of Agricultural Economics, 10 (1983), pp. 1-14

2.2.1 Input and output balances

The construction of the model is process-oriented rather than stream-oriented. A process is a transformation of inputs into outputs. In a stream-oriented model the flows of inputs and outputs are taken as the programming variables, whereas in a process-oriented model the rates of transformation of inputs into outputs by so-called activities are taken as programming variables. In the present model such activities are, for example, the land-use activities.
There are four central activities or variables in GOAL that will now be described. These are land-use activities, the processing of primary and secondary products, the nutrient value equivalent transformations and the raising of grazing livestock.

Land-use activities relate to arable farming, grasslands, permanent crop cultures and forestry. The other activities are not directly related to the use of land. The processing of primary and secondary products includes the raising of pigs and poultry, the processing of dairy products and the transformation of primary agricultural products into consumable products. The nutrient value equivalent transformations convert forage and fodder of different origins into nutrient values.

The geographical location of the land-use activities is taken into account. An allocation of these activities over 58 regions of the Community leaves room for optimizing the program's objective values. As has already been indicated, such an allocation gives shape to the idea that agricultural production may concentrate in well-endowed regions, while placing other regions into a more marginal position. With the exception of activities related to the raising of grazing livestock, the other activities are not necessarily restricted to a special region. Their geographical location within the Community does not necessarily depend on the allocation of land-use activities.

To start with the exception, the raising of grazing livestock depends on the presence of forage growing, whether fodder maize, perennial fodders or rough grazings. While other types of livestock such as poultry or pigs live on concentrated feedingstuffs, grazing livestock needs a minimum of structure in their diet. Concentrated feedstuffs can hardly fulfil this need. The assumption in GOAL is that interregional transport of roughage is not viable on any large scale due to high transport costs as compared to concentrates. This implies that farming of grazing livestock is linked to land-use for roughage cropping. So grazing livestock raising activities must be specified for every region.

Animal feed is expressed in metabolizable energy (ME) and digestible crude protein (DCP). The use of these general nutrient equivalent values enables substitution between different feedingstuffs. To ensure a minimum of structure in the feed mix for grazing livestock, a structure accounting balance has to be kept for this feed mix in every region. So the presence of grazing livestock requires nutrient value equivalent transformations to be specified for every region.

Primary or secondary product processing activities in the model bear no relation to any specific region. The European market for food products is considered a single market. Transport costs for products other than forage are not taken into consideration. This assumption has less drawbacks for processed products than for primary products e.g. those products used for animal feed, as transport costs for processed products take a smaller part in the product value.

2.2.1.1 *The product balance equations*

A starting point in the search for an allocation of land-use is the desired level of production. In the model this level results from exogenously given levels of consumption, by households and industries, exports and imports. The product balance requires all activities to take such values that this desired level of production will be fulfilled. For any of the relevant products, whether primary, intermediary or final, a product balance equation has been formulated. Most product balance equations are formulated to cover the whole Community, but some have been defined for every region. This has been done for forage products that, as assumed before, will not be transported outside the region. For forage products, production and use have to be in balance within every region.

In this block of equations "to be in balance" has the meaning that as much can be used as is produced.

The product balance equations describe how the desired level of production can be reached. The equations take account of all production possibilities that soil and climate in the Community offer. The production possibilities in GOAL have been formulated in terms of input-output relations. The following elaborates on the modelling of the production possibilities.

Intermezzo

The input-output coefficients that occur in the product balance equations have been normalized such that the values of the land-use activities indicate land-use per activity in million hectares; the unit in which consumption, export and import are expressed is million ton fresh weight. The output coefficients of those land-use activities that relate to arable farming are corrected for sowing-seed requirements in tonnes per hectare. Losses on pastures by trampling are also implicit in output coefficients. Average storage losses of fodder both in terms of nutrient values and dry matter are implicit in the nutrient value equivalent coefficients.

Starting points for the computation of the output coefficients of arable farming have been the so-called potential and water-limited yields that result from simulations with the crop growth model WOFOST. Maximum attainable yields for every region have been computed in situations where no limiting factors other than soil and climate either with sufficient irrigation or without irrigation limit crop growth. The yields in these situations are referred to as respectively potential and water-limited yields. The simulation results were tested against best known yield levels attained in current agriculture. Counterexpertise from other EC memberstates indicates that the simulation results are rather conservative and not overestimates of highest attainable yield levels.

Arable farming techniques in GOAL have been derived from WOFOST simulations via a set of agronomic considerations that will be subsequently

discussed here. Only those types of arable farming have been considered that apply best technical means, i.e. only the techniques on the production possibility frontier have been considered. So the set of relevant production techniques is reduced.
For most crops two levels of investment have been discerned, one corresponding to rain-fed agriculture for which the WOFOST water-limited yields and inputs are the point of reference and one corresponding to irrigated agriculture for which the potential yields from the WOFOST simulation have been taken as a point of reference. For grains and grass a third level of investment has been discerned that corresponds to extensive dryland cereals cultivation or to extensive rangelands. Yields under this level of investment are low. Between certain limits they vary over the regions according to the variation in water-limited yields of cereals and grass.

Next to the distinction in several investment levels, a distinction has also been made as to the extent to which the rural environment is affected by arable farming. Under the assumption of best technical practice certain spills of agricultural chemicals into the environment are unavoidable given a certain yield level. However, spills could be reduced at the cost of a lower yield level. For the first two investment levels of irrigated and rain-fed agriculture some arbitrary level of spills reduction in an alternative input-output relation has been chosen to introduce a trade-off between environment and economics in GOAL.

Thus, while three levels of investment have been discerned without reference to specific environmental interests, two levels of investment are discerned that will be grouped under the flag of environmental orientated agriculture (EOA). The term yield oriented agriculture (YOA) will be reserved for the first two of the other three investment levels, while the term land-use orientated agriculture (LOA) will be connected with the last and lowest level of investment of the three.

In arable farming, crop yield levels are related to the rotation in which the crops are grown. The application of wide or narrow rotation schemes affects pest incidence. In GOAL arable farming activity is linked to rotation schemes. To avoid discontinuities in the input-output coefficients depending on the rotation, the rotation itself, rather than the cultivation of single crops, is taken as a model variable. Such rotation related discontinuities would arise in output coefficients and in coefficients of biocides use (e.g. nematicides, herbicides, fungicides) and of course in the other related coefficients.

In a region, the year to year occurrence of the crops is supposed to be uniformly distributed according to the rotation scheme. It is moreover assumed that within a rotation scheme all or otherwise no crops are irrigated.

To summarize arable farming techniques in GOAL are assumed to be efficient[4] and they are distinguished according to level of investment, environmental objectives and rotation.

Yet, depending on physical characteristics of regions some further refinements in the input-output relations have been made.

As already noted, physical endowments in the regions are held responsible for regional variation in potential and water-limited crop yields.

Field application efficiency of irrigation is assumed to be dependent on slope, soil texture and climate.

Nutrient application efficiency is restricted to the behaviour of nitrogen. Nitrogen uptake is held to be crop-specific and to depend on soil texture and climate type. In GOAL a distinction is made between the application of nitrogen and the uptake of nitrogen, whereas the difference is being recorded as losses of nitrogen. These losses may be due to leaching, volatilization or denitrification.

An efficient application of pesticides is conditional upon the occurrence of crop growth disturbances. Crop-specific and rotation-specific factors are important in this respect. In broad lines these disturbances are also found to be dependent on climatological and soil conditions. Moreover the efficient application of fungicides in YOA is held to depend on yield levels. A clear (assumed) distinction has been made between the use of pesticides in YOA and in EOA. In LOA no pesticides are used at all.

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4 A farming activity in GOAL is called efficient if the vector of input and output coefficients for technical reasons cannot be dominated by another vector of input and output coefficients.

In a rather tentative way, regional variation in the efficiency of irrigation, nutrient application and in the rational use of pesticides has been included in the input coefficients. Agronomic insights prevail in the collected knowledge base of arable farming techniques in GOAL[5].

Continuation

At this stage enough has been said about input-output relations of arable farming to be able to proceed with the discussion of product balance equations. Sofar, attention has only been paid to physical inputs like water, nutrients and biocides. At a later stage, the input coefficients of production factors like labour and capital will be discussed.

The product balance equation for products of arable farming reads[6]

$$\sum_{reg,oil,rot} output_{rot,oil,reg,acr}\, AFL_{rot,oil,reg} + \sum_{proc} ioproc_{acr,proc}\, PROCL_{proc} + \sum_{nueql} ionueq_{acr,nueql}\, NUEQL_{nueql} = c_{acr} + x_{acr} - m_{acr} \qquad (1)$$

The right hand side of (1) stands for the desired level of production resulting from consumption, imports and exports of a particular product. The first term on the left hand side indicates the production of that product, aggregated over all regions and be it with or without irrigation, with either YOA, EOA or LOA and within whatever rotation. The product can either be an input to the food processing industry, used as animal fodder, or be used for human consumption. The processing into consumable or intermediary products is described in the second term. The third term deals with an auxiliary conversion of the product into a bundle of a few standard but imaginary feedingstuffs with different proportions of metabolizable energy (ME) and digestable crude protein (DCP). These standard feedingstuffs are introduced to save on the number of nutrient

5 Koning,G.H.J.de, H.Jansen and H.van Keulen, Input and output coefficients of various cropping and livestock systems in the European Communities; Working Document W62, The Hague, WRR, 1992

6 At the end of this chapter the listing of the symbols that are used in the equations can be found.

equivalence accountings, especially when these accountings are region specific.

By convention the coefficients for product inputs of activities carry a negative sign. This should be borne in mind when interpreting the signs of the terms that occur in equations like (1).

Whether annual (green maize) or perennial (grass), roughage is region-bound because of high transport costs. Roughage balances for green maize and grass are defined for every region.

$$\sum_{oil,rot} output_{rot,oil,reg,rcr}\; RFL_{rot,oil,reg} +$$

$$\sum_{nueq2,rcr} ionueq_{rcr,nueq2}\; NUEQRL_{nueq2,reg} - \delta_{rcr}^{past}\; SHRL_{reg} = 0\ , \qquad (2)$$

$$\delta_{rcr}^{past}=1 \text{ if } rcr=past, \text{ else } 0$$

(2) expresses that the sum of any roughage production in a region is converted to metabolizable energy (ME) and digestable crude protein (DCP). However part of the grass production can be used for sheep farming. As the feedings requirements for sheep are only accounted for in terms of ME, grass consumption by sheep is directly accounted for in the last term of (2).

So far, we have dealt with roughage production on soils suited for high yields. Part of the agricultural areas are only suited for pastures that ,because of physical drawbacks, can never reach the measure of productivity that has been referred to before as potential or water limited yield. In GOAL, the use of these marginal grasslands is limited to sheep farming. This seems no serious limitation as potentially productive grassland (for other grazing livestock) is abundant all over the Community. The next formula (3) accounts for the roughage balance for sheep farming.

$$mrout_{reg}\; MRL_{reg} + SHRL_{reg} + iosra_{pr\text{-}past}\; SRAL_{reg} = 0 \qquad (3)$$

The balance is defined for every region.

In (1) arable crops are identified with a few standard feed ingredients. These standard feed ingredients contain nutritional value in terms of ME and DCP. They are either used for dairy or drystock farming or for non-ruminants like pigs and poultry. Unlike ruminant feedingstuffs, non-ruminant feedingstuffs are not specified regionally. Thus, a distinction is made between a ruminant and a non-ruminant bound transformation of the standard feedingstuffs into their nutritional components. Moreover, the ruminant bound feedingstuffs are separately decomposed in every region. (4) describes the decomposition.

$$\begin{aligned} &\sum_{nueq1} ionueq_{prot,nueq1}\ NUEQL_{nueq1} + \\ &\sum_{nueq2} ionueq_{prot,nueq2}\ NUEQL_{nueq2} + \\ &\sum_{reg,nueq2} ionueq_{prot,nueq2}\ NUEQRL_{nueq2,reg} = 0 \end{aligned} \qquad (4)$$

The first term in (4) refers to the set of activities, a subset of which also occurs in (1), the activities that identify arable crops with standard feedingstuffs. In (9) we will see that not only arable crops but also intermediary products can be identified with the standard feedingstuffs. The second and the third term relate to the decomposition in nutritional components.

Nutritional components that are bound for non-ruminants equate the feed requirements of this type of livestock. This is expressed in (5). It is assumed that none of the nutritional components is in excess-supply. By avoiding an excess-supply of digestable crude proteins (DCP), the throughput of mineral nitrogen is limited. The balancing of nutritional components in animal feed can reduce the amount of nitrogen losses to the environment. Such agricultural practice is in the same category as the aforementioned arable farming techniques that make use of the best technical means. The equal sign in (5) is motivated by this assumption.

$$\begin{aligned} &\sum_{nueq2} ionueq_{n.r.comp,nueq2}\ NUEQL_{nueq2} + \\ &\sum_{proc} ioproc_{n.r.comp,proc}\ PROCL_{proc} = 0 \end{aligned} \qquad (5)$$

Ruminants are either fed on pure roughage or on a mix of concentrates and roughage. Thus both the nutritional components (ME and DCP) of a basket of roughage feedingstuffs and of a basket of mixed roughage and concentrate feedingstuffs are distinguished. Both baskets are related to different yields per animal. In dairy farming a mixed ration of roughage and concentrates is accompanied by higher milk yields than pure roughage feedingstuffs. In drystock farming similar effects exist. With respect to yield levels arising from different feedingstuffs rations, several types of livestock raising are distinguished. The total supply of the nutritional components of one type of basket corresponds to the requirements of the livestock that feeds on this particular basket. This also is the case for non-ruminants exact balance between supply and requirements of ME and DCP is assumed.

In contrast with the raising of non-ruminants in GOAL all ruminant related activities are specified for every region. The basic reason is that ruminants need roughage that is assumed not to be exported outside the region. Equation (6) summarizes the provision in nutritional components.

$$\sum_{nueq2} ionueq_{r.comp.rat,nueq2}\ NUEQRL_{nueq2,reg} + \sum_{cra} iocra_{r.comp.rat,cra}\ CRAL_{cra,reg} = 0 \qquad (6)$$

A healthy digestion of ruminants requires a basket of feedingstuffs with at least a certain part of fibrous contents. The fibrous contents are expressed as a percentage of total dry matter contents.
As has already been noted, the yields per animal depend on the fibrous contents of food. The more concentrates are added to the feedingstuffs of cows, the higher the yields. High yields per animal imply efficient resource use, because a fixed quantity of feedingstuffs is used for the sheer maintenance of the animal. Other costs (such as housing), also depend on the size of the herd and therefore indirectly on the yield.
As concentrates contain few fibres there are clear limits to their use. The model discerns between two yield levels, both for dairy cows and other cattle. One of these yield levels is taken so low that it can be reached on a staple diet of green maize and grass. The other yield is fixed on a high level which implies a maximal use of concentrates.
A feed basket in dairy and drystock farming not only has to be balanced in terms of nutritional components, but, if it is composed of a mix of roughage and concentrates, it also has to fulfil certain requirements concerning fibrous contents. It does not matter what products are contained in the feedingstuffs basket if only there is some check on the fibrous contents they contain. To this end, a set of fibrous contents accounting equations is formulated.

$$\sum_{nueq2 \text{ if } ionueq_{r.comp.rat=mix,nueq2} \neq 0} NUEQRL_{nueq2,reg} \times \left(ionueq_{coef=fibers,nueq2} - \xi \; ionueq_{coef=dry\ matter,nueq2} \right) = 0 \tag{7}$$

The fibrous contents accounting equations have to be defined for every region in respect of transport restrictions for roughage.

