



The University of Reading



Modelling the impact of different policy scenarios on farm business management, land use and rural employment

P. J. Jones and R. B. Tranter

**Project Document No. 13
Workpackage No. 5, Report No. 02
June, 2007**



Implications of a Nutrition Driven Food Policy for Land Use and the Rural Environment

CONTENTS

1.	The Land Use Allocation Model	2
1.1	Introduction	2
1.2	Overview	2
1.3	Model Structure	3
1.4	Enterprise data (input/output coefficients)	8
1.5	Livestock stocking rates	9
1.6	Intermediate products	9
1.7	Purchased feeds	10
1.8	Rotations	10
1.9	Calibration of model data	10
2.	Revisions to the LUAM	13
2.1	Introduction	13
2.2	Software platform	14
2.3	Model structure	14
2.4	Enterprise and restraint data	15
2.5	Policy	16
3.	Scenario runs	17
3.1	Data requirements	17
3.2	Technology change	17
3.3	Price change	17
3.4	Demand and supply change	18
4.	Results	19
4.1	Output volumes	19
4.2	Regional production	21
4.3	Farm labour	30
4.4	Financial performance	31
5.	Discussion and conclusions	32
Appendix A	The CEH land classification system	35
Appendix B	LUAM data sources	38
Appendix C	The key provisions of the Fischler reforms of the CAP	40
Appendix D	Improving the spatial resolution of LUAM output	46
Appendix E	Scenario 1: data sources and methodology	50

1. THE LAND USE ALLOCATION MODEL

1.1 Introduction

The purpose of WP5 is to test the impact of different policy scenarios and new agricultural technologies, *via* consumer attitudes to those technologies, on land use and production in England and Wales. As a means to achieving this objective it was proposed, in Task 2 of Work Package 5, to use a spatially explicit model of agriculture in England and Wales to identify the land use implications of new policies and technologies, together with their associated economic and farm employment impacts. The outputs of the modelling exercise would then be used to drive an examination of the wider rural employment implications of the scenarios, plus predict their likely impacts on landscape and biodiversity. For this purpose, it was proposed to use a pre-existing model of England and Wales Agriculture, known as the Land Use Allocation Model (LUAM), subject to its being brought up to date with recent technological developments and the latest market and policy conditions. This document reports on the LUAM modelling exercise, beginning with a description of the model, then providing an account of both the updating of the model and the running of it on a set of policy scenarios.

1.2 Overview

The LUAM model represents the agricultural system in England and Wales as if it were a single ‘farm’. This ‘farm’ employs a variety of different production ‘activities’ to produce various agricultural products while using a range of different inputs (chemical, fertilisers etc.) and resources (labour and different types of land). In producing these outputs the model uses resources (land and labour), which can potentially also be used for non-agricultural rural enterprises such as recreation and forestry, or for ‘new’ crops not currently grown. The LUAM is a comparative static model, reflecting only annual agricultural enterprises or an annual average of longer-cycle enterprises, such as dairy animals or permanent horticultural crops.

The model allocates different types of land to different activities subject to specific constraints, some or all of which might be binding under given scenarios:

- (i) constraints on the availability of land and labour and the capacity to switch these resources between different uses;

- (ii) constraints on the total amount of production and input use which can be produced or used by the agricultural system, reflecting the demands for the products and the supplies of the inputs;
- (iii) policy constraints which restrict production activities or land utilisation patterns in certain areas to conform to environmental objectives.

Within these constraints, land utilisation is modelled according to the net economic margins which can be earned by the various activities. These margins are generated from the sale of enterprise outputs, less the cost of the inputs and resources required to produce them. The ‘net margins’ reflected in the model are thus measures of returns to land, management and capital, with both self-employed and hired labour costs being accounted for in the model structure.

Each activity contributes to the total net margin of the model as a whole. This overall margin is known, in modelling terminology, as the ‘Objective Function’. The model is required to maximise this value.

1.3 Model structure

The mathematical structure of the LUAM is that of an ordinary LP model, that is:

Maximize: $Z = cx$

subject to: $Ax \leq b$

$x \geq 0$

where Z is the objective function given as the scalar product of c and x vectors, b is the resource endowment and input availability vector, c is the vector whose elements are returns and costs, and x is the output vector. A is the matrix of input/output coefficients (a_{ij}) representing the amount of input i required per unit of output (j).

Within each Land Class a variety of production activities and associated inputs are available (see Table 1).

Table 1. List of activities and associated inputs available in each Land Class

Inputs	Enterprises/activities
Labour regular	Dairy
Labour casual/seasonal	Beef
Fertiliser	Sheep
Machinery	Wheat
Cattle feeds	Barley
Crop miscellaneous	Oats
Crop protection	Mixed cereals
General miscellaneous costs	Peas/beans (for stockfeed)
Farm maintenance	Sugar beet
Coarse fodder	Potatoes
	Oilseeds
	Field-scale vegetables
	Top fruit
	Soft fruit
	Set-aside (compulsory)

Pig and poultry activities are excluded from the model because, at present, they are not major users of land.

The list of enterprises has been deliberately restricted to prevent the model from becoming excessively large. This fact, of course, is a limitation, but not a major one however, as the enterprises included account for most of the agricultural land use in England and Wales. It is also worth pointing out that other enterprises can be added at will if specific scenarios require them and modelling work has in the past included such land uses as farm forestry, flax, sunflowers, voluntary set-aside and even non-agricultural activities such as caravan parks and farm-based recreation and tourism.

Altogether, the model considers over 210 agricultural production activities which ‘contribute’ to and ‘draw upon’ the England and Wales outputs and input use as reflected in national published statistics. Thus, the aggregate output and the input quantities and resources needed to produce it are specified as ‘balance equations’ which ‘close’ the model. This means that a given volume of output must be produced, but it is up to the model to distribute production over the various Land Classes. Thus, for example, for cereals output, this relationship becomes:

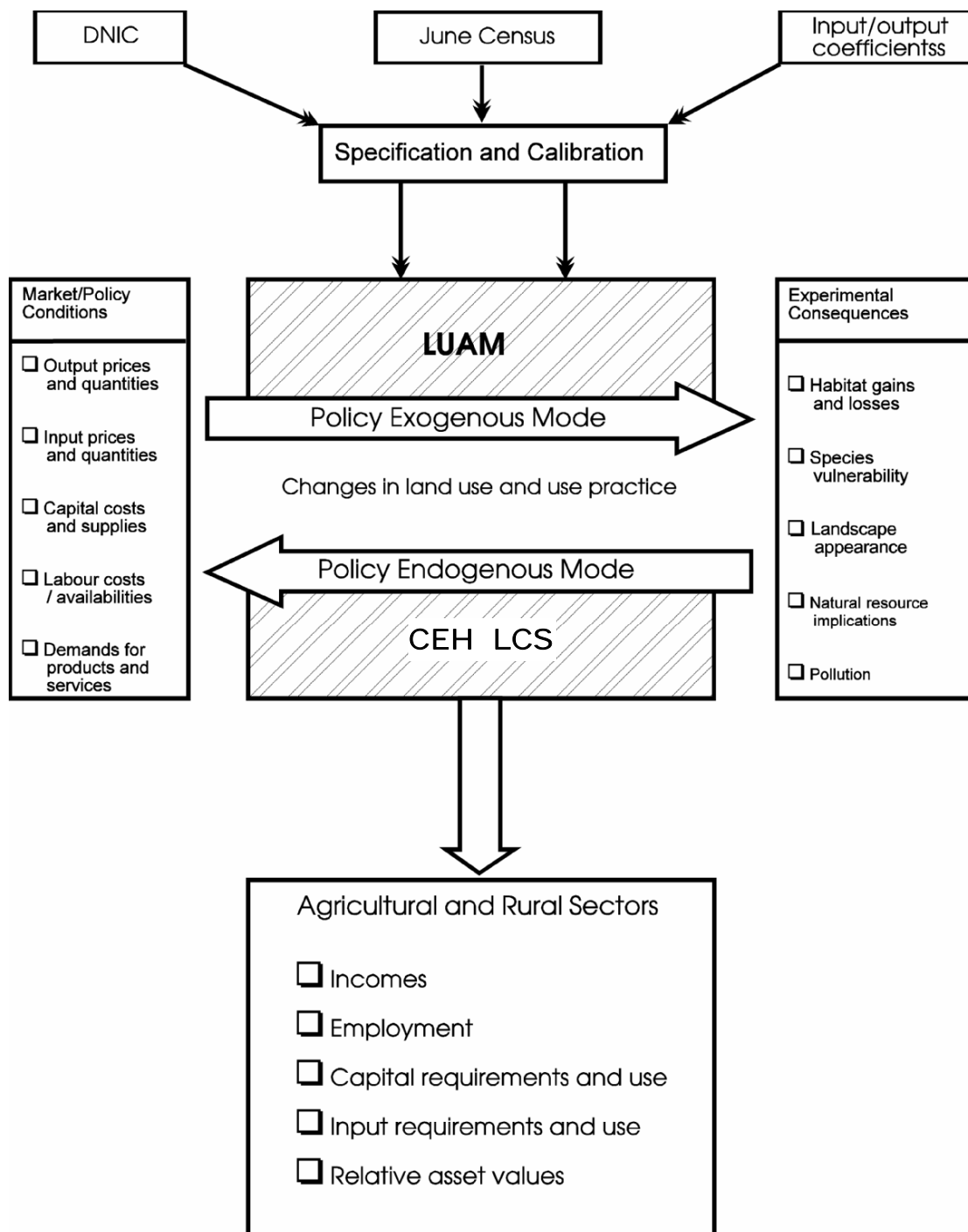
$$\sum_{k=1}^{15} a_{ck} \cdot x_k = C$$

Each of these land using activities has associated with it specific requirements for inputs and resources and specific output levels. Except for land, these are specified in terms of their monetary equivalents, implying particular physical volumes and prices per unit of output or input. Agriculture in England and Wales is carried out at the ‘average’ production intensity observed in practice, where intensity is defined in terms of input use per ha. Stocking rates are set endogenously within certain limits set by cross-compliance conditions. More will be said of this later.

Figure 1 illustrates the various components of the model framework. The top line of the figure shows the Defra Departmental Net Income Calculation (DNIC) and the Defra June Agricultural Census data. The DNIC is essentially the agricultural sector’s GDP calculation and provides estimates of national outputs, inputs and resource use in value terms¹. The June Census provides data annually, from all farms, on the areas under various land uses together with livestock numbers. The DNIC and June Census data are treated as the ‘ground truth’, against which the model is reconciled (see Section 1.9 on ‘calibration’ below). Also, on the top line of Figure 1, is indicated a requirement for input/output coefficients. These are derived from the Farm Business Survey (FBS) and other published farm management sources (see Appendix B). These input-output relationships reflect the average practice on the farms in each Land Class and to that extent are as accurate a reflection of present practice as can be obtained from existing information (for more information, see Section 1.4).

¹ As DNIC data are not published for England and Wales separately from the UK, Defra kindly produced this specifically for the project.

Figure 1. A Schematic representation of the LUAM



The central part of Figure 1 represents the two components of the modelling framework - the LUAM and the CEH LCS (Land Classification System). The LCS is a structured representation of the geographical, ecological and environmental characteristics of the land base of agriculture in England and Wales. The LUAM is itself a simulation model which projects land use and use practice, on the basis of

economic and policy conditions, and the LCS reflects the land base in the model. Further details on the LCS are provided in Appendix A. The LCS distinguishes 28 classes of land in England and Wales and these are combined into 15 Land Class categories in the model. Within each model Land Class, three major land types are distinguished: arable/ley, permanent pasture and rough grazing. Leys (temporary grass) are sown grasses under 5 years old and are almost entirely part of the arable rotation; therefore, no distinction is drawn between these two types of land in terms of their permitted uses and transfer between the two do not incur any cost. The availability of any type of land in the model is limited to the areas observed in the reference year. Land cannot transfer from one type to another within a Land Class, neither from one Land Class to another.

The left and right wings of Figure 1 show the major environmental and market/policy inputs and outputs to the modelling exercise. As reflected by the ‘policy endogenous’ and ‘policy exogenous’ arrows, the model can be run in two directions. In the ‘policy exogenous’ case the effects of alterations in market and policy conditions can be input, in which case the land use and use practice effects imply changes in the natural habitat. In the ‘policy endogenous’ mode of operation, particular characteristics required for the natural environment can be specified as inputs, in which case the implications for agricultural and other rural activity returns are determined by the model, which in comparison with the base situation, defines the penalties and incentives necessary to achieve the particular environment specified.

In either mode of operation, the model generates estimates of incomes and returns to rural resources (land and management) and associated use of labour, which can then be incorporated into regional economic and social analysis, as illustrated at the bottom of Figure 1. Since the model is constructed on the basis of 15 Land Classes and since these are defined on a 1 km Ordnance Survey (OS) grid basis, the results can be aggregated to any desired regional specification, providing that the regional specification can also be referenced in these terms. However, the resolution of the model structure is such that the degree of approximation increases as the level of aggregation is reduced.

1.4 Enterprise data (input/output coefficients)

The model requires data on the output values generated by enterprises in each Land Class, i.e. produce prices and enterprise yields, and their associated input costs and level of resource use. These ‘production relationships’ have been derived from the FBS data set and other published farm management sources, such as Nix Pocketbook and a number of Defra data sources (see Appendix B).

1.4.1 Enterprise yields

Enterprise yields were derived from the FBS dataset for the year 2004. This was the most recent year for which FBS data were available at the time of model construction. As FBS farms could not be directly identified with CEH Land Classes, in order to preserve the confidentiality of the farms in the sample, an indirect approach had to be employed to derive enterprise yield estimates from the FBS on a Land Class basis. This was achieved by generating yield estimates on the basis of Government Office Region and then a set of coefficients was used to redistribute these yield values to CEH Land Classes. These coefficients were based on the percentage share of each GOR, belonging to each Land Class.

Crops

Crop yields were estimated on a tonnes per hectare basis and converted to an output value in the model by multiplying by the relevant product price, where prices were derived from published data.

Livestock

Each unit of the three grazing livestock types is represented in the model on a Livestock Unit (LSU) basis rather than 1 head of a particular livestock type. No distinction is made between different types of animal within a breed, therefore these LSUs are composites, representing not only more than one animal, but more than one class of animal, depending upon the mix of animals found within a breed in the national herd/flock. Accordingly, the yields associated with each LSU reflect the mix of animals on which it is based.

Dairy (milk) yield

From the FBS data, total milk output (litres/herd/year) were divided by total LSU per herd to derive a milk yield per average dairy LSU. These yields were converted to output values in the model by multiplying by appropriate prices.