In livestock farming, a precise match of nutritional requirements is assumed in order to reduce the throughput of nitrogen. In the same spirit it is assumed that an efficient use is made of manure from drystock and dairy farming. It is assumed that within each region this manure is exclusively applied in the cultivation of roughage.
Both in dairy farming and drystock farming several systems have been distinguished. As has already been noted these systems relate to different baskets of feedingstuffs and associated yield levels, but they also relate to grazing and non-grazing systems. Excretion by grazing cattle is considered a pure loss of nutrients. Manure production in the stables is by assumption fruitfully applied in roughage production. However with respect to nitrogen losses are unavoidable. Part of the manure production at the stable is considered a loss. Moreover, at application on the field nitrogen losses from mineral nitrogen in manure are assumed to be equal to losses from fertilizers. With respect to organic nitrogen in manure, it is assumed that in the long run an equilibrium between nitrogen flows in the soil exists.
In addition to these preliminary assumptions concerning the nitrogen balance it is required that no more mineral nitrogen from manure is applied in roughage production than is strictly needed. Moreover, manure is applied in the region of origin. This restriction influences the stocking rate. The restriction, that holds for every region, is expressed in (8).

$$\sum_{cra} iocra_{coef=nitrout,cra} \; CRAL_{cra,reg} \leq \sum_{rot,oil} input_{rot,oil,reg,coef=nitr} \; RFL_{rot,oil,reg} \tag{8}$$

In intermediate processes, primary and secondary products are transformed until they are ready for consumption. The intermediate processes involve the generation of usable by-products. In the model, a balance has been sought between an accurate and extensive description of agricultural product processing industries in order to match primary production and final demand and a loose description that only concentrates on the impact that process routes have on the allocation of land-use and thereby on the objective variables. Livestock production is a special case of such intermediate production. The provision in feedingstuffs has already been given attention. The output of livestock production is treated in equation (9) where the other intermediate processes occur also.

$$\sum_{proc} ioproc_{secpr,proc}\ PROCL_{proc} + \sum_{nueql} ionueq_{secpr,nueql}\ NUEQL_{nueql} + \sum_{reg,cra} iocra_{secpr,cra}\ CRAL_{cra,reg} + \sum_{reg} iosra_{secpr}\ SRAL_{reg} = c_{secpr} + x_{secpr} - m_{secpr} \tag{9}$$

In the second term of (9) intermediate products are identified with standard feed ingredients. These products may arise from processes captured by the first term. The activities in the first term may also process products from dairy farming that are contained in the third term. The production of sheep meat in the fourth term is directly delivered to consumption. As the coefficients for sheep meat in the first three terms are zero, these terms do not occur in the product balance for sheep meat.

Yet, another transport restriction in the model has been introduced for intensive drystock farming. Intensive beef production has a direct relation to dairy farming. Calf birth initiates the lactation period of a dairy cow. Only part of the calves born from dairy cows are needed for the procreation of the dairy herd. The other calves are fattened in intensive drystock farming. It is assumed that this fattening partly takes place within the calves' region of birth. The assumption is motivated by transport costs. It is expressed in (10)

$$\sum_{cra\ if\ iocra_{pr=milk,cra} \neq 0} CRAL_{cra,reg} \times iocra_{pr=calf,cra} \leq \zeta \sum_{cra\ if\ iocra_{pr=calf,cra} < 0} CRAL_{cra,reg} \times iocra_{pr=calf,cra} \tag{10}$$

Only a few permanent crops are included in GOAL. They have been selected on the basis of their present land-use. Especially in the mediterranean zones, the area involved is significant. For any of the selected permanent crops several cropping systems have been distinguished. These cropping systems indicate whether irrigation is applied or not and whether the plantation is treated with intensive or extensive management techniques. In the model permanent crops can be processed or directly consumed. (11) gives the product balance for permanent crops.

$$\sum_{sys,reg} yield_{permcr,sys,reg}\, PCAL_{permcr,sys,reg} + \sum_{proc} ioproc_{permcr,proc}\, PROCL_{proc} = c_{permcr} + x_{permcr} - m_{permcr} \qquad (11)$$

Forests occupy large territories in the Community. European forestry is very diverse and serves many goals. Wood production is just one of these goals. Large parts of the European forests are however not exploited for this purpose. Those forests that serve a production goal are as an average not very productive in relation to their potential. There are several reasons for the relative low productivity of the Community forests. Certainly one of these reasons is that the less fertile soils are covered by forests and the more fertile soils are in use for agriculture. There are no indications that the productivity of existing forests could be raised to any level more proximate to potential levels of productivity within the foreseeable future. Therefore, the focus of GOAL will not be on existing forests but on new forest areas that may be located on former agricultural areas.

The European Community is by no means self-sufficient in its requirements of wood and derivatives. The aim of GOAL with respect to forestry in the Community is to investigate the possibilities for achieving self-sufficiency in forestry products when using former agricultural areas. Thus we investigate the (technical) possibilities for import substitution.

Two wide categories of primary forestry products are distinguished, round wood and other wood. Imports of the latter category are mainly destined for wood-based panels or paper production. Round wood can be used for sawn-wood. In GOAL three classes of tree species have been distinguished with respect to growth and required soil characteristics. These classes are fast growing trees, normal growing trees with more and normal growing trees with less demands to soil characteristics. Only the fast growing trees can reach maturity within the horizon of the study. Fast growing trees (poplar, eucalyptus) are an important source for the category "other wood". Because of the limited horizon of this study we focus on the product balance for this latter category only.

Regional yield levels for wood are not only specified for different tree classes, they are also differentiated according to soil suitability. We distinguish soils with moderate and soils with no limitations for tree growth, next to unsuited soils. Tentatively, yield levels are specified for combinations of tree class, soil condition and regional climatological conditions.

The product balance for primary wood import substitution is given in (12)

$$\sum_{reg,soil,class=fast} woodgrowth_{reg,soil,class}\ FORAL_{reg,soil,class} = m_{wood} \qquad (12)$$

2.2.1.2 *Land-use balance equations*

Not every soil type is suited for the cultivation of any crop. Moreover, mechanised farming can be hindered by inclinations. If one is willing to make the necessary abstractions, it is possible to discern a hierarchy between crops stemming from the demands they put on soil quality. At least three hierarchical levels can be specified. Root crops are among the most demanding in terms of soil quality. Grains and oilseeds grow where root crops do, but also give good yields on soils of lesser quality. Intensive cultivation of grass can take place in an even wider area. Outside the area where land qualities are sufficient for high yielding grass only some permanent crops and forestry are feasible land-uses. This is also the area where the rough grazings are to be found.
Thus, according to this hierarchy every region in Europe can be subdivided into three nested segments and a fourth segment that lies outside these segments. In each of these segments some form of agricultural activity can take place. Outside these segments the soil is useless for agriculture.
It must be noted that for every region soil quality segments can be distinguished and that correspondingly for every region land-use balances relating to these segments will be defined.

Land-use by agricultural activities is restricted by this segmentation in soil qualities. In arable farming the area for each rotation is restricted to the segment that is available for the most demanding crop in the rotation. The share of each segment in the total area of a region has been assessed in a land evaluation of each of the 58 regions in the Community. So, the shares for root crops, mowing crops and grass are known.

The suitability of the land in every region has also been assessed for several permanent crops and for forestry. As a more refined technique of land evaluation has been used for these land-use activities, the hierarchical tripartition could no longer be preserved. However, suitability for permanent crops and forestry can be expressed in shares of the three segments, for root crops, mowing crops and grass. Moreover, the area outside these three segments in the above mentioned fourth segment of the region has also been evaluated on suitability for permanent crops and forestry.

Thus, for every permanent crop and every kind of forestry four shares of total area in each region are known, indicating suitability in the root crops segment, the mowing crops segment, the grass segment and in the area outside these three segments.

In the case of forestry, even more information is available from the land evaluation. For each of the four shares of the total area a subdivision is made between soils with no limitations for tree growth and soils with moderate limitations for tree growth.

Three sets of land-use restrictions have been formulated, one for each of the three first segments, for root crops, mowing crops and grass. In these restrictions the land-use activities related to arable farming and roughage production occur. Next to these land-use activities segmented land-use for permanent crops and forestry occurs. For every permanent crop and forestry activity four land-use variables have been defined. One variable for total land-use by a permanent crop or forestry activity in a region, and one auxiliary variable for its land-use in each of the three first segments.

In two sets of additional equations, one for permanent crops and one for forestry, the restriction is formulated that the sum of the land-use of a permanent crop in each of the three first segments should not exceed total land-use of that permanent crop. This forces land-use of the activity in the fourth segment to be positive.

The use of the auxiliary variables for permanent crops and forestry makes it possible to verify that total land-use in one of the segments root crops, mowing crops or grass by land-use activities, that are bound to that segment, does not exceed the area of the segment. Furthermore, it is possible to verify that land-use by a permanent crop or forestry in a segment does not exceed that part of the segment that is suited to it.

(13) gives expression to the land-use balance for the root crops segment. For a correct interpretation of this and other land-use balances, it should be kept in mind that input-output coefficients of land-use activities are normalized with respect to the unit of area (hectare).

$$\sum_{rot \in rtcrops, oil} AFL_{rot,oil,reg} + \sum_{permcr, sys} PCAL^{aux}_{permcr,sys,reg,seg=rtcrop} +$$

$$\sum_{soil, class} FORAL^{aux}_{reg,soil,class,seg=rtcrop} \le ar_{reg}\ suit_{reg,seg=rtcrop} \tag{13}$$

$$PCAL^{aux}_{permcr,sys,reg,seg=rtcrop} \le ar_{reg}\ suit_{reg,seg=rtcrop}\ pcshare_{permcr,sys,reg,seg=rtcrop}$$

$$FORAL^{aux}_{reg,soil,class,seg=rtcrop} \le ar_{reg}\ suit_{reg,seg=rtcrop}\ forshare_{soil,class,reg,seg=rtcrop}$$

(14) gives the analogous expression for the mowing crops segment. As green maize is a mowing crop, a term is added for roughage production.

$$\sum_{rot \in mwcrops, oil} AFL_{rot,oil,reg} + \sum_{rot \in mwcrops, oil} RFL_{rot,oil,reg} +$$

$$\sum_{permcr, sys} (PCAL^{aux}_{permcr,sys,reg,seg=mwcrop} + PCAL^{aux}_{permcr,sys,reg,seg=rtcrop}) +$$

$$\sum_{soil, class} (FORAL^{aux}_{reg,soil,class,seg=mwcrop} + FORAL^{aux}_{reg,soil,class,seg=rtcrop})$$

$$\le ar_{reg}\ suit_{reg,seg=mwcrop} \tag{14}$$

$$PCAL^{aux}_{permcr,sys,reg,seg=mwcrop} \le ar_{reg} \times$$

$$(suit_{reg,seg=mwcrop} - suit_{reg,seg=rtcrop})\ pcshare_{permcr,sys,reg,seg=mwcrop}$$

$$FORAL^{aux}_{reg,soil,class,seg=mwcrop} \le ar_{reg} \times$$

$$(suit_{reg,seg=mwcrop} - suit_{reg,seg=rtcrop})\ forshare_{soil,class,reg,seg=mwcrop}$$

(15) gives the land-use balance for the grass segment

We recall that rotations that only include grass grow in the grass segment but also in the mowing crops and the root crops segments. In the

$$\sum_{rot \in grass,oil} AFL_{rot,oil,reg} + \sum_{rot \in grass,oil} RFL_{rot,oil,reg} +$$

$$\sum_{permcr,sys,seg*seg4} PCAL^{aux}_{permcr,sys,reg,seg} +$$

$$\sum_{soil,class,seg*seg4} FORAL^{aux}_{reg,soil,class,seg} \leq ar_{reg}\ suit_{reg,seg=grass} \tag{15}$$

$$PCAL^{aux}_{permcr,sys,reg,seg=grass} \leq ar_{reg} \times$$

$$(suit_{reg,seg=grass} - suit_{reg,seg=mwcrop})\ pcshare_{permcr,sys,reg,seg=grass}$$

$$FORAL^{aux}_{reg,soil,class,seg=grass} \leq ar_{reg} \times$$

$$(suit_{reg,seg=grass} - suit_{reg,seg=mwcrop})\ forshare_{soil,class,reg,seg=grass}$$

same way, rotations that include a mowing crop as the most demanding crop grow in both the root crops segment and the mowing crops segment. Rotations including a root crop only grow in the root crop section. Contrary to this nested suitability of arable farming land-use activities, auxiliary land-use activities for permanent crops have not been defined in a cumulative way.

The auxiliary land-use activities in the fourth segment are forced positive in the two sets of equations given in (16)

$$\sum_{seg*seg4} PCAL^{aux}_{permcr,sys,reg,seg} \leq PCAL_{permcr,sys,reg}$$

$$\sum_{seg*seg4} FORAL^{aux}_{reg,soil,class,seg} \leq FORAL_{reg,soil,class} \tag{16}$$

Rough grazings and the remaining land-use by permanent crops and forestry are located in the fourth segment of each region. As in the other segments, land-use activities have to share the available area in the fourth segment. From the land evaluation no information is available as to what extent the suited soils for rough grazings, forestry and the permanent crops coincide in the fourth segment. It is therefore supposed that the land-use activities in the fourth part of a region compete for the best soils. In other words suitable areas coincide. Now the area of the fourth segment is defined to be the maximum of the suitability over all feasible land-use activities outside the three first segments. On this assumption a land-use balance (17) is defined for land-use activities in the fourth segment.

For rotations that include maize as the most demanding crop, the land-use restriction must be defined somewhat tighter than for other mowing crops,

$$\sum_{permcr,sys} (PCAL_{permcr,sys,reg} - \sum_{seg*seg4} PCAL^{aux}_{permcr,sys,reg,seg}) + \sum_{reg,soil,class} (FORAL_{reg,soil,class} - \sum_{seg*seg4} FORAL^{aux}_{reg,soil,class,reg,seg}) + MRL_{reg} \le ar_{reg} \times \max(\max_{permcr,sys} mrgpcsuit_{reg,permcr,sys}, \max_{reg,soil,class} mrgforsuit_{reg,soil,class}, suitroughgrz_{reg}) \tag{17}$$

owing to the fact that climatological conditions restrict the cultivation of maize more severely than that of other cereals. So, additional land suitability selection criteria are applied. Equation (18) describes these additional restrictions.

$$\sum_{rot \text{ if } output_{rot,oil,reg,pr=maize} \neq 0} AFL_{rot,oil,reg} \le ar_{reg}\, maizesuit_{reg} \tag{18}$$

The land-use balances presented sofar are based on the results of a land evaluation procedure. The present use of land by agriculture can also be taken into account. Given the steady rise in yields of most agricultural products and the limited opportunities for extending production, it is unlikely that agriculturally used area in most regions will increase. Moreover, the area not used for agriculture and forestry is, especially in the well-populated regions, already in intensive use. Therefore, present use of land by agriculture and forestry can be taken as an upper limit for future agricultural land-use activities.

$$\sum_{rot,oil} AFL_{rot,oil,reg} + \sum_{rot,oil} RFL_{rot,oil,reg} + MRL_{reg} + \sum_{permcr,sys} PCAL_{permcr,sys,reg} + \sum_{soil,class} FORAL_{reg,soil,class} \le aua_{reg} \tag{19}$$

Note that in (19) new forests on former agricultural area have been included also.

2.2.1.3 *Water use balance equations*

Accounting for water use and supply on the regional level, on which GOAL is formulated, is bound to be simplifying. Moreover, a balance has to be kept in dealing with different production factors, among which water, relative to their importance. Water use is divided into three categories. In GOAL water use for irrigation is endogenous, water use by industry and households is exogenous. Water supply is in principle dependent on two factors: precipitation and inflow by rivers.

Groundwater reserves are supplied by precipitation. For every region some estimate has been made for sustainable groundwater depletion. Sustainable groundwater use means that inflow and extraction from groundwater reserves are in balance. Apart from groundwater, surface water can also be used.

Surface water resources mainly originate from superficial run-off of precipitation. The total run-off in a region depends on the precipitation rate and the area of the region. Moreover, climate characteristics and morphology determine the part of the precipitation that recurs to the surface water reserves. This part of the precipitation is known as the run-off coefficient, an estimate of which has been found for every region. The rest of the precipitation disappears by percolation into the deeper groundwater reserves or due to evapo-transpiration.
Only part of the superficial run-off will be used by the three demand categories. The rest is lost due to seasonal variations in precipitation, lack of natural or artificial basins and the need for a certain level of outflow through rivers. In general, water availability is not equally distributed over a region. It may abound in some parts, while it may be scarce in other parts.

Surface water also becomes available from the inflow of border crossing rivers. Just like superficial run-off originating in the region, there generally is some seasonal variation in the regional inflow. This is one of the reasons that only a part of the natural surface water inflow can be used by sectors of water demand.

A characteristic of water use in many processes is that water has the function of an intermedium. The same quantity of water that is used as an input in a process evolves as an output in the same process. In general it is polluted to some degree by then. However, recycling may be feasible, e.g. large volumes of industrial water use only serve cooling purposes and could be used again for other ends. It is assumed therefore that part of the water supply to industrial and household sectors does not limit the water availability to agriculture. On the contrary, net water demand by agriculture amounts to pure loss by crop transpiration.

The issue of water pollution arose in relation to the possibility of water recycling. It is clear that agricultural use of surface water is affected by the degree of water pollution. The sources of water pollution other than from agricultural sources fall outside the scope of the study. Furthermore, the effects of polluted irrigation water on crop growth could not be taken into consideration. Such omissions inevitably affect the validity of the results of the analysis. The study thus limits itself to the case that surface water is clean enough to be used for irrigation.

The regional water balance (20) confronts water supply with water demand.

$$\begin{aligned} & GWDEPL_{reg} + SWDEPL_{reg} - \theta\ (wd^{ind}_{reg} + wd^{hh}_{reg}) - \\ & \sum_{rot,oil} input_{rot,oil,reg,coef=water}\ AFL_{rot,oil,reg} - \\ & \sum_{rot,oil} input_{rot,oil,reg,coef=water}\ RFL_{rot,oil,reg} - \\ & \sum_{permcr,sys} pcin_{permcr,sys,reg,coef=water}\ PCAL_{permcr,sys,reg} \geq 0 \end{aligned} \tag{20}$$

Sustainable exploitation of groundwater reserves is dependent on the percolation rate and on the precipitation. Both percolation rate and precipitation are region-specific. Groundwater depletion is described in (21)

$$GWDEPL_{reg} \leq ar_{reg}\ percol_{reg}\ precip_{reg} \tag{21}$$

The formulation of surface water depletion has been made dependent on the position of a region in the network of natural waterways. Several cases have been distinguished. In the most simple case a region has no inflow and no outflow through major rivers. Then only a small amount of superficial run-off can be tapped to meet demand. This is described in (22)

$$SWDEPL_{reg} \leq \phi\ ar_{reg}\ runoff_{reg}\ precip_{reg} \tag{22}$$

The next case is when a region has zero inflow but non-zero outflow through a set of rivers. The outflow through these rivers equals the statistical discharge of these rivers minus the quantity of water withdrawn from the run-off to these rivers. The statistical discharge of a river is measured at a certain point along the river. The outflow refers to the flow at this point. Again the amount of superficial run-off that can be withdrawn is limited. The case is described in (23)

$$\begin{aligned} &SWDEPL_{reg} \leq \phi\ ar_{reg}\ runoff_{reg}\ precip_{reg} \\ &\sum_{riv} OUTFLOW_{riv} + SWDEPL_{reg} \leq \sum_{riv} discharge_{riv} \end{aligned} \qquad (23)$$

Another case that is distinguished is a coastal region that has non-zero inflow through a set of rivers that flow into the sea. The water supply in this region comes from both river inflow and superficial run-off. Only a part of the river inflow can be put to use. The same applies to superficial run-off. The inflow in the region is of course the outflow from another region measured at a point near the border. The case is described in (24).

$$SWDEPL_{reg} \leq \phi\ ar_{reg}\ runoff_{reg}\ precip_{reg} + \psi \sum_{riv} OUTFLOW_{riv} \qquad (24)$$

The synthesis of the former two cases applies when a region has an inflow through a set of rivers and an outflow through these and other rivers. It is clear that inflow and outflow are taken at different points along the river, in principle at the borders. Equations (25) describe the synthesis. For the sake of simplicity no restrictions have been formulated to the distribution of withdrawal from inflowing rivers. The restriction that only a part of the inflow can be withdrawn is applied to the total inflow through all waterways.

$$\begin{aligned} &SWDEPL_{reg} \leq \phi\ ar_{reg}\ runoff_{reg}\ precip_{reg} + \\ &\qquad \psi \sum_{riv \in rivinflow} OUTFLOW_{riv} \\ &\sum_{riv \in rivinflow} OUTFLOW_{riv} + ar_{reg}\ runoff_{reg}\ precip_{reg} - \\ &\qquad SWDEPL_{reg} = \sum_{riv \in rivoutflow} OUTFLOW_{riv} \end{aligned} \qquad (25)$$

Restriction (26), which formulates that outflow cannot outrate statistical discharge, applies to all these cases.

$$OUTFLOW_{riv} \leq discharge_{riv} \qquad (26)$$

The water balance becomes more complicated when the border between regions follows the course of waterways. In such cases withdrawal from a river is made explicit for any of the bordering regions. The total withdrawal from that river along a certain part is again subject to the restriction that only part of the waterflow can be withdrawn. In the equation that accounts for the throughflow of a region, the withdrawal by other regions from a shared waterway is described by an extra term. The formulation of this complicated case is given in (27), which also makes reference to a certain region and a certain shared waterway.

$$
\begin{aligned}
& SWDEPL_{reg^0} \le \phi \; ar_{reg^0} \; runoff_{reg^0} \; precip_{reg^0} + \sum_{riv \in rivinflow} WITHDRAW_{reg^0,riv} \\
& \sum_{reg} WITHDRAW_{reg,riv^0} \le \psi \; OUTFLOW_{riv^0} \\
& \sum_{riv \in rivinflow} OUTFLOW_{riv} + ar_{reg^0} \; runoff_{reg^0} \; precip_{reg^0} - \\
& SWDEPL_{reg^0} - \sum_{riv} \sum_{reg \neq reg^0} WITHDRAW_{reg,riv} = \\
& \sum_{riv \in rivoutflow} OUTFLOW_{riv}
\end{aligned}
\qquad (27)
$$

2.2.2 Goal variables

The purpose of the model is to investigate possible conflicts between policy goals that could arise in the long term development of the Community's agricultural system. This has been set out in the introduction. Several policy goals have been quantified in the model. They can be optimised subsequently and will therefore be called the object variables. Policy goals are distinguished with respect to agricultural productivity, with respect to the employment situation and with respect to agricultural pollution. The equations that link the object or goal variables to the agricultural activities in GOAL are now discussed subsequently. In this connection attention will also be paid to input-output relations. This applies in particular to inputs that have not yet been discussed, for example the production factors labour and capital.

2.2.2.1 *The costs of agricultural production*

In GOAL the focus is upon the functioning of the entire agricultural system. No costs are accounted on the farm or even on the regional level. Cost figures relate to the entire agricultural system.
Imports and exports are determined exogenously. Substitution possibilities for imports or exports are not analyzed in GOAL. Thus, costs or revenues from external trade need not be accounted for.

Feed costs for livestock production are not separately accounted. Only if livestock feedingstuffs are produced internally, their costs are included in the total costs as part of the costs of primary production. In this case substitution of feedingstuffs can influence the total costs of the agricultural system.

It is acknowledged that shifting trade relations matter in the analysis of possible future developments of the agricultural system. However, no information has been gathered on the agricultural potentials of the Community's trade partners. Thus, it was decided to restrict the scope of the explorations and to resort to the results of other studies for the implementation of plausible future trade relations. Two different and extreme trade strategies have been confronted to the Community's agricultural potentials, one strategy aiming at self-sufficiency and the other aiming at free trade strategy.

Several cost components of agricultural activities are distinguished. The costs of intermediary inputs, such as nutrients, pesticides and energy are determined exogenously. As already noted the costs of feedingstuffs form an exception. The costs of feedingstuffs are part of the costs of primary production. The costs of the production factors labour and capital are based on opportunity costs that are supposed to be known. The costs of land are determined endogenously. The structure of the different cost components will now be discussed.

The unit costs of physical inputs such as water, nutrients, pesticides and energy have been supposed to be uniform over the Community.

The cost of water for irrigation falls apart in two components. The cost of on-field irrigation equipment and on-field infrastructure is accounted on a per hectare basis of irrigated area. The cost of infrastructure for irrigation water supply is accounted on a per volume basis of water supplied. It is clear that the regional conditions for irrigation infrastructure vary considerably. Therefore, the assumption of uniform costs for irrigation infrastructure per m^3 of water supplied may appear unduly strong. However, there are some considerations that indicate why this approach may provide a rough indication of infrastructure costs all over

the Community. The extraction of irrigation water from surface water reserves requires both storage systems and transport systems. The costs of these systems per m^3 of irrigation water supplied are inversely proportional to each other. Large scale storage is relatively cheap but requires long distance transport and viceversa. So whatever the scale of the irrigation infrastructure, the same order of magnitude of infrastructural costs applies.
Irrigation water is also extracted from ground water reserves. It appears that infrastructural costs of the extraction from groundwater are in the same order of magnitude as the extraction from surface water resources.

Nutrients arise from two different sources. Commercial fertilizers are applied in arable farming, permanent crops and roughage farming. These fertilizers bear uniform per unit costs all over the Community. The second source of nutrients is the manure gathered from on stable dairy and drystock farming. In the model these nutrients bear no costs.

The costs of energy use are implicit in the fixed costs of livestock farming and the cultivation of permanent crops. In arable and roughage farming energy use is related to the use of machinery. For every crop considered a calendar of agricultural tasks is provided depending on orientation and investment level. From the specific energy use of traction power needed for each of these tasks total energy use is derived for every rotation, orientation and investment level. So energy use of an agricultural activity in GOAL is not region specific. Neither is the cost per unit of fuel.

To the discussion of costs of physical inputs one remark must be added. The costs of sowing seeds are implicit in the production of usable product.

The remuneration of the production factor labour in GOAL has been assumed to be in line with the remuneration in other sectors. Over the long run, little can be said with certainty about the development of wages in the European economy. For the calculations with GOAL it is quite arbitrarily assumed that wage levels in the Community converge towards a level found in the richer memberstates. It is likely that this assumption affects the results of the model calculations.

Depreciation and interests payments as well as maintenance and repair costs of both machinery and estates has been calculated for land-use activities in agriculture and forestry.
In livestock farming these costs relate to a few standard farming systems that are assumed to be applicable all over the Community. Costs have been specified for several items such as housing, sanitary provisions, milking equipment, feeding installations, manure storage and general expenses. The costs in permanent crop cultivation vary according to permanent crop and cropping system. No distinction has been made in costs over different regions. This is also the case in forestry where fixed costs only vary among classes of tree species.

More detail has been brought into the capital costs of arable farming, including roughage cultivation. For every crop a calendar of agricultural tasks has been considered. Every task requires the use of specified machinery in many cases in combination with traction. This machinery requires a specific period of time to cultivate an area. The machinery may again be used at another time of the year or it may be used for another crop in the same rotation. Capital costs are accounted on the basis of a rotation. The costs of some type of machinery depend on its peak use within a rotation during any period of the year. The crop calendars vary according to orientation and investment level. So, in arable farming, for every rotation, orientation and investment level, different capital costs result.

Several assumptions have been made to account for capital costs of arable farming. Capital costs have not been calculated at the farm level but in relation to a rotation. This leaves aside the possibility of even more cost-effective combinations of rotations, but it excludes inefficiencies due to indivisibilities. The assumption has also been made that crop calendars have an identical structure all over the Community. Whereas sowing and harvesting periods may differ among the regions, it has been assumed that if the time table indicates that certain tasks for different crops in a region fall in the same period, this will be the case in all regions.

Capital costs depend to some extent on operation times because with higher operation times less capital goods are needed. High operation times shorten lifetime but on balance reduce capital costs. Especially for harvesting equipment capital costs are relatively high. Maximal operation times of this kind of machinery depend on the humidity of the crop. On the basis of climatological conditions it is possible to discern between maximal operation times of harvesting equipment between regions. In this way a regional differentiation in capital costs of arable farming is introduced. The costs of capital in arable farming have been derived along the lines of (28)

$$input_{rot,oil,reg,coef=capital} = \sum_{type} speccost_{type,reg} \times \max_{period} \sum_{crop} rotscheme_{rot,crop}\ machuse_{crop,oil,period,reg,type} \tag{28}$$

The costs of land have not been included in the total costs. Rather, they follow as the result of a land-use allocation. It could of course be argued that opportunity costs for land exist, e.g. for nature development, but this line of thought is not further pursued here.