Beef and sheep yield

These two livestock enterprises generate a very varied range of outputs depending on the class and age of animal sold. Consequently it was not possible to generate a consistent physical measure of yield from the FBS data. Therefore, the value of all outputs was derived on a per LSU basis. A similar method was adopted for the beef output component from the dairy enterprise, which was expressed as average beef output value per dairy LSU.

1.5 Livestock stocking rates

The grazing livestock activities are not constrained, exogenously, to operate at fixed stocking rates. Rather, stocking rates are determined endogenously. Each source of livestock feed: grasses of three kinds, fodder crops and purchased feeds, contributes to the ME requirements of livestock and the model is at liberty to vary the contribution of each of these sources on an enterprise by enterprise basis. Effectively, the greater the contribution of purchased feeds, the higher the stocking rate. Purchased feeds are an amalgam of concentrates and coarse fodder.

There is an upper constraint on stocking rates, set at 2 LSU/ha, reflecting the enforcement of cross-compliance conditions designed to prevent overgrazing. A minimum stocking density of 0.5 LSU/ha is also enforced, to prevent under-grazing, again consistent with cross-compliance requirements to maintain grassland in good agricultural condition.

1.6 Intermediate products

The LUAM does not separately identify intermediate products, therefore feed crops, except grass, are 'traded' items. For instance, feeding barley, even if home-grown for animal feed, is 'sold' and then 'bought' for feeding. However, the output of the fodder crops activity are not sold off the farm, but provide ME availability for livestock enterprises.

1.7 Purchased feeds

For the purposes of simplification, purchased feeds are limited to concentrates (based on cereals, fish meal, soya, etc.). Coarse fodder (i.e. various kinds of conserved grasses and some fodder crops) are assumed to be produced on the farm. Purchased feeds are priced in the objective function at values prevailing in the reference year.

1.8 Rotations

The model includes constraints on the relative proportions of cereals and oilseeds to break crops (e.g. root vegetables, peas and beans, leys, etc.), reflecting rotational practice. These proportions are derived from actual practice observed in the UK FBS data for the reference year.

1.9 Calibration of model data

The LUAM is ‘grounded’ in reality at a given point in time, in this case 2004, by means of calibration processes. Calibration ensures that the parameters of the model are consistent with the observed data on livestock numbers and crop/grass areas from the Defra June Census and also with the estimates of total outputs and input use recorded in the DNIC. This means that subsequent policy runs of the model can be compared with a recognisable base position, which is important for both validation and scenario testing. Calibration was carried out in five stages:-

- (i) calibration of the LCS estimates of arable and grass areas;
- (ii) calibration of livestock numbers;
- (iii) calibration of enterprise yields, i.e. outputs per hectare and per LSU;
- (iv) calibration of input costs per hectare and LSU;
- (v) calibration of grassland yields.

1.9.1 Calibration of the LCS estimates of arable and grass areas

CEH estimates of the areas of arable enterprises and grasses in each Land Class were adjusted to equate with Defra June Census estimates at the national level while preserving the proportionality between Land Classes. In the model, the total available area of arable land in any Land Class is defined as the sum of the calibrated areas of the 11 arable enterprises present in the LUAM in 2004. The areas of the three grassland types recorded in the LCS are not calibrated to equate with the June Census, as the June Census classifies leys and permanent pasture in a different way to the

LCS. In the LCS, leys and permanent pasture are classified on the basis of species composition. In the June Census they are classified according to age since sowing, with grasses <5 years designated as leys. As species composition is likely to be a better indicator of productivity than age, the LCS designation is preferred.

1.9.2 Calibration of enterprise yields (expressed as outputs per ha and per LSU)

The enterprise output values per hectare and per LSU used in the model were derived from the FBS sample. As the FBS does not capture very small farms, it may, therefore, not be wholly representative of the population of farms in England or Wales. For this reason it was necessary to adjust the enterprise yields to ensure that they were simultaneously consistent with:-

- (i) the total crop and grass areas and livestock numbers recorded in the June Census in 2004; and
- (ii) the total values of the various outputs as reported in the DNIC in 2004.

Crops

The calibration procedure for crop output values was a straightforward one. Output values per hectare were multiplied by the calibrated areas of the appropriate crops on a Land Class basis. The resulting aggregate estimate of national output was then compared with the equivalent DNIC figure for total output. Any discrepancy between the two estimates was then used to adjust the coefficients for output per hectare in each Land Class on a uniform basis. The calibrated output values are thus consistent with the June Census and DNIC output levels. In effect, this procedure treats the June Census and DNIC data as ‘the truth’ and adjusts the estimated output coefficients from the FBS to preserve these truths in the model. This calibration procedure was spreadsheet based and external to the model. The calibration of livestock outputs and all inputs reported below involved running the model under conditions of tight constraints. These are known as ‘calibration runs’.

Livestock

The calibration of livestock output values was complicated by the fact that a significant part of total beef production derives from the dairy herd, while the output associated with the dairy enterprise in the DNIC data relates solely to milk and milk products.

To calibrate livestock outputs the model was run, while constrained at the national level to produce exactly the number of each type of livestock observed in 2004. The aggregate national output values generated for milk, beef and sheep were then compared with equivalent national data derived from the DNIC. Any differences between the two were used to generate calibration coefficients to adjust the livestock output values per LSU, such that DNIC output values for 2004 could be generated using June Census estimates of livestock numbers. In the case of the beef outputs the value of dairy beef was added in to the output of the beef activity before comparison with the DNIC data. Calibration coefficients were applied across Land Classes uniformly, thus preserving the FBS-derived land class differences.

1.9.3 Calibration of input costs per ha

Input costs were calibrated by means of a 'calibration run' of the model. The model was run under rigid restraint to mirror, as closely as possible, observed conditions in 2004 in terms of crop areas, livestock numbers, output produced etc. The inputs used by the model in the calibration run were then compared with the input use recorded by the DNIC. Direct comparisons were not possible for all inputs because of differences in definition between DNIC and FBS, but a reasonable correspondence was achieved in most cases. Differences between the model estimate and the DNIC were used to adjust model input use. Use of inputs by each enterprise were adjusted uniformly as no assumptions could be made about which enterprises might over or under-represent use of particular inputs.

1.9.4 Calibration of grassland yields

Grassland yields are estimated and calibrated in the following way:

- (i) The total annual metabolizable energy (ME) requirement, in MJ, of all animals in the calibration run model is calculated (these animal numbers having been calibrated to exactly match the number of animals recorded in the June Agricultural Census). All animals are represented as LSUs and thus each have the equivalent ME requirement of a single dairy cow (published data provide the ME requirement of dairy cows).

- (ii) A national metabolizable energy availability is estimated. This is achieved by applying published ME² values (Soffe, 1995³; MAFF, 1984⁴) to the calibrated areas of each type of grassland and fodder crops. Added to this total is an estimate of the ME available from purchased concentrate feeds, where the calibration run is constrained to use the volume reported in the DNIC for 2004.
- (iii) The national calibration run ME requirement is then compared to the calibration run ME availability and the difference between the two is used to calibrate the grassland and fodder crop yields such that the calibration model ME requirement and availability balances.