We are now ready to formulate the total costs of the agricultural system. In (29) the costs of arable farming are formulated.

$$\begin{aligned} COST_{arfarm} = & \sum_{rot,oil,reg} AFL_{rot,oil,reg} \times \\ & (input_{rot,oil,reg,coef=water}\ irrinfracost + irrfieldcost + \\ & input_{rot,oil,reg,coef=nitr}\ fertcost + input_{rot,oil,reg,coef=pest}\ pestcost + \\ & + input_{rot,oil,reg,coef=fuel}\ fuelcost + \sum_{acr} output_{rot,oil,reg,acr}\ treatcost_{acr} + \\ & input_{rot,oil,reg,coef=capital} + input_{rot,oil,reg,coef=housing} + \\ & (input_{rot,oil,reg,coef=fieldlabour} + non\text{-}fieldlabour_{oil})\ wage + genexp_{oil}) \end{aligned} \tag{29}$$

Except for nutrients supply the costs of roughage cultivation in (30) are analogous. The costs saved by using manure in roughage cultivation have been subtracted from the fertilizer costs.
The costs of grazing livestock farming are expressed in (31).
The costs of permanent crops and forestry include the costs of water, nutrients, pesticides, labour and indirect costs. Irrigation is not applied in forestry, but nutrients may be applied for fast growing

$$\begin{aligned} COST_{roughfarm} = \sum_{rot,oil,reg} RFL_{rot,oil,reg} \times \\ (input_{rot,oil,reg,coef=water}\ irrinfracost + irrfieldcost + \\ input_{rot,oil,reg,coef=nitr}\ fertcost + input_{rot,oil,reg,coef=pest}\ pestcost + \\ + input_{rot,oil,reg,coef=fuel}\ fuelcost + \sum_{acr} output_{rot,oil,reg,acr}\ treatcost_{acr} + \\ input_{rot,oil,reg,coef=capital} + input_{rot,oil,reg,coef=housing} + \\ (input_{rot,oil,reg,coef=fieldlabour} + non\text{-}fieldlabour_{oil})\ wage \\ + genexp_{oil}) - fertcost \sum_{cra} iocra_{coef=nitrout,cra}\ CRAL_{cra,reg} \end{aligned} \quad (30)$$

$$\begin{aligned} COST_{grazinglivestock} = \sum_{reg,cra} CRAL_{cra,reg} \times \\ (iocra_{coef=labour,cra}\ wage + iocra_{coef=housing,cra} + \\ iocra_{coef=san,cra} + iocra_{coef=feedeq,cra} + \\ iocra_{coef=manurestor,cra} + iocra_{coef=genexp,cra}) + \\ \sum_{reg} (shlabour\ wage + shcost)\ SRAL_{reg} \end{aligned} \quad (31)$$

species. (32) expresses the costs of permanent crop cultivation and (33) the costs of forestry.

$$\begin{aligned} COST_{permcrops} = \sum_{permcr,sys,reg} PCAL_{permcr,sys,reg} \times \\ (pcin_{permcr,sys,coef=water}\ irrinfracost + irrfieldcost + \\ pcin_{permcr,sys,coef=nitr}\ fertcost + pcin_{permcr,sys,coef=pest}\ pestcost + \\ pcin_{permcr,sys,coef=labour}\ wage + pcin_{permcr,sys,coef=indcost}) \end{aligned} \quad (32)$$

$$\begin{aligned} COST_{forestry} = \sum_{reg,soil,class} FORAL_{reg,soil,class} \times \\ (forin_{class,coef=nitr}\ fertcost + forin_{class,coef=pest}\ pestcost + \\ forin_{reg,soil,class,coef=labour}\ wage + forin_{class,coef=indcost}) \end{aligned} \quad (33)$$

Several intermediary (by-)products are used as feedingstuffs. It is necessary to consider the costs of intermediary processes to get a correct balance between the costs of processed and unprocessed feedingstuffs. In (34), the costs of intermediary processes are accounted for.

$$COST_{processing} = \sum_{proc} proccost_{proc}\ PROCL_{proc} \quad (34)$$

Summing up over all cost components of the agricultural system, (35) gives the goal variable that relates to cost-effectiveness. With respect to an exogenously stated demand and to restrictions on other goal variables, this variable controls the cost-effectiveness of the imaginary, but technically feasible agricultural systems that are described in the scenarios developed by means of the GOAL model.

$$COST = COST_{arfarm} + COST_{roughfarm} + COST_{grazinglivestock} + COST_{permcrops} + COST_{forestry} + COST_{proccost} \tag{35}$$

2.2.2.2 *Aggregate soil productivity*

Technological progress in agriculture has resulted in rising yields per unit of area and per animal. In the GOAL model, the limits to growth are emphasized. Yield levels that are considered as the utmost attainable from an agronomic perspective have been explicitly considered in the model. Yield levels vary according to physical endowments, orientation and investment level. Aggregate soil productivity measures to what extent potential yield increases in a scenario are realized.

Because agricultural demand is exogenously stated, it is possible to simplify the question as to what aggregate yield is realised, to the question what area is needed to meet this agricultural demand. So, in the model only the agriculturally used area has been considered. This area varies with respect to stated demand and restrictions on other goal variables.

(36) gives total agriculturally used area.

$$AGRAREA = \sum_{reg,oil,rot} (AFL_{rot,oil,reg} + RFL_{rot,oil,reg}) + \sum_{reg} MRL_{reg} + \sum_{permcr,sys,reg} PCAL_{permcr,sys,reg} \tag{36}$$

2.2.2.3 *Aggregate employment*

Labour requirements have been considered in terms of full-time labour equivalents. No attention has been paid to seasonal peaks in labour demand as has been done in the case of machinery. The assumption is made that labour is more flexible than capital goods, i.e. labour is less dedicated to certain tasks than capital goods.

In arable farming and in roughage cultivation labour requirements are distinguished according to field and non-field activities. In forestry, labour requirements for felling are proportional to yields.

The income situation of farmers is a matter of great concern in agricultural policy. An unsustainable development of agricultural incomes affects the agricultural employment situation over the longer term. This has been the reason to introduce aggregate agricultural employment as a goal variable in the model.

(37) accounts for employment in those agricultural activities that use land as a production factor.

$$\begin{aligned} AGREMPL_{reg} = \\ \sum_{rot,oil} (input_{rot,oil,reg,coef=fieldlabour} + non\text{-}fieldlabour_{oil})\ AFL_{rot,oil,reg} + \\ \sum_{rot,oil} (input_{rot,oil,reg,coef=fieldlabour} + non\text{-}field\text{-}labour_{oil})\ RFL_{rot,oil,reg} + \\ \sum_{cra} iocra_{coef=labour,cra} CRAL_{cra,reg} + shlabour\ SRAL_{reg} + \\ \sum_{permcr,sys} pcin_{permcr,sys,coef=labour}\ PCAL_{permcr,sys,reg} + \\ \sum_{soil,class} forin_{reg,soil,class,coef=labour}\ FORAL_{reg,soil,class} \end{aligned} \tag{37}$$

$$AGREMPL_{tot} = \sum_{reg} AGREMPL_{reg}$$

2.2.2.4 *Regional loss of employment*

Not only the development of total agricultural employment in the Community is a concern to agricultural policy, but more specifically the regional distribution of remaining agricultural employment is a factor in the opportunities for rural development. Especially in those regions of the Community where agricultural employment still accounts for a considerable part of the total employment the chances for a continued agricultural activity count. One objective in GOAL is therefore to maintain as much as possible of the current agricultural employment.

The perspective from which the regional employment situation is seen, is an extreme one. Rather than preserving employment by only gradually improving on labour productivity the situation has been analyzed where

labour efficiency is high and no regional differences in labour efficiency exist. Of course, the scenarios based on this assumption show only one side of the coin. Emphasis has been placed on the redistribution of agricultural activity in order to restrict the loss of agricultural employment. No attention has been paid to the potential role of regional wage differentials and associated variations in labour productivity.
Thus, this formulation can provide meaningful insights into the role of regional distribution of production. However, the scenarios developed by means of GOAL should be interpreted with care. Once again, it must be stressed that the scenarios serve to explore the technical boundaries for the development of the agricultural system.

The objective to minimize the gap between current regional employment and regional employment in the scenarios is formulated as a minimax equation. The objective is to minimize some relative loss that is greater than the relative loss in any of the Community's regions. (38) expresses this loss fraction.

$$LOSS \geq 1 - \frac{AGREMPL_{reg}}{agremplcurr_{reg}} \qquad (38)$$

2.2.2.5 *Aggregate nitrogen loss*

Agricultural pollution is considered along two dimensions, the loss of nitrogen and the use of pesticides. Nitrogen losses arise where nitrogen is applied in arable farming or in roughage cultivation and in livestock farming where a distinction is made between nitrogen lost during grazing and nitrogen lost as a fraction of nitrogen in manure storage. The interest in aggregate nitrogen loss arises because it can be related to some measure of aggregate output. This would give an idea of the amount of nitrogen lost in the production of a certain bundle of agricultural products.

(39) gives the total loss of nitrogen

$$NITRLOSS = \sum_{rot,oil,reg} input_{rot,oil,reg,coef=nitrloss} \, AFL_{rot,oil,reg} + \sum_{rot,oil,reg} input_{rot,oil,reg,coef=nitrloss} \, RFL_{rot,oil,reg} + \sum_{cra,reg} iocra_{coef=nitrloss,cra} \, CRAL_{cra,reg} \quad (39)$$

2.2.2.6 *Aggregate use of pesticides*

Analogous to nitrogen loss the aggregate agricultural use of pesticides is modelled in (40). Pesticides are used in arable farming, in roughage cultivation and in the cultivation of permanent crops. An indication of the use of pesticides for a certain bundle of agricultural products is also of interest.

$$PESTUSE = \sum_{rot,oil,reg} input_{rot,oil,reg,coef=pestuse} \, AFL_{rot,oil,reg} + \sum_{rot,oil,reg} input_{rot,oil,reg,coef=pestuse} \, RFL_{rot,oil,reg} + \sum_{permcr,sys,reg} pcin_{permcr,sys,coef=pest} \, PCAL_{permcr,sys,reg} \quad (40)$$

2.2.2.7 *Nitrogen loss per area*

Whereas nitrogen loss or pesticide use per bundle of products gives an indication of the efficiency of its use, nitrogen loss and analogously pesticide use per area in use for agriculture is a measure of agricultural pollution.

In a linear model, it must be avoided that ratios of two variables occur. In this case these variables are aggregate loss of nitrogen and agriculturally used area. To avoid a ratio variable, a linear index of nitrogen loss per area is created. Both nitrogen loss and agricultural area are divided by some reference value in order to force the value of the ratio variable into the neighbourhood of the value one. By taking the logarithm and remembering that it can be linearly approximated in the neighbourhood of the value one the index (41) follows.

$$NITRLOSSperAREA^{index} = 1 + \frac{NITRLOSS}{NITRLOSS^0} - \frac{AGRAREA}{AGRAREA^0} \tag{41}$$

2.2.2.8 *Pesticide use per area*

The index for pesticide use per area in agricultural use is created analogously in (42)

$$PESTUSEperAREA^{index} = 1 + \frac{PESTUSE}{PESTUSE^0} - \frac{AGRAREA}{AGRAREA^0} \tag{42}$$

2.3 Symbol listing

Indices:

reg	*region*
oil	*investment level and orientation*
rot	*rotation*
sys	*cultivation system*
soil	*soil limitation for forestry*
class	*class of tree species*
seg	*segment of soil suitability*
riv	*river section*
type	*machinery type*
period	*seasonal partition*
pr	*product*
acr	*arable crop*
rcr	*roughage crop*
secpr	*secondary product*
crop	*crop*
permcr	*permanent crop*
prot	*standard feedingstuff*
n.r.comp	*non-ruminant nutritional component*
r.comp.rat	*ruminant nutritional component by basket*
proc	*intermediary process*
nueq1	*standard feed ingredient identification*
nueq2	*nutritional value equivalency*
cra	*cattle raising activity*
coef	*coefficient*

Variables:

$AFL_{rot,oil,reg}$	*arable farming*
$RFL_{rot,oil,reg}$	*roughage cultivation*
$PROCL_{proc}$	*intermediary processing*
$NUEQL_{nueq1}$	*identification with standard feedingstuffs*
$NUEQL_{nueq2}$	*accounting for nutritional values*
$NUEQRL_{nueq2,reg}$	*idem specified by region*
$SHRL_{reg}$	*sheep grazings*
$SRAL_{reg}$	*sheep raising*
MRL_{reg}	*rough grazings*
$CRAL_{reg}$	*cattle raising*
$PCAL_{permcr,sys,reg}$	*permanent crop cultivation*
$FORAL_{reg,soil,class}$	*forestry activity*
$PCAL^{aux}_{permcr,sys,reg,seg}$	*permanent crop cultivation by segment*
$FORAL^{aux}_{reg,soil,class,seg}$	*forestry by segment*
$GWDEPL_{reg}$	*ground water depletion*
$SWDEPL_{reg}$	*surface water depletion*
$OUTFLOW_{riv}$	*outflow at river section*
$WITHDRAW_{reg,riv}$	*withdrawal river by region*
$COST$	*costs*
$AGRAREA$	*area in agricultural use*
$AGREMPL_{reg}$	*agricultural employment*
$AGREMPL$	*idem*
$LOSS$	*relative loss of agricultural employment*
$NITRLOSS$	*nitrogen loss*
$PESTUSE$	*pesticide use*

Parameters and coefficients:

$output_{rot,oil,reg,pr}$	*arable and roughage crop yields*
$input_{rot,oil,reg,coef}$	*idem input coefficients*
$rotscheme_{rot,crop}$	*idem crop share in rotation*
$machuse_{crop,oil,period,reg,type}$	*idem machinery usage per area*
$non\text{-}fieldlabour_{oil}$	*idem general labour requirements*
$genexp_{oil}$	*idem general expenses*
$mrout_{reg}$	*rough grazing yield*
$yield_{permcr,sys,reg}$	*permanent crop yield*
$pcin_{permcr,sys,reg,coef}$	*idem input coefficients*
$woodgrowth_{reg,soil,class}$	*forestry yield*
$forin_{reg,soil,class,coef}$	*forestry input coefficients*
$iocra_{pr,cra}$	*i-o coef of cattle raising*
$iosra_{pr}$	*idem of sheep raising*
$ioproc_{pr,proc}$	*idem of intermediary processing*
$ionueq_{pr,nueq1}$	*idem feedingstuff identification*
$ionueq_{pr,nueq2}$	*idemin nutritional value accounting*
shlabour	*labour in sheep raising*
shcost	*other costs in sheep raising*
$proccost_{proc}$	*unit cost of intermediary processing*
$speccost_{type,reg}$	*specific machinery cost*
irrinfracost	*irrigation infrastructural costs*
irrfieldcost	*irrigation field equipment costs*
fertcost	*unit fertilizer cost*
pestcost	*unit pesticides cost*
fuelcost	*unit fuel cost*
treatcost	*product storage and treatment cost*
wage	*uniform wage level*

ξ	share of fibrous to dry matter
ζ	share of birth-region bound calves
c_{pr}	consumption
x_{pr}	export
m_{pr}	import
ar_{reg}	total area
$suit_{reg,seg}$	soil suitability share
$pcshare_{permcr,sys,reg,seg}$	segment share suited for permanent crop
$forshare_{soil,class,reg,seg}$	segment share suited for forestry
$mrgpcsuit_{reg,permcr,sys}$	fourth segment share permanent crop
$mrgforsuit_{reg,soil,class}$	fourth segment share forestry
$suitroughgrz_{reg}$	suitable share for rough grazings
$maizesuit_{reg}$	suitable share for maize cultivation
aua_{reg}	area currently used by agriculture
wd_{reg}^{ind}	industrial water use
wd_{reg}^{hh}	water use by households
θ	recyclable share
$percol_{reg}$	percolation rate
$precip_{reg}$	precipitation
$runoff_{reg}$	runoff coefficient
ϕ	withdrawable share runoff
$discharge_{riv}$	statistical discharge
ψ	withdrawable share inflow
$agremplcurr_{reg}$	current agricultural employment

3. CHARACTERISTICS OF GOAL RESULTS

3.1 Introduction

In the first part of this document the formal structure of the GOAL model has been presented. In this second part, optimizations with GOAL serve to explain the capabilities of the model. The confrontation of the formal model with the GOAL database creates a better understanding of the data per se. Moreover, the implications of the model structure become clear. The findings that are described in this part are useful for the interpretation of the scenarios that have been developed by the Council.

Below, three subjects are paid attention to. In 3.2 several possible substitutions within the agricultural system are systematically described. Also, attention will be given to the robustness of the regional allocations. In 3.3, the gain in a goal variable will be confronted with the corresponding loss in another goal variable. Trade-offs will be shown between environment and employment and between environment and costs. Finally, it will be shown what land rents can be derived from simple cost minimizations.

3.2 Substitution possibilities in GOAL

Basically, GOAL focuses on three different substitution possibilities. Firstly what can be gained in terms of a goal variable by changing the way in which production takes place; secondly what can be gained by changing the regional allocation of land-use; and thirdly what can be gained by changing production routes within the agricultural production system. The first two categories relate to substitution as a consequence of a change in a single element in the production system, the last category relates to substitution as a consequence of a change in the interaction between several elements in the production system.

In the discussion of substitution effects it is convenient to follow the results of unrestricted optimizations of the goal variables. These optimizations have been carried out for two levels of demand, a low level corresponding with current levels of food consumption and free trade relations, and a high level corresponding with high levels of food consumption and autarchy.

3.2.1 Substitution by changing techniques

We will first discuss substitution induced by the way of production will be discussed. The question is which orientation or investment level contributes most to a certain goal variable. In several cases it will appear that conclusions on the effects of different production orientations or investment levels are conditional upon the region.

Aggregate agricultural land-use depends on the level of crop yields. In one region, highest yields are attained with YOA under irrigation, lowest yields are attained with rain-fed EOA and for those crops where LOA applies, its yields are even lower. For the yield levels in between, it depends on the regional precipitation deficit whether rain-fed YOA has higher yields than EOA with irrigation. In several southern regions with low precipitation irrigated EOA for most crops has higher yields than rain-fed YOA.

In comparing the cost levels of possible investment levels and agricultural orientations a distinction must be made between the costs per hectare and the costs per ton of product. In terms of costs per hectare irrigated agriculture bears more costs than rain-fed agriculture and if applicable rain-fed agriculture bears more costs than LOA. In terms of costs per ton of product, the same applies for most regions. This means that the data show decreasing returns to intensity of production. However in some regions with high precipitation deficits there is an exception to this rule and irrigated agriculture bears lower costs than rain-fed agriculture per ton of product.
Such conclusions for a single land-use activity can only be derived unambiguously in the case of single crop rotations. The cost of a single crop in a multi-crop rotation depends on the opportunity costs of producing the other crops in that rotation and these costs vary with the system characteristics.
From the optimization with respect to aggregate costs of the agricultural system it appears that LOA and YOA, whether irrigated or rain-fed, are

more cost-effective than EOA. It also appears that broad rotations are more cost-effective than narrow rotations.

A maximization of agricultural employment sorts out land-use options that require more labour than other options. It is clear that low yield levels in the aggregate require more labour than high yield levels. Therefore, EOA is compatible with maximal (but efficient) use of labour. Also, irrigation is a labour consuming activity. In several regions with high precipitation deficits, irrigation labour outweighs the reduction of aggregate labour requirements due to higher yields.

Efficiency in nitrogen use in terms of reduction of nitrogen losses per ton of output is reached by applying irrigation whether in YOA or in EOA. The data clearly show lower nitrogen losses in irrigated land-use activities than in rain-fed activities. If not nitrogen loss per ton of output is at stake but rather nitrogen loss per hectare greatest efficiency is seen in the case of irrigated EOA and LOA. These classes of activities have lower outputs and thus require lower nitrogen input.
It is also remarkable that rotations which contain a nitrogen fixing crop, e.g. a protein crop, are among the most efficient in terms of both net nitrogen loss per ton of output and in terms of net nitrogen loss per hectare.

The data show that lowest use of pesticides in relation to output can be achieved with irrigated EOA and with LOA. LOA does not use pesticides at all. Lowest use of pesticides per hectare can be achieved with LOA and irrigated or rain-fed EOA. Both irrigated and rain-fed EOA have equal pesticide use per hectare.

3.2.2 Substitution by regional shifts in production

In this section substitution by regional allocation of land-use will be discussed. The issue is the extent to which a certain land-use activity scores on a goal variable. This may vary from region to region. Most land-use activities can take place in every region. For certain goal variables it makes almost no difference in which region an activity takes place, for other goal variables it does matter. This issue touches upon the robustness of a regional allocation of land-use that results from an optimization.

Again agricultural land-use is dependent on yield levels. Potential yields vary considerably less over regions than water-limited yields. This is especially the case for arable crops. Roughage crops such as grass and green maize show more variation in potential yields. It is remarkable that for these crops potential yields are significantly above average in those regions where water-limited yields are significantly below average as the result of the precipitation deficit. This is the case for most of the regions in the south of the Community. It appears that the conditions for irrigation, i.e. the availability of water or the costs of irrigation, are of great relevance for the allocation of land-use over the regions of the Community.

The costs of production of a certain crop within a region of the Community can only be assessed in conjunction with the production in other regions and of other crops. It is however possible to compare the production costs for a specific single crop rotation over regions. Such a comparison is only partial and does not reflect the cost levels derived from the various production possibilities within the system. The comparison may however give some idea of regional cost differences. It appears for instance that the costs of producing one ton of cereals can vary up to one third of the production costs of cereals in the most cost-efficient regions. For other crops in single crop rotations, the costs per ton may even double compared to the costs in most cost-efficient regions.

The major source of regional variation in production costs as measured in costs per hectare is the application of irrigation. Not only do irrigation infrastructure and on-field irrigation equipment add to the costs per hectare but also the labour required to operate the equipment gives rise to substantial costs. If the higher costs of irrigated crops in regions with high precipitation deficits are compensated by higher yields the costs per output may be lower than in regions with low precipitation deficits but also with lower yields. As indicated before, roughage crops have higher potential yields in southern regions than in northern regions. This is not the case for arable crops. It is therefore more

likely that southern regions have a potential cost advantage over northern regions for roughage crops rather than for arable crops.
In an optimization relative to the aggregate costs of production, a cost balance can be made visible between rain-fed production in regions with low precipitation deficit and irrigated production in regions with high precipitation deficit. It has already been observed that in most regions decreasing returns to investment prevail in the data. However, in some regions with high precipitation deficit, the data show increasing returns to investment. Because of significant differences in yield levels rain-fed production in humid regions is more cost-efficient than rain-fed productions in arid regions. In general rain-fed production in humid regions is also less costly than irrigated production in arid regions. However, since land in humid regions available to meet the demand for agricultural products is limited more costly irrigated production in arid regions may arise.

Because of the large variety of rotations that can be applied in every region, differences in the costs of production are smoothed compared to the regional differences in the costs of a single rotation. This caveat being made, the cost structure of two representative rotations is presented for a range of regions. In figure 1, the costs of a typical arable farming rotation (maize-wheat-beans-wheat-rapeseed) are given for irrigated YOA. In figure 2 gives the costs for irrigated YOA pastures. In both figures, a distinction is made between capital costs of irrigation (water), labour costs for both irrigation and other labour, and in other costs, which include other intermediary costs and the factor costs of capital. It appears that other costs are not very important. Labour costs are high whenever irrigation costs are high because of the high labour requirements of irrigation. It is remembered that a uniform wage is assumed all over the Community. Without exception high cost regions are situated in the south of the Community.

The cost range of 1000-2000 ECU/ha is representative for arable farming rotations that do not involve root crops. Rain-fed agriculture appears at the bottom of this range. LOA clearly falls outside this range.
The zero shadow costs regions in figure 5 and 6 indicate where production is allocated if aggregate production costs are minimized without restric-

tions on other goal variables. Figure 5 gives the allocation for a current consumption free trade environment and figure 6 relates to a high consumption autarchy environment. A well-known characteristic of linear programming solutions can be recognized: arable farming is exclusively concentrated in certain regions while other regions remain idle. The figures show a linear programming corner-solution or what might be called an extreme allocation.
One might question the robustness of these allocations. What mutations in the costs of arable farming techniques can upon minimization of aggregate costs result in another regional allocation? The minimal cost reduction necessary to activate one arable farming technique in that region is depicted in figure 5 and 6. Possible activity of LOA techniques is excluded from this exercise because of their deviating cost structure. It appears that in most of the regions that are not situated in the south of the Community, a cost reduction of less than 100 ECU/ha is necessary to activate at least one arable farming technique (excluding LOA). This is less than 10% of the representative cost range.

An analogous question has been answered with regard to roughage cultivation. The cost range in figure 2 is between 750-1500 ECU/ha. It must be noted that figure 2 concerns the costs of intensive cultivation of grass (irrigated YOA). The costs of rain-fed pastures are at the bottom end of this range. In figures 7 and 8, the zero shadow cost regions are the regions where roughage cultivation is allocated. Again this is an extreme allocation. It appears that a cost reduction of less than 50 ECU/ha suffices to activate at least one technique of roughage cultivation (excluding LOA) in most of the regions of the Community. Again this is less than 10% of the representative cost range.

It must be noted that arable farming and roughage farming compete for the same area. This may explain why 'white spots' can occur, especially on the arable farming maps of figure 5 and 6. If land-use by an arable farming technique would replace land-use by a cost-efficient roughage farming technique, the minimal reduction costs would include both the reduction of costs in the arable farming technique per se and the costs made by replacing a cost-efficient roughage cultivation technique.

It is remarkable that most rotations show considerable regional variation in loss of nitrogen. Figure 3 gives regional variation in nitrogen loss for the rotation maize-wheat-beans-wheat-rapeseed with irrigated EOA. The choice for irrigated EOA is motivated by the observation that, of all investment levels and orientations (except LOA), irrigated EOA shows lowest nitrogen loss. Figure 4 gives regional variation in nitrogen loss for irrigated EOA pastures. For both rotations nitrogen loss is in the range from 25-50 kg N/ha. These are unavoidable losses at EOA yields. The data show that losses at LOA cereal production are less than half of the loss level of irrigated EOA techniques and that losses of LOA grass production are negligible.

An allocation that results from the minimization of aggregate nitrogen losses is given in figures 9 and 10 for arable farming and in figures 11 and 12 for roughage cultivation. Figures 9 and 11 relate to a current consumption free trade environment and figures 10 and 12 relate to a high consumption autarchy environment. Both arable farming and roughage cultivation activities are allocated in the zero shadow cost regions. These are extreme allocations.
One may wonder how much aggregate nitrogen losses at least increase if an activity in another region is activated. Least polluting activities in not allocated regions are LOA activities. Figures 9 to 12 show therefore what increase in nitrogen loss results when LOA land-use are activated. As LOA pasture causes no nitrogen loss, figures 11 and 12 provide no information on regional susceptibility to nitrogen losses by other orientations. Regions that have not been allocated fall in the 0-1 kg N/ha range. From figures 9 and 10 it can be seen that it makes a substantial difference to nitrogen losses where arable activities are allocated. Several regions are within the 10-25 kg N/ha range of nitrogen loss. Arable activities cause at least 10-25 kg N/ha more nitrogen loss than the arable activities that are active in other regions. Compared to the highest losses of 50 kg N/ha that were shown in figure 3 this makes for 20-50% of total losses. Thus, it can be concluded that regional allocations with respect to minimizing aggregate nitrogen loss are much more robust than allocations with respect to minimizing aggregate costs.

The data show few variation in pesticide use over regions despite the efforts made to indicate what factors might influence regional pesticide requirements. Therefore, almost no gain in aggregate pesticide use reduction can be derived from alternative regional allocations of agricultural land-use.

Apart from the robustness of regional allocations that is the subject of the discussion above, one can also question the robustness of the values that the goal variables take. The issue is especially interesting for the goal variable land-use. Changes in the parameters of land-use oriented activities might influence the total amount of land used.

3.2.3 Substitution by change in production route

Next substitution effects of a change of production route within the agricultural system will be discussed. In a large model such as GOAL, many 'integrated' substitution effects can occur. Here only three examples of integrated substitution effects will be given.
One of the goal variables is the agriculturally used area. It may be a goal to minimize this area, for instance in connection to a policy of nature development. A large part of the crops is used to feed the livestock. Agriculturally used area may be reduced by choosing crops with a high nutritional value per unit of area. This may be done by increasing the portion of rootcrops.
Another example relates to the goal variable of preserving the regional agricultural employment as much as possible. An optimum of this goal variable is reached if labour intensive agricultural activities are allocated in regions with relatively high agricultural employment. For instance, dairy farming is a labour intensive activity. A maximum of employment within a region can be preserved if the stocking rate increases, for instance buy applying a higher portion of concentrates in the dairy stock food basket.
A last example is given that relates to the goal variable of aggregate costs. In current agriculture, it is often seen that concentrates are fed to dairy stock. Since, concentrates increase the milk yield, this may be a solution to the land shortages that many farmers experience. However, it appears from the optimization results that aggregate costs of agricul-

ture are reduced if concentrate feedings to dairy stock are eliminated. This would reduce the milk yields. The cost reduction that can be achieved by growing high yielding roughage to dairy stock outweighs the cost advantages that can be derived by increasing milk yields.

3.3 Trade-off between goal variables

GOAL is a model with multiple objectives. Several goal variables can be optimized either in isolation or in relation to each other. In this section it will be examined to what extent the optimization of one goal variable limits the feasible range of another goal variable. We will concentrate on two specific trade-offs between goal variables.
The first trade-off is between the level of aggregate employment and the loss of nitrogen as an indicator for agricultural pollution of the environment. It is likely that low nitrogen losses match with a high level of aggregate employment. The reasoning is as follows. In section 2.2.1. it was pointed out that nitrogen losses are minimized with irrigated EOA or YOA. EOA is more labour intensive than YOA and also irrigated agriculture is more labour intensive than rain-fed agriculture. Notwithstanding a great deal of coherence between the two variables, there may be some amount of conflict between them and this is what a constrained optimization can reveal.
The second trade-off occurs between the level of aggregate cost and the loss of nitrogen. It is likely that conflicts exist between these two goal variables. EOA bears more costs than YOA and in general irrigated agriculture is more costly than rain-fed agriculture.