2. REVISIONS TO THE LUAM

2.1 Introduction

While the LUAM pre-existed this particular study and had in the past been regularly used in policy analysis exercises on behalf of policy makers and private sector organisations⁵, the model had not been recently used and, therefore, required a number of revisions to make it suitable for the current exercise. Revisions were required in the following areas:

- (i) software platform;
- (ii) model structure;
- (iii) enterprise and restraint data;
- (iv) policy and market data.

² The purpose of these calculations is simply to convert the various sources of nutrition available to farmers into a 'common currency' to permit substitution between them. ME proved a convenient measure for this purpose, from among a number of alternatives that might have been used.

³ Soffe, R.J. 1995 (ed). *The Agricultural Notebook*. Blackwell Science, Oxford.

⁴ MAFF, 1984. Reference Book 433. *Energy Allowances and Feeding Systems for Ruminants*.

⁵ Jones, P.J., Rehman, T., Hallam, D. and Little, G.P.J. 1998. *Investigating the impacts of the Agenda 2000 CAP reform proposals using the Land Use Allocation Model (LUAM)*. A report to the Ministry of Agriculture Fisheries & Food. Centre for Agricultural Strategy, University of Reading, Reading; and Jones, P.J., and Little, G.P.J. 1998. *Modelling the impacts of the revised Agenda 2000 CAP reform proposals on Agriculture in Wales*. A report to the Welsh Office. Centre for Agricultural Strategy, University of Reading, Reading.

2.2 Software platform

The extant LUAM has been run using a number of LP software applications, most recently XPRESS by Dash Associates. In recent years, GAMS has become the industry standard in many countries, offering new solvers and increased functionality advantages over earlier packages. It was felt that the modelling would benefit from migration to GAMS, in part, by making the model code accessible to other modellers for peer review. As a first step, therefore, the model was rebuilt in GAMS.

2.3 Model structure

The purpose of this modelling exercise was not model development and so the model structure remained largely unchanged from the existing version. However, one particular refinement was made to improve the performance of the model over earlier versions.

A number of factors determine the extent of production of enterprises and their persistence through time. The primary factor is, of course, the profit that can be gained from producing them which is a function of the yield of enterprises, the costs of production and the prices that can be obtained. The existing model already captured these factors. However, there are other determinants of land use decisions, such as the presence in the region of production and marketing infrastructure, levels of skills and expertise, capital endowments, tradition and inertia, and complementarities with the production of other enterprises. Without attempting to explain the relative importance of these drivers and restraints, or even measuring them, the revised model employs a set of weights to capture the effects of these other drivers on past land use decisions and applies them to future production decisions.

The revised LUAM is, therefore, a multi-objective programming (MOP) model, whereby the model selects a production mix based upon the weighted sum of two quantifiable objectives rather than a single objective as was previously the case⁶.

⁶ Any number of objectives could have been operationalised for modelling and profit maximisation (gross and net margin); labour utilisation (the goal being to maximize leisure and off-farm working opportunities); and risk (minimisation of risk), have all been modelled in the past. Using economic theory, these objectives are chosen *a priori*, on the basis that they all contribute, to a greater or lesser extent, to land use decisions.

Thus, an enterprise which persistently covers a large percentage of a Land Class will be attributed a high weight and an enterprise which covers only a small percentage of a Land Class, or is present only rarely, will be attributed a low weight. Appendix D gives more detail on the derivation of these weights.

The weights are applied to the objective function row of the model and their effect is to adjust the contribution of each enterprise to the model's net margin. The desired effect of the introduction of these weights is to produce spatial distributions of enterprise production which are much closer to the observed reality than has been achieved in previous LUAM modelling exercises. The necessity of this development is increased by the addition to the model, for the first time, of three relatively minor enterprises: field-scale vegetables, top fruit and soft fruit. Previous versions of the model have had particular difficulties with minor enterprises, in that total national production tends to be allocated as a single block to one Land Class, on the basis that doing so yields a minor increase in model net margin. The introduction of these weights is intended to prevent this particular anomaly.

2.4 Enterprise and restraint data

As the model had not been run for some time, it was necessary to bring it up to date with market developments and developments in production technology. The general principle employed here is that the most up to date data should be used, even if that requires the use of data for different years for different purposes.

Enterprise data, reflecting current production technology, were updated using 2004 (harvest year) FBS data. This was the most recent data available at the time of model updating. More detail on the procedures used in this regard can be found in Section 1.4.

The model contains a minimum of restraints on the extent and distribution of production activities. The only restraints imposed on the model are national restraints on the maximum volume (expressed in value terms) of enterprise outputs that can be produced. The model is free to produce up to this maximum and distribute this production freely.

These restraints on maximum output volume reflect observed demand for home-produced commodities in 2006, the most recent date for which DNIC data are available. In the case of milk volume, however, the restraint represents the milk quota volume for 2006.

2.5 Policy

Finally, the LUAM has been brought up to date with the prevailing policy environment, or rather with current policy developments, since the model was last updated. Model scenario runs are compared not against the present state of agriculture, but against a projection of the future in the absence of the experimental developments of the scenario runs. Therefore, the reference future needs to be based on all information that can be known about the policy conditions that will prevail in that future. In the case of this LUAM updating exercise, this meant that all of the current reforms of the Common Agricultural Policy, including those that will not be implemented until 2012.

The central tenet of the recent package of CAP reforms, known as the Fischler reforms, is the decoupling of support payments from production decisions and the introduction of a Single Farm Payment (SFP) paid on an area basis. UK payments will be paid on wholly area basis by 2012. Receipt of this payment is subject to meeting certain minimum farming standards - commonly known as cross-compliance conditions. For more detail on the provisions of the Fischler reforms as applied in England and Wales, see Appendix C.

Because payments by 2012 will be fully decoupled, economic theory indicates that they will no longer influence farm production decisions (although some economists argue that they may still do so in part). For this reason, they argue, the value of support payments should not be accounted for in calculating enterprise net margins. In the model, therefore, CAP support payments are ignored, as they provide no enterprise any relative advantage.

3. SCENARIO RUNS

3.1 Data requirements

When the LUAM is used to project a hypothetical future state of agriculture, data on a number of aspects of the future economic, social and policy environment are required. These data are generally based on assumptions, or the output of other models. The model's scenario data requirements are as follows:

- (i) Future technical yield change.
- (ii) Future commodity demand/supply change.
- (iii) Future producer price change (outputs and input costs).
- (iv) Future policy change.

The sections that follow detail the assumptions and data underpinning the first Scenario run, which supposes full compliance of the UK population with WHO healthy eating guidelines.

3.2 Technology change

In farm management terms, technology change may come in a number of forms:

- (i) new management practices, tools or techniques;
- (ii) new plant or livestock technologies, i.e. cultivars and breeds;
- (iii) novel enterprises.

This particular scenario makes no assumptions concerning technology change; therefore it is assumed that agricultural technology remains unchanged from the present. Although it is likely that some technological change will take place over the period of the outworking of the scenario, this is not the focus of the scenario, and so it is not necessary that technology change be modelled, only that both the Scenario run and the Reference run be consistent in this regard.

3.3 Price change

Modelling scenarios may involve changes in market conditions, including the prices of outputs and inputs. The Reference run of the model is based on output and input prices prevailing in 2006, the most recent year for which official data were available

plus any institutional price changes anticipated as a consequence of the implementation of the 2003 reform of the Common Agricultural Policy (see Appendix C). This scenario makes no assumptions about prices and so these are assumed to remain unchanged from the Reference run.

3.4 Demand and supply change

As well as prices, market conditions are also shaped by demand for agricultural commodities and levels of supply.

The scenario provisions address the issue of supply and demand directly. On the demand side, the scenario supposes that there is a significant consumption shift towards healthier foods, in order to achieve a more balanced diet. It is, therefore, necessary to adjust the model's restraints to reflect new upper maxima on each agricultural commodity. Demand is thus exogenously set.

The model is constructed such that supply is endogenously determined, i.e. the model decides how much of the exogenously set demand it wishes to meet, on the basis of resource availabilities and economic margins. However, there is one additional factor that has to be accounted for on the supply side and that is competition for UK market share from imports. As the LUAM does not account for imports it is necessary to set the market share of UK producers exogenously. In the case of this scenario, it has been assumed that the proportion of domestic demand met by domestic supply remains unchanged, thus, for example, if up to a maximum of 75% of domestic demand for vegetables can be met by domestic producers in the Reference run, the same maximum percentage will apply in the Scenario run, even if the total domestic demand for vegetables increases.

Table 2 shows the demand changes applied to the model restraints in modelling this scenario.

Table 2. Demand change imposed in modelling Scenario 1

Enterprise	Demand (£m) Reference run	Demand change (%) Scenario run
Wheat	1082	0 ¹
Barley	372	+1.8
Oats	30	+19.5
Other cereals	2	+64.3
Peas and beans ²	70	-20.0
Potatoes	425	+23.4
Sugar beet	168	-31.4
Oilseeds	289	-5.1
Field scale vegetables	865	+41.4
Top fruit	250	+56.4
Soft fruit	220	+101.2
Milk	1929	-42.2
Beef (meat)	1358	-15.5
Sheep (meat)	634	-28.2

¹ This assumption is based on a rise in demand for milling wheat, cancelled out by a correspondingly large fall in demand for feed wheat.

² For stockfeed only.

For more detail on the generation of this scenario data, see Appendix E.

4. RESULTS

4.1 Output volumes

Table 3 shows the volumes of agricultural outputs produced under both the Scenario and Reference runs. These volumes are presented as values in constant 2006 prices and do not necessarily reflect revenues received. Under the Reference run conditions, the model is constrained in terms of the maximum volume of each commodity that can be produced, but not for minima. Table 3 shows that in the Reference run case, the model has produced up to the maximum allowable, in spite of significant cuts in the institutional prices of milk and sugar.

The percentage changes in demand imposed by the scenario conditions are mirrored exactly in the model scenario outputs.

Table 3. National production volumes (expressed as values - 2006 prices)

	Reference (£m)	Scenario 1 (£m)	% change
Wheat	1082.0	1082.0	0.0
Barley	272.0	276.9	1.8
Oats	30.0	35.9	19.5
Other cereals	2.0	3.3	64.5
Peas / beans	70.0	56.0	-20.0
Potatoes	425.0	524.5	23.4
Sugar beet	168.0	115.3	-31.4
Oilseeds	289.0	274.3	-5.1
Field vegetables	865.0	1223.1	41.4
Top fruit	250.0	391.0	56.4
Soft fruit	220.0	442.6	101.2
Milk	1929.0	1114.9	-42.2
Beef	1358.0	1145.5	-15.6
Sheep	634.0	455.2	-28.2

While the changes in production volume are largely reflected in the changes observed in the national area of each enterprise produced, Table 4 shows that there are some interesting anomalies. Driven by increased demand, the volume of Other cereals (minor cereals such as rye and triticale) produced, increases by 19%. However, the area of the crop planted falls by a little over 27%. This has been achieved by the transfer of existing production, away from some regions, particularly the North and Midlands, into others e.g. East Anglia and the South East, where yields of such crops are higher.

In the case of field vegetables, the volume of output increases by 41%, while the area produced increases by 48%. This is explained by the fact that a significant part of additional production takes place in regions more marginal for vegetable production where yields are lower than are found in the South East and East Anglia.

Table 4. National enterprise production area

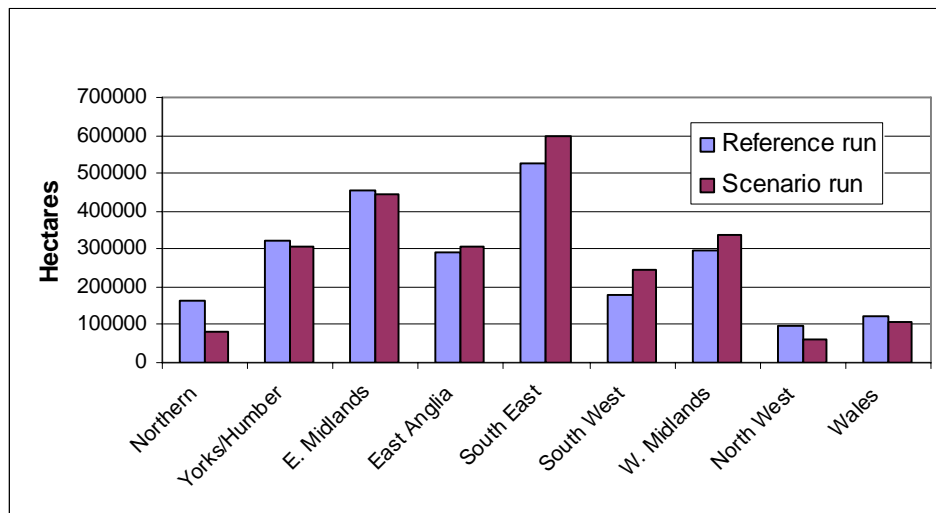
	Reference (ha)	Scenario (ha)	% change
Wheat	1684913	1690681	0.3
Barley	623946	635024	1.8
Oats	104121	123442	18.6
Other cereals	46281	33544	-27.5
Peas/beans	228127	180470	-20.9
Potatoes	133037	164270	23.5
Sugar beet	124043	74203	-40.2
Oilseeds	497215	473850	-4.7
Fodder crops	164500	164500	0.0
Field vegetables	168963	250359	48.2
Top fruit	28806	44448	54.3
Soft fruit	8025	16417	104.6
Dairy	1762728	1019076	-42.2
Beef	1977016	1754842	-11.2
Sheep	1723925	1248507	-27.6

4.2 Regional production

In gross volume terms, there is only a very modest rise in the supply of cereals. This results because the large percentage increase in demand for milling wheat is cancelled out by a drop in demand for feed wheat. Also, the large percentage rises in demand for other cereals are applied to very small base production areas. As a consequence there is very little pressure to readjust production of cereals over the regions.

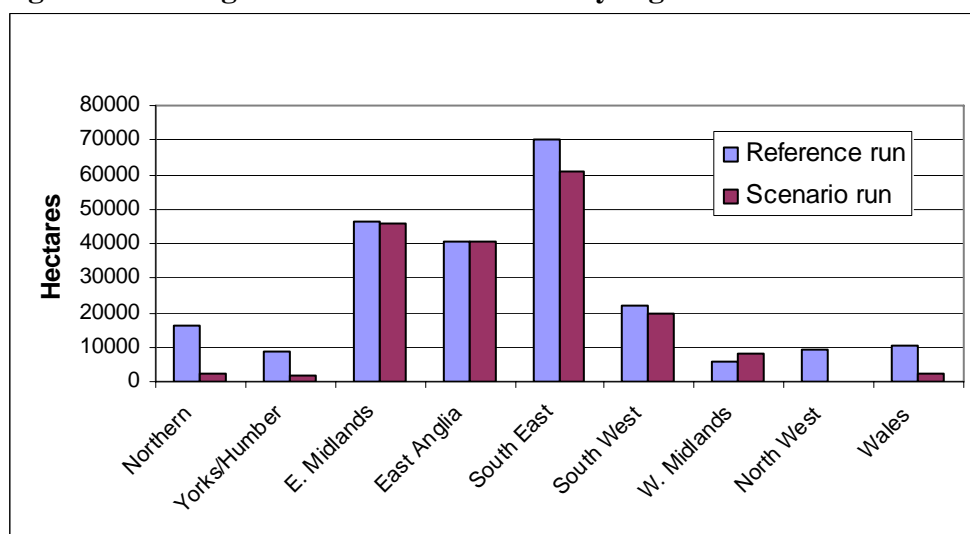
As Figure 2 shows, there is some modest switching of cereals production between regions, but this is most likely to be driven by adjustments taking place in the production of other enterprises. An example is the considerable fall in area for these crops in the Northern and North West regions.

Figure 2. Change in Cereals area by region



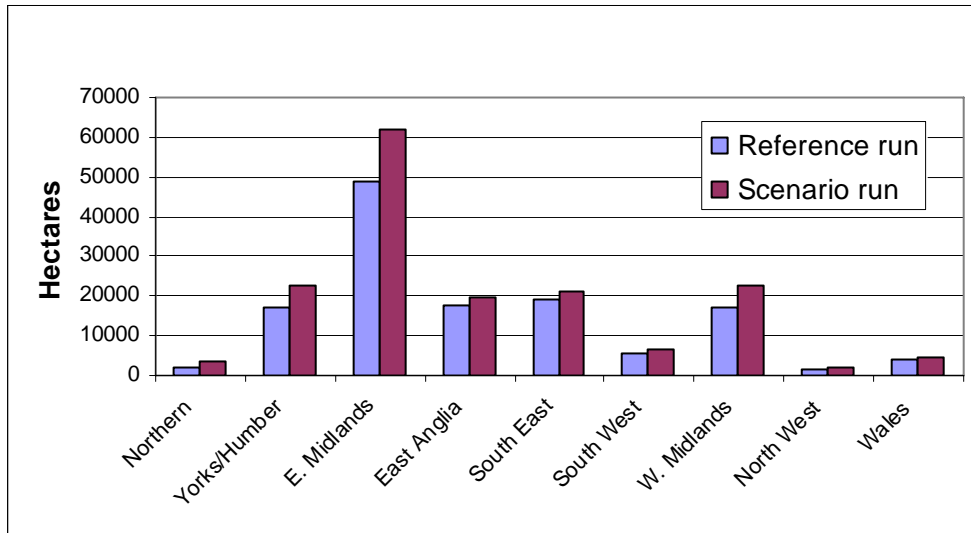
Field-scale peas and beans are produced for stockfeed. As demand for meat falls under this scenario, so too does demand for animal feeding stuffs. The 20% fall in the production of peas and beans projected under this scenario takes place largely in the North and Wales. Production is retained in the South, perhaps for two reasons. First, sheep numbers are maintained preferentially in the South, while in other regions they decline and second, in these arable heartlands peas and beans form an integral part of arable rotations. The use of peas and beans primarily as a break crop may make them worthwhile, even if they only achieve low prices on the open market (actually they are often more profitable than cereals).

Figure 3. Change in Peas and beans area by region



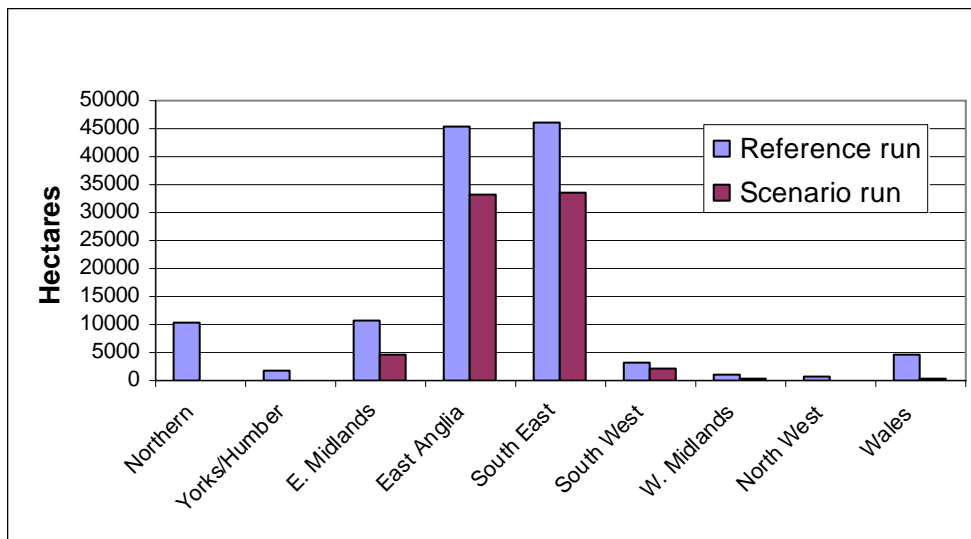
The model projects a 23% increase in potato production under the scenario and Figure 4 shows that these additional areas are spread over all regions, as potatoes are suitable for a broad range of growing conditions. However, the largest percentage increases in production are seen in the midlands and Yorks. and Humber, perhaps in part, as a replacement break crop for peas and beans.

Figure 4. Change in Potatoes area by region



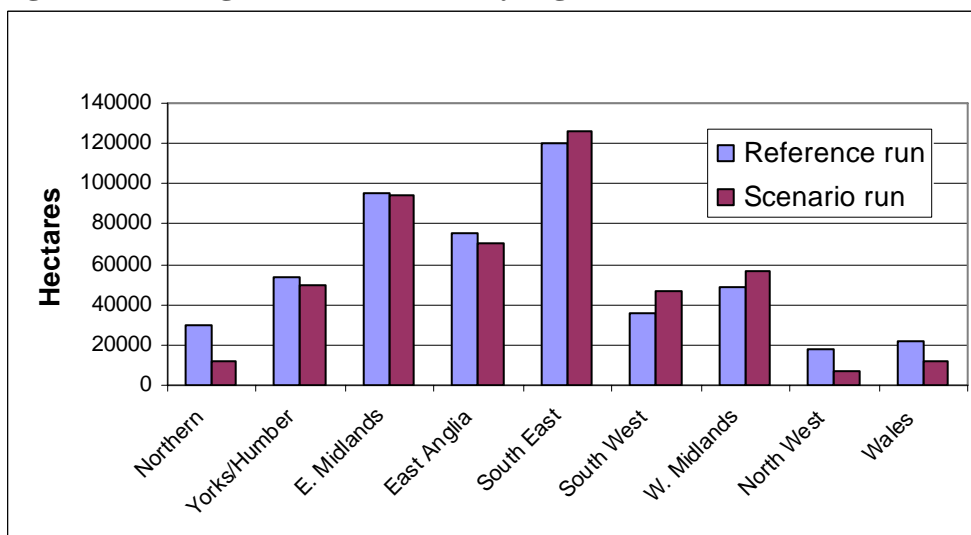
The area of sugar beet produced declines by 40% under this scenario and Figure 5 shows that this is lost from all three major producing regions. Production is all but lost in more marginal areas and all but lost in the midlands, where announcements of processing plant closures have recently been made. Under this scenario, production is concentrated in the most agronomically suitable areas, i.e. East Anglia and the South East. With prices likely to be 36% lower than at present, and with compensation for price cuts largely lost due to the redistribution effects of the SFP, it is likely that production will survive only in the highest yielding areas and close to processing plants.

Figure 5. Change in Sugar beet area by region



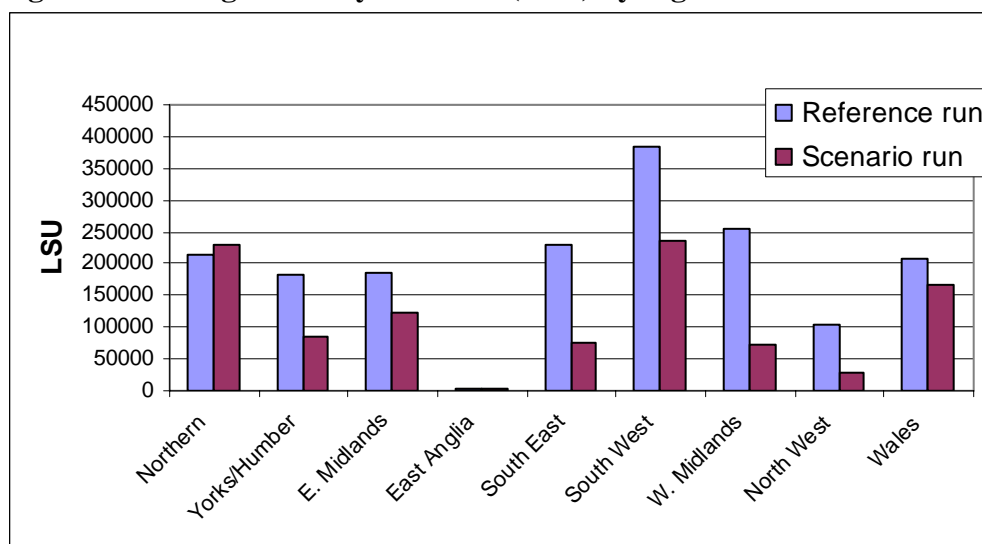
The oilseeds production area is projected to decline only marginally under this scenario and so no major regional distributional changes are to be expected. As was the case with cereals, it is likely that the small-scale re-distributions seen in Figure 6 are driven by changes in the distribution of other enterprises, particularly the need to find alternatives to peas and beans and temporary grass in arable rotations. However, the results do show a slight tendency for loss of oilseeds production in more marginal arable regions.

Figure 6. Change in Oilseeds area by region



Driven by a 42% fall in demand for milk (and other dairy products) under this scenario, livestock numbers fall by a similar percentage. As a consequence, the model projections show that most regions experience dairy LSU losses, with the exception of the Northern region (Figure 7). Production also holds up relatively well in the traditional dairy heartlands of the South West and Wales, with the most extreme losses seen in the South East and West Midlands. This projection is possibly an underestimate of the dairy LSU losses that would actually be seen under this set of market conditions, as decreasing milk prices will certainly drive a move to higher yielding animals. (It will be remembered that, in the model, such technological change is not captured.)

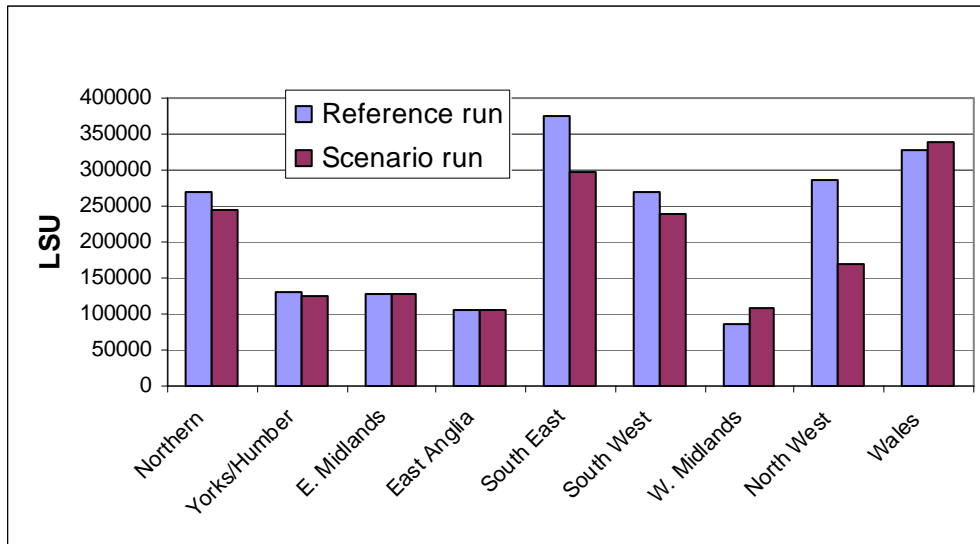
Figure 7. Change in Dairy numbers (LSU) by region



Demand for beef falls by 15% under this scenario, driving an 11% fall in the size of the national beef herd. Figure 8 shows that losses occur in the major beef producing regions, particularly in the North West, but that production holds up well in Wales and in regions with less of a beef producing tradition. It is possible that beef numbers are holding up best in mixed farming environments and suffering where specialist beef farming predominates. Two points are worth noting which perhaps explain the relatively small scale of change projected under this scenario. The first is that beef consumption has been declining for many years, as a consequence of competition from chicken, which is both cheaper and more versatile and which has a health cachet, therefore demand does not have so far to fall under the scenario. Second, beef prices

are already at historic lows and therefore, much of the ‘bad news’ as far as the beef industry is concerned is already built in and therefore some of the sector re-structuring has already taken place.

Figure 8. Change in Beef numbers (LSU) by region



Lamb consumption is found to fall by 28% under this scenario, driving a similar percentage reduction in the national flock. Figure 9 shows that this production is lost from the West Midlands and Yorks. and Humber and production is maintained in the South and East. One apparently anomalous result that needs explanation here is the very low level of sheep production in Wales. This is the result of changes in the distribution of grazing livestock production that result from the Reference run. As already explained, the Reference run represents the future in the absence of the scenario conditions, but incorporating current market and policy signals, including those elements of the recent CAP reforms yet to be implemented. Essentially, the Reference run tells us where agriculture will go if the current policy environment, plus policies in the pipeline, remains unchanged. According to the model, this will result in a switch out of sheep production in Wales and into beef, with sheep production expanding, in compensation, in the South and East where dairy is being lost.

Figure 9. Change in Sheep numbers (LSU) by region

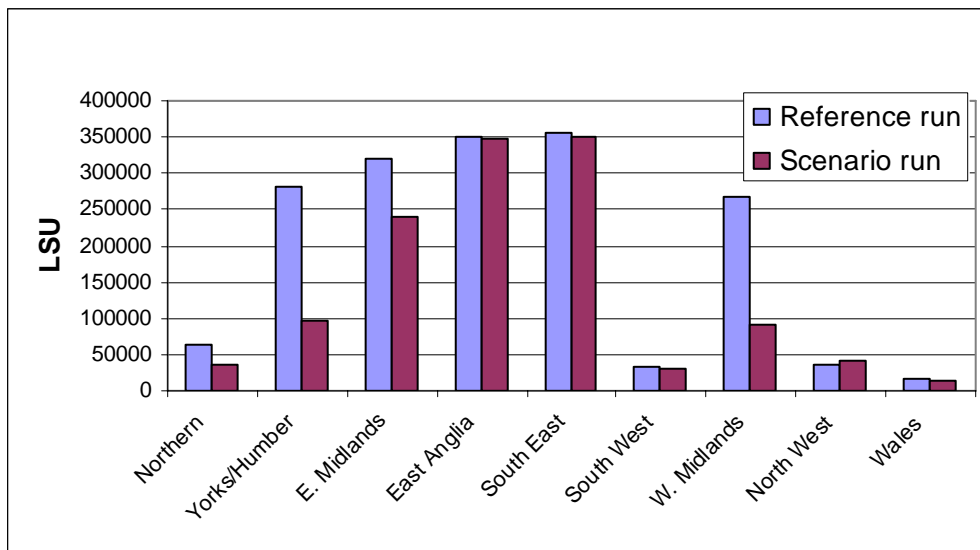
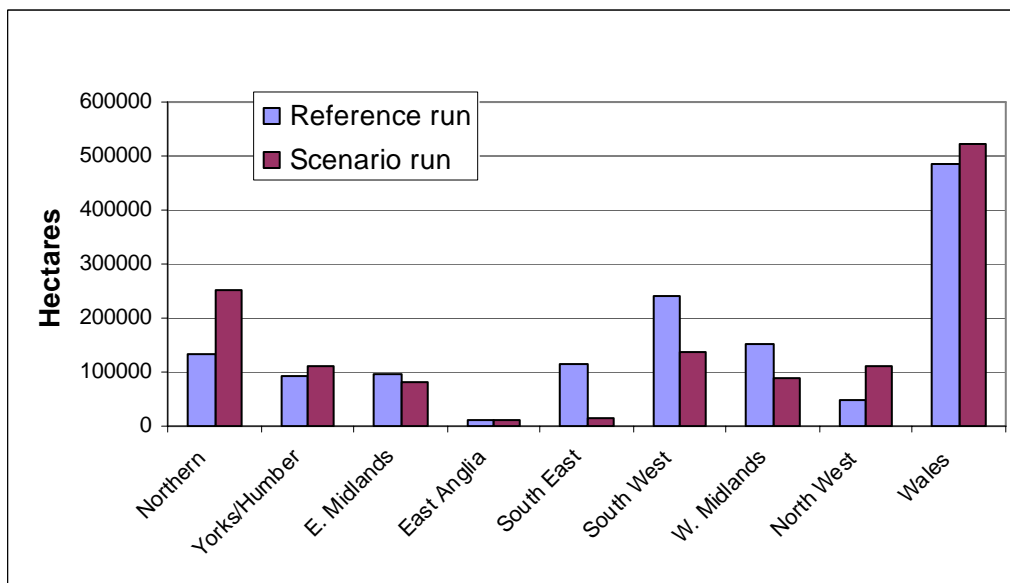


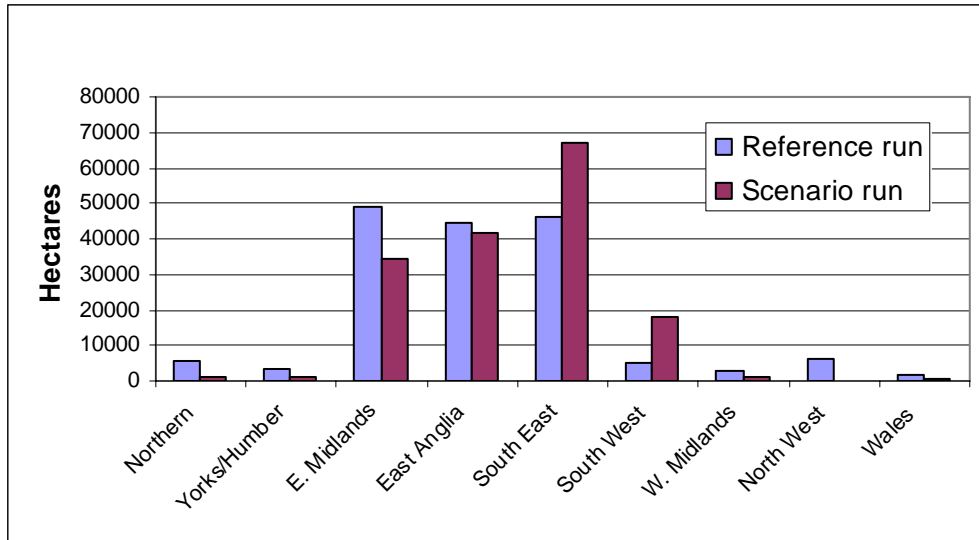
Figure 10. Change in Ley area by region



As might be expected, with greater demand for arable crops and reduced demand for livestock products, the area of short term grass leys declines in many regions, as more of this land is used for arable production. This is particularly the case for the South and the midlands, perhaps as a consequence of lost dairy production and to a lesser extent, lost beef. Another consequence of reduced livestock numbers is the return to more grass-based feeding systems, and reduced use of purchased animal feeds. This is evident in Figure 15, which shows falling use of purchased feeds in most regions. According to the model, use of purchased feeds is all but eliminated, except in the

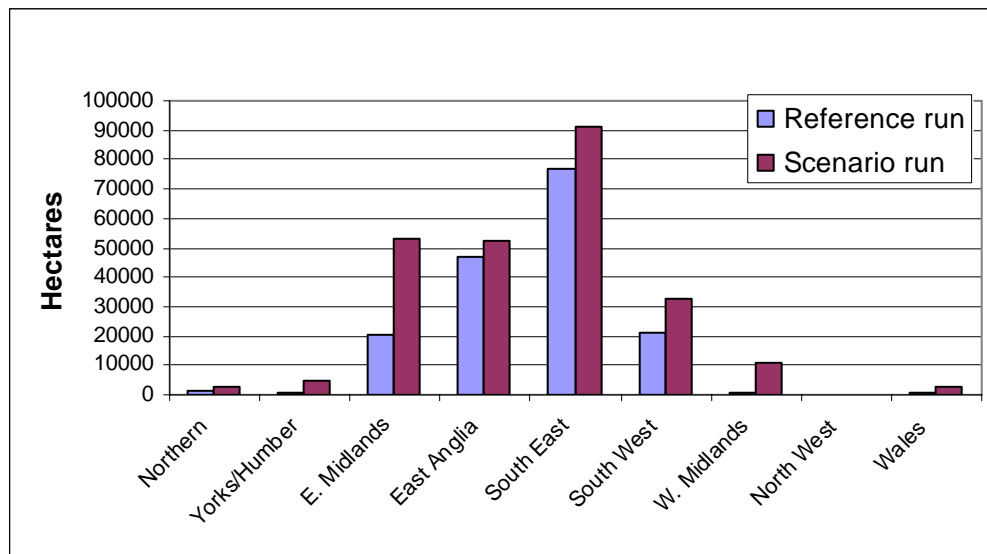
South and East, where beef and sheep numbers and highest. It is here also that greatest use of fodder crops is maintained (see Figure 11).

Figure 11. Change in Fodder crops area by region



According to the scenario, demand for fruit and vegetables grows markedly, driving