The trade-off between *employment and nitrogen loss* is shown over a range of aggregate employment. The limits of this range are determined as follows. First, maximal employment is determined when no restrictions on the other goal variables exist. Then minimal nitrogen loss is determined also without further restrictions being imposed. This minimal nitrogen loss is taken as a restriction (upper bound) on the goal variable of nitrogen loss in a subsequent maximisation of employment. Next, a series of restricted minimizations of nitrogen loss is carried out. The restriction is put on employment as a lower bound. The restrictions range from the restricted maximal employment value found in the third optimization to the unrestricted maximal employment found in the first optimization. It can be seen from figure 13 that the more the restriction on employment is tightened, the more nitrogen loss increases (units are billion working hours and million ton of nitrogen). The more the one goal variable reaches its unrestricted optimum, the less it becomes compatible with the other goal variable.

It must be observed that for the level of demand to which figure 13 relates, i.e. current consumption and free trade relations, minimal and maximal values in unrestricted optimizations are 1.55 and 4.74 million ton of N for nitrogen loss and 2.64 and 8.26 working hours for aggregate employment. It appears that the employment level deviates less from the unrestricted optimum than nitrogen loss does if the goal variable of aggregate employment is restricted. The size of the bubbles is related to the deviation of aggregate costs over the unrestricted minimum (113.7 billion ECU). It can be seen that all cost figures are in the same range (184.6 to 195.8 billion ECU) and lay significantly above the unrestricted minimum.

In the same spirit, the trade-off between aggregate costs and nitrogen loss is shown over a certain range of aggregate costs. The limits of this range are the minimal aggregate costs on the one hand and the minimal cost while nitrogen loss is restricted to its minimum on the other hand. In figure 14 the trade-off is given for the demand level that corresponds to a high level of food consumption and autarchy (units are billion ECU and million ton of nitrogen). Again we can see that the more the one goal variable reaches its unrestricted optimum the less it is compatible with the other goal variable. The difference with the former trade-off is that it now conforms to expectations.

Minimal and maximal unrestricted values of goal variables for the high demand level are 173.2 respectively 266.2 billion ECU for aggregate costs and 2.81 respectively 6.31 million ton N for nitrogen loss. Both maximal values will not be approached unless more goal variables are restricted.

The size of the bubbles is related to the deviation of employment from unrestricted maximal employment (9.19 billion working hours). Here, it will be seen that the level of aggregate employment goes down with rising nitrogen loss (the difference with unrestricted maximal employment becomes bigger). This sounds familiar since it has already been remarked that nitrogen loss can be restricted through labour intensive activities. Employment in figure 14 lays between 4.90 and 6.12 billion working hours. The value of 6.12 billion working hours relates to an optimum with absolute minimal nitrogen loss and the corresponding minimal costs. The 6.12 billion working hours are significantly below maximum. If the restriction of minimal costs were deleted, maximal working hours at absolute minimal nitrogen loss would come to 6.81 billion working hours, which is still significantly below the maximum of 9.19 billion working hours. In the first trade-off that was analyzed for the low demand case, maximal working hours under the most stringent nitrogen loss restriction were much closer to unrestricted maximal working hours. It appears that in the high demand case conflicts between these goal variables are more distinct than in the low demand case.

3.4 The rent of land

In a land-use model such as GOAL, it is possible to derive the factor reward for land. Basically there are two ways to derive the land rent. The first is to interpret the marginal values of the land balances as the factor reward for land. This interpretation makes sense because the other factor costs, labour and capital costs, are included in the cost function together with the intermediary costs. In this way, the land rent in a region equals the reduction in aggregate costs if more land in that region had been available. The second way is to derive Ricardian land rents as the difference between revenues and costs. In this case, the marginal values of the product balances are interpreted as product prices and regional revenues can be derived from them. In the second approach land rents are derived as a difference to marginal production costs. A difference between both methods is also that the first relates to the rent of available land and the second relates to the rent of used land. Of course all land available in a region is used in many cases.

GOAL distinguishes between several qualities of land for each of which a land-use balance has been defined. Some of these balances may become restrictive and provide a marginal value, while other balances in the same region will not become restrictive. The use of marginal values of land-use balances to represent land rents will therefore provide a heterogeneous and incomplete picture that is not an ideal basis for interregional comparison. For this reason, the regional land rents that are derived in the second way, by making use of marginal product costs, are shown. These land rents are irrespective of the land qualities distinguished in GOAL.

To derive a Ricardian land rent, the difference between revenues and costs in a region is taken. In the cost variable, all factor costs except for the costs of land are included. Also the costs of intermediary products, e.g. animal feedings, from outside the region are included in the cost total. The revenues are composed of the value of intermediary products produced in the region and the value of final products provided their production is explicitly linked to the region. In figures 15 and 16 the land rents thus derived are represented for the low demand and the high demand variant respectively in an unrestricted cost minimization.

Both figures combine a box plot with a mapping of the 58 regions. The box gives the interquartile range of the land rents derived for the regions. The central vertical line gives the median. The lines to the left and the right of the box indicate the value range outside the box of values that are not greater than one and a halve times the interquartile range. Asterisks and empty circles indicate typical outliers.

In the map, the values of lambda are given. The lambda of a region is defined as a value between zero and one that gives the position of the land rent of a region between the lowest and the highest land rent in the set of regions as shown in the box plot as follows:

$$\mathit{land\ rent}_{reg} = (1 - \lambda) \times \min_{reg} \mathit{land\ rent}_{reg} + \lambda \times \max_{reg} \mathit{land\ rent}_{reg}$$

It is not surprising that the derived land rents are incomparable to present-day land rents. The assumptions made in GOAL are not reflected in the present-day agricultural situation of the Community.
Land rents are generally higher in the high demand variant (figure 16) than in the low demand variant (figure 15). This reflects the scarcity of

land. In the high demand variant, the costs of submarginal production are higher than in the low demand variant. It is remarkable that in some regions land rents are quite high, for instance Rheinland-Pfalz and Sicilia in the low demand variant and Scotland and Sicilia in the high demand variant. Land rents in Sicilia are high in both variants because of the allocation of permanent crops. In the low demand variant, a high stocking rate in Rheinland-Pfalz forces land rents up. In the high demand variant, the high land rents in Scotland must be attributed to high yielding arable farming.

3.5 Concluding remarks

In this section several characteristics of the GOAL model have been presented. It was shown how the GOAL model allows for several substitution effects. An illustration was given of the trade-off between several goal variables. The information given in this section should enable the reader to get a better understanding of the land-use scenarios that have been constructed by means of the GOAL model. The scenarios themselves have been presented in the Councils Report to the Government[7].

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7 WRR, Ground for choices. Four perspectives for the rural areas in the European Community; Reports to the government nr. 42, 's-Gravenhage, Staatsuitgeverij, 1992.

Figure 1

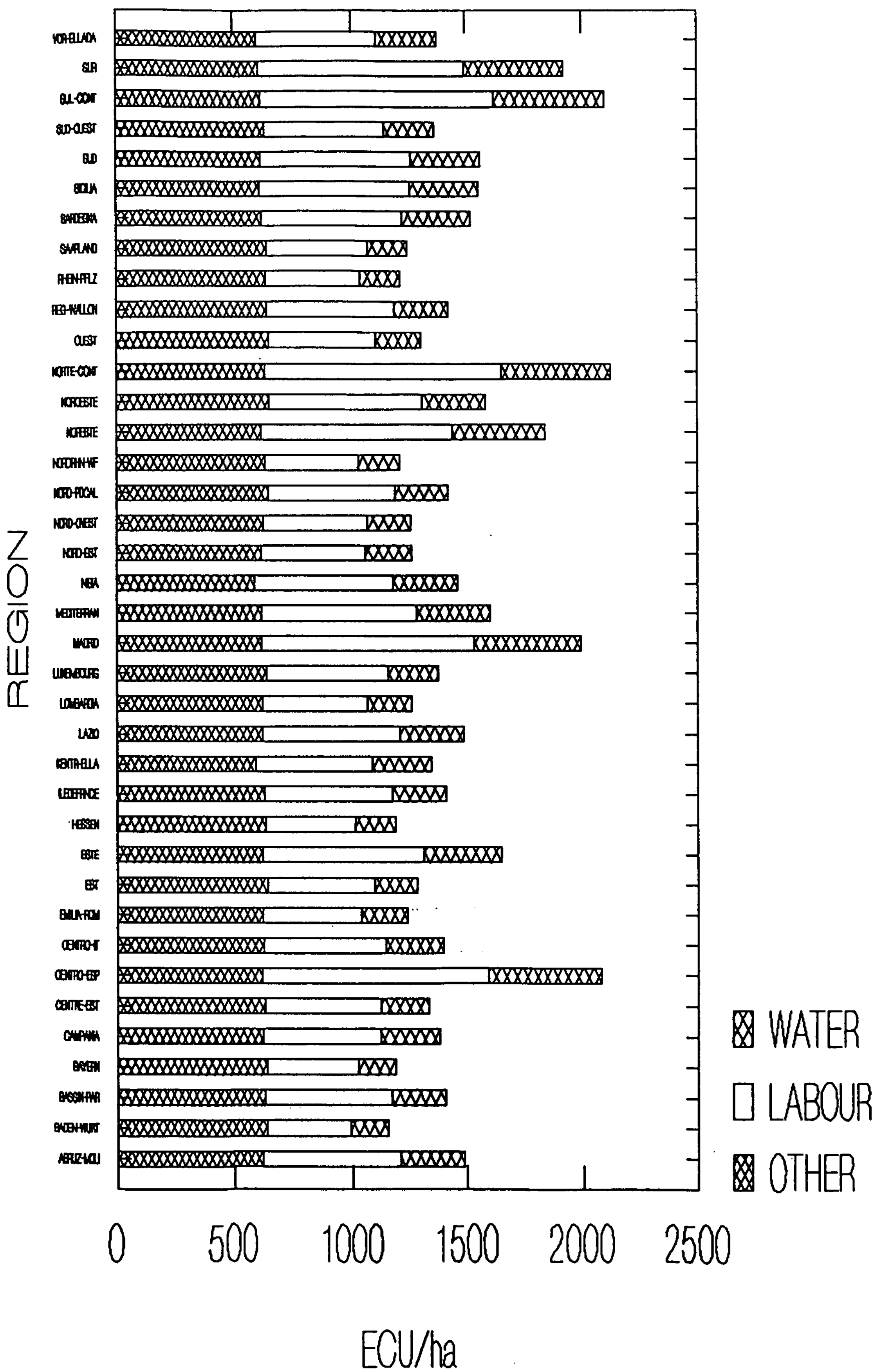


Figure 2

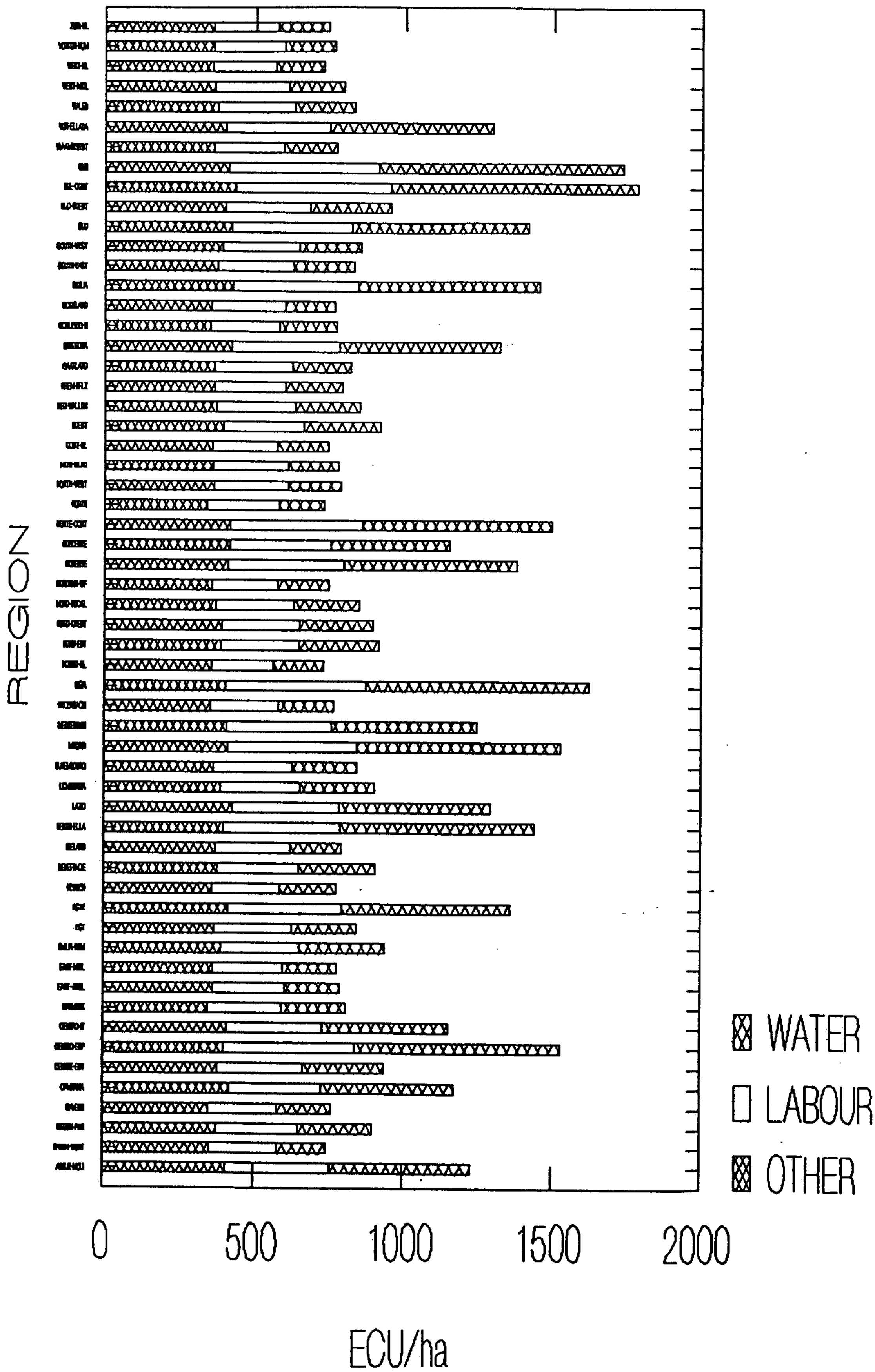
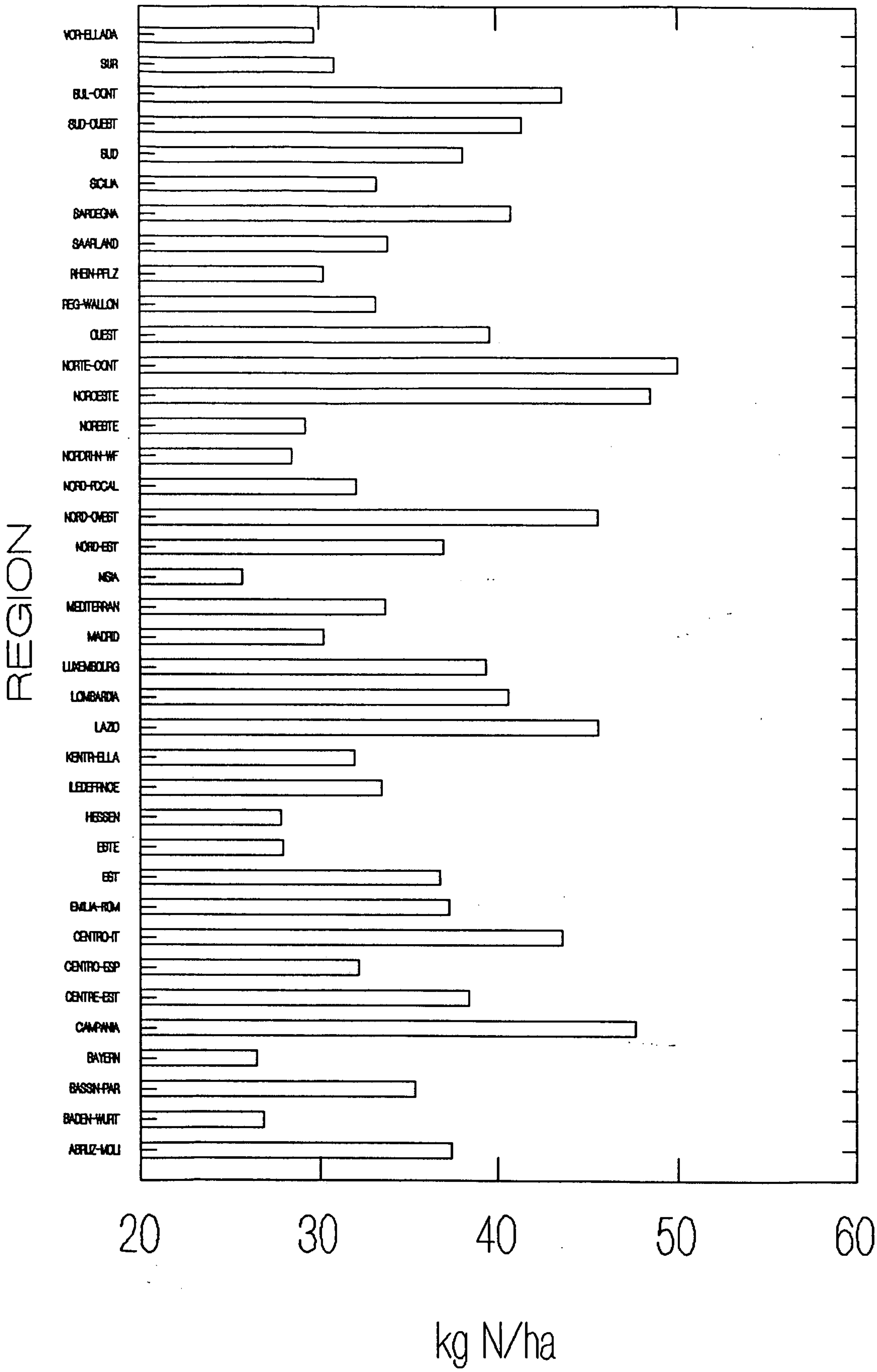


Figure 3



VOR-ELLADA
SUR
BUL-CONT
SUD-OUEST
SUD
SICILIA
SARDEGNA
SAARLAND
RHEIN-PFLZ
REG-WALLON
OUEST
NORTE-CONT
NOROESTE
NORESTE
NORDRHN-WF
NORD-PDCAL
NORD-OVEST
NORD-EST
NISIA
MEDITERRAN
MADRID
LUXEMBOURG
LOMBARDIA
LAZIO
KENTR-ELLA
ILEDEFRNCE
HESSEN
ESTE
EST
EMILIA-ROM
CENTRO-IT
CENTRO-ESP
CENTRE-EST
CAMPANIA
BAYERN
BASSN-PAR
BADEN-WURT
ABRUZ-MOLI
REGION
20
30
40
50
60
kg N/ha

Figure 4

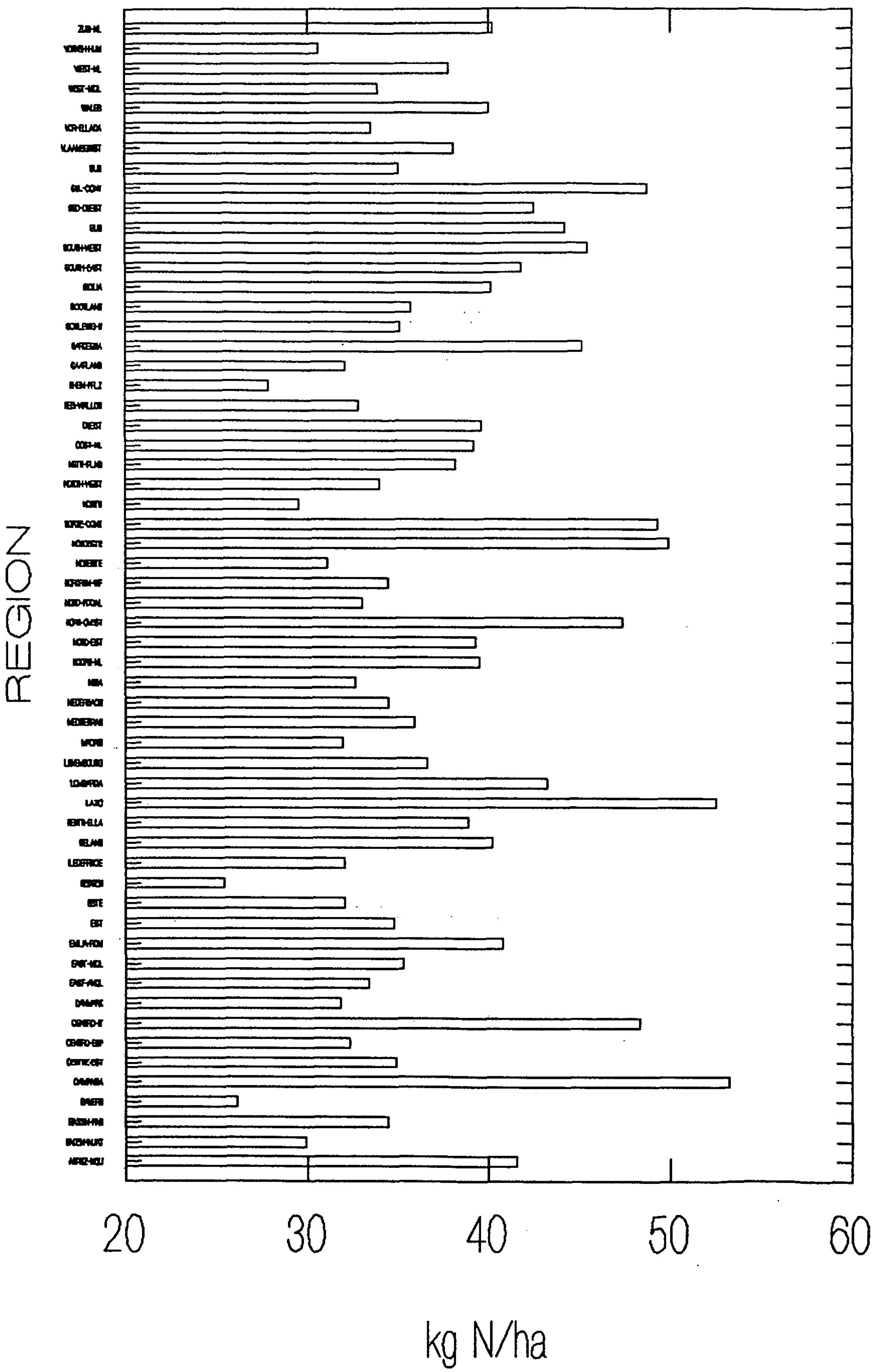


Figure 5

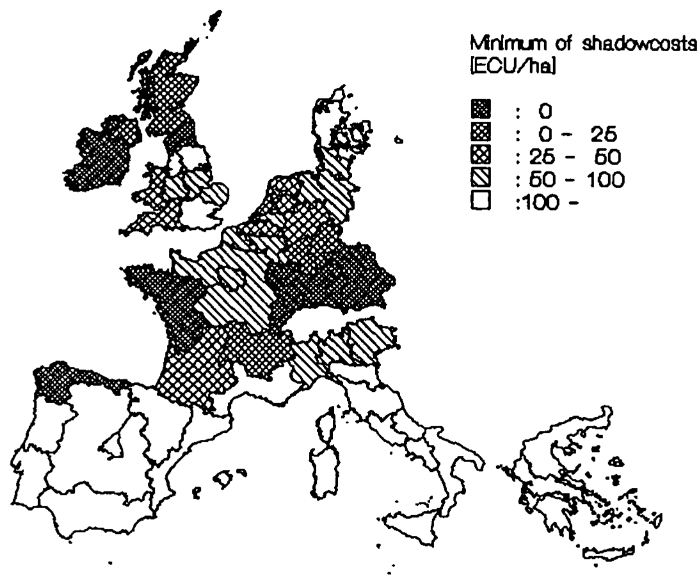


Figure 6

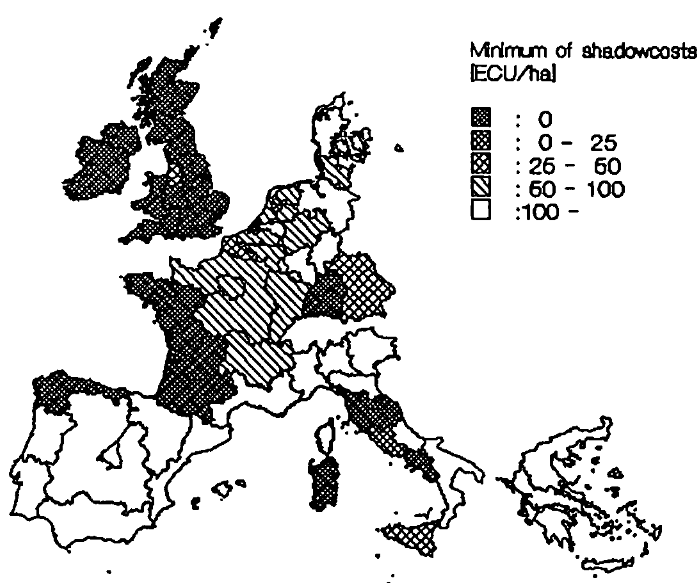
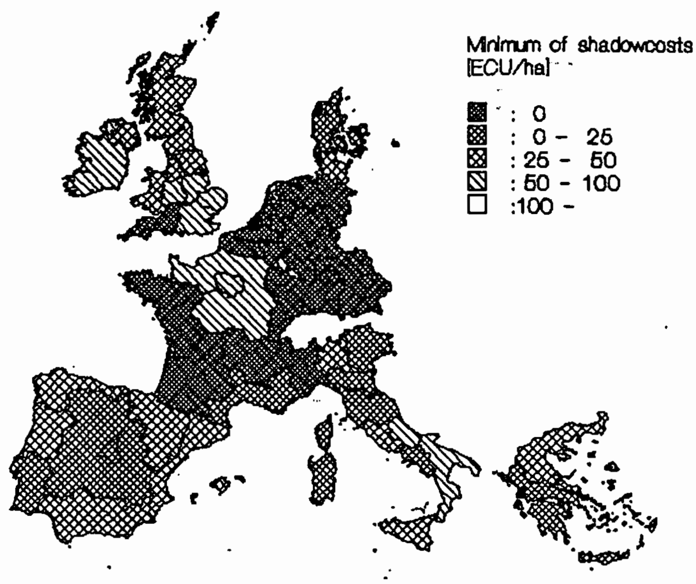


Figure 7



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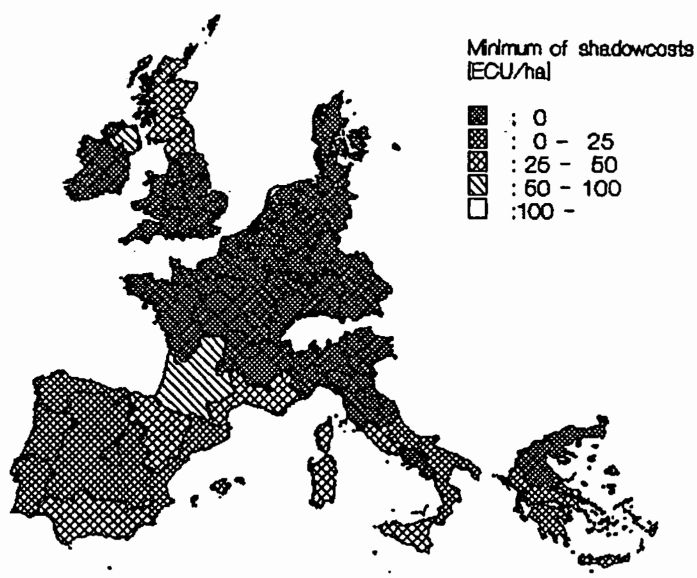


Figure 9

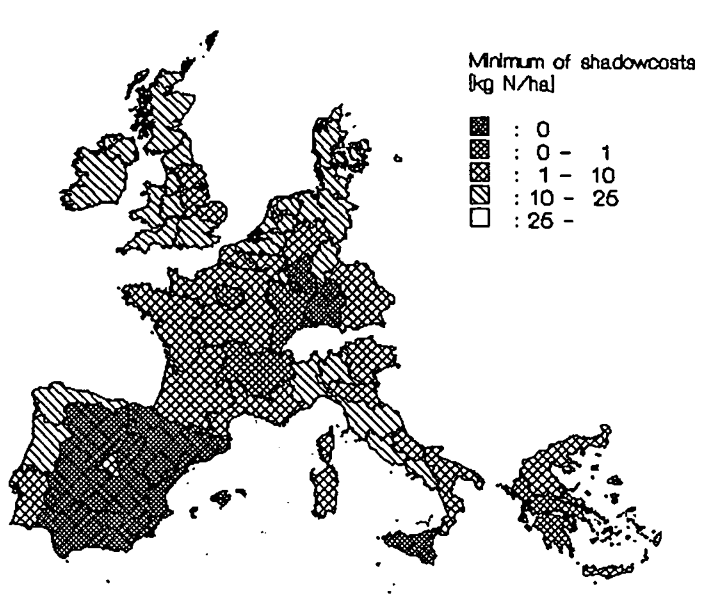


Figure 10

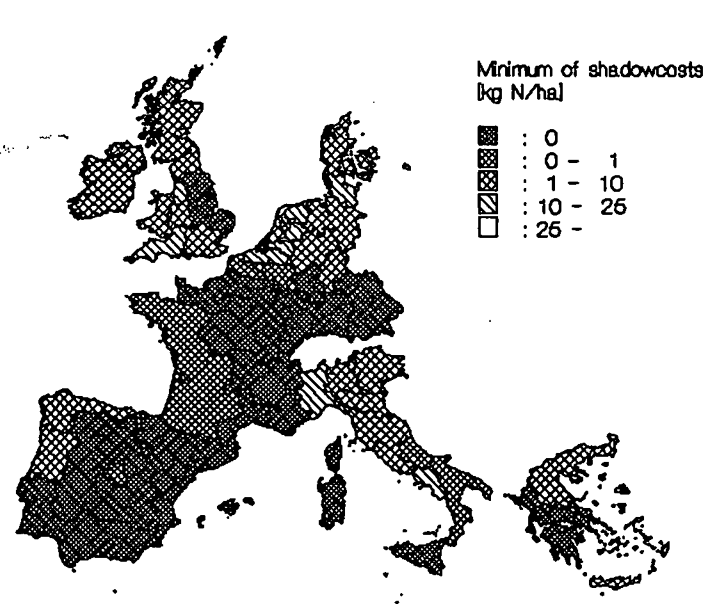


Figure 11

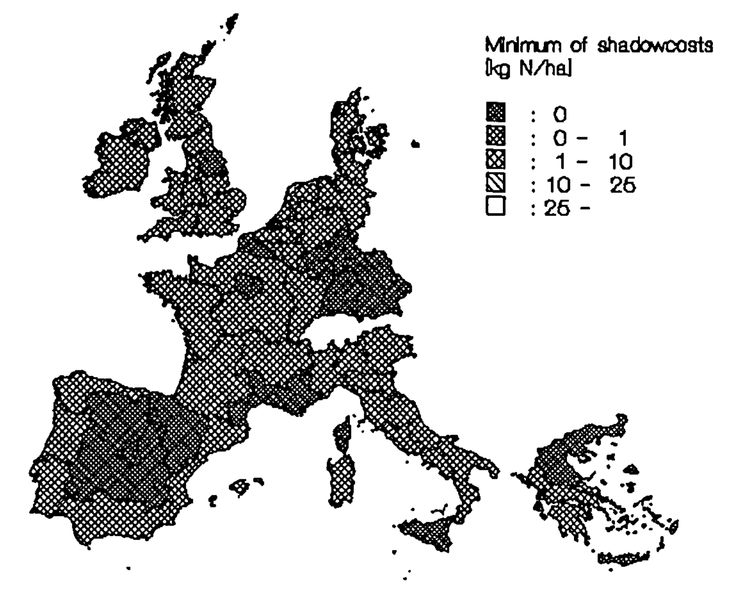


Figure 12

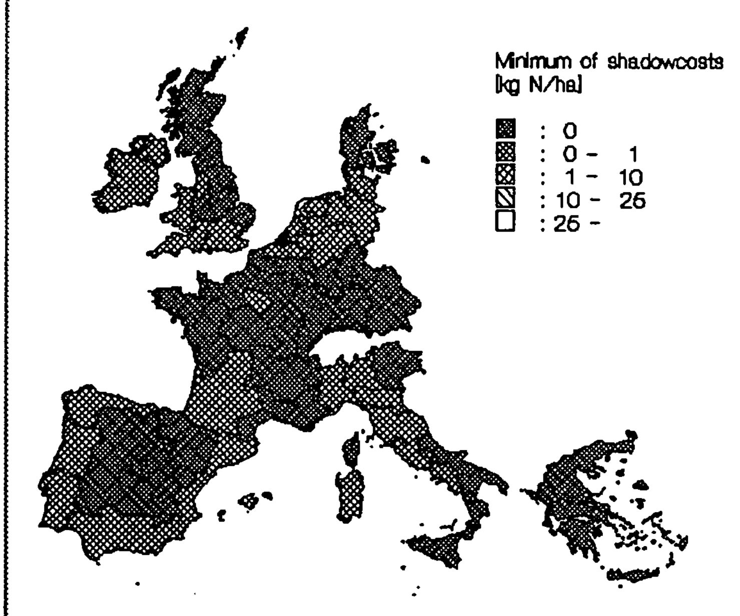


Figure 13

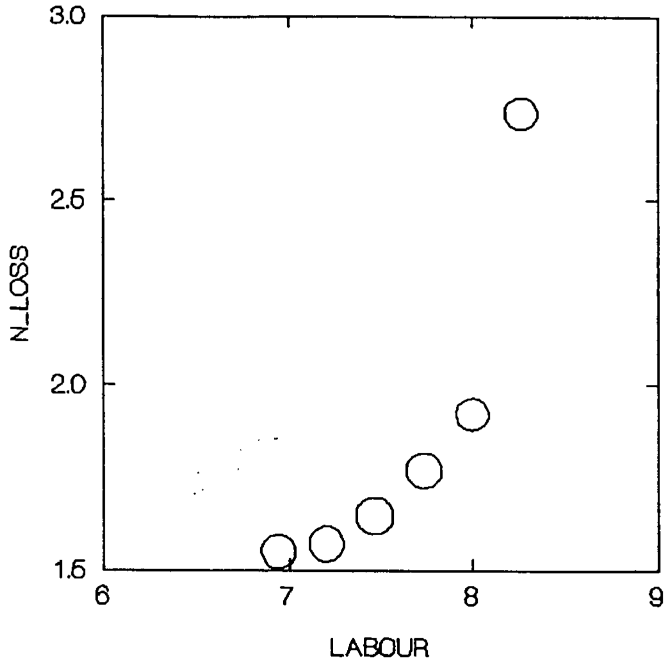


Figure 14

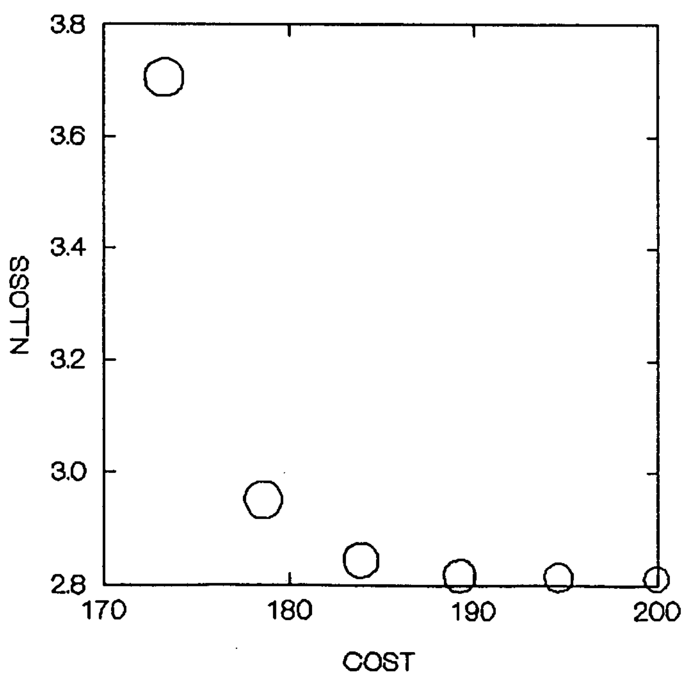


Figure 15

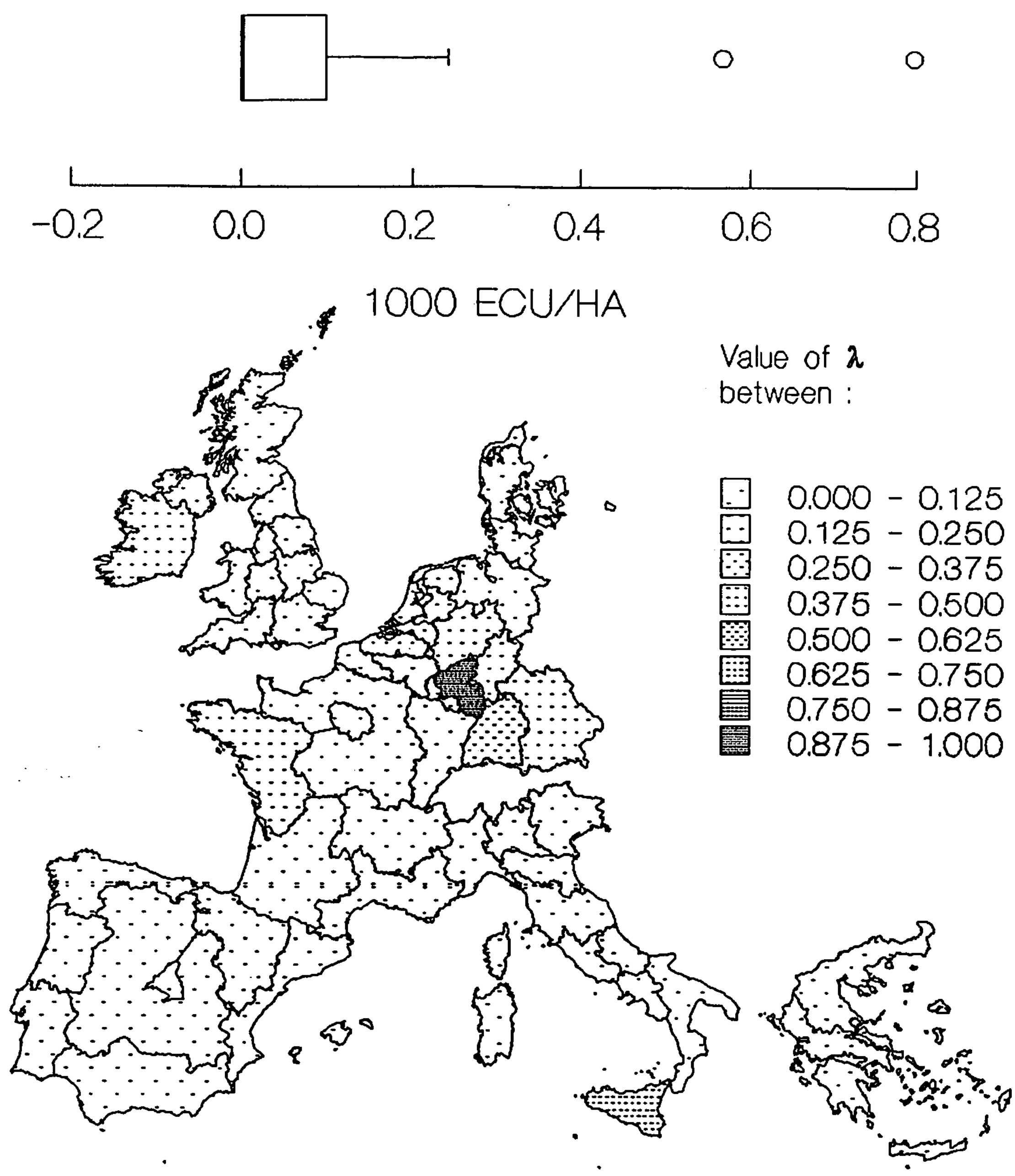
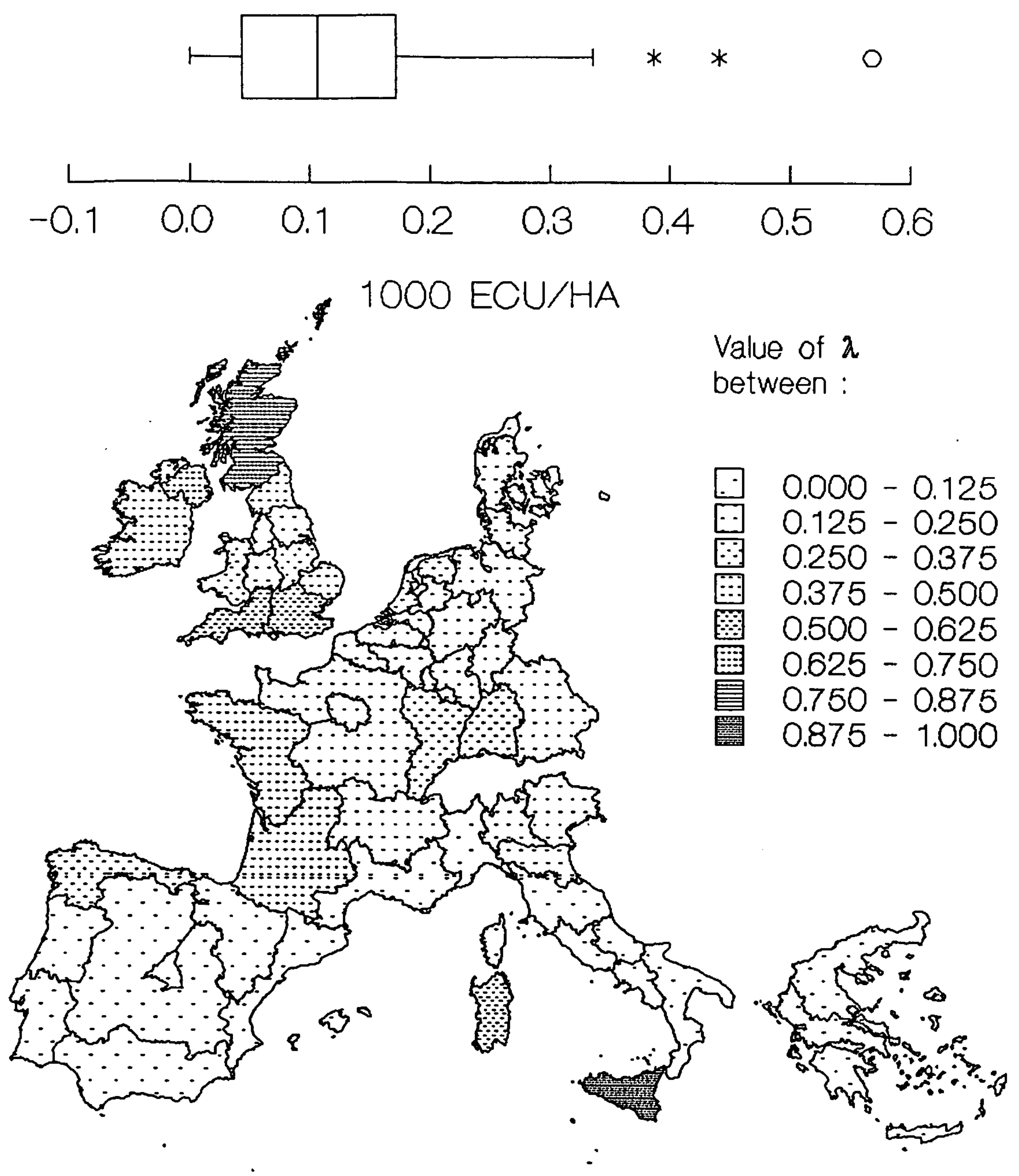

-0.2
0.0
0.2
0.4
0.6
0.8
1000 ECU/HA
Value of λ
between :
0.000 - 0.125
0.125 - 0.250
0.250 - 0.375
0.375 - 0.500
0.500 - 0.625
0.625 - 0.750
0.750 - 0.875
0.875 - 1.000

Figure 16


-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
1000 ECU/HA
Value of λ
between :
0.000 - 0.125
0.125 - 0.250
0.250 - 0.375
0.375 - 0.500
0.500 - 0.625
0.625 - 0.750
0.750 - 0.875
0.875 - 1.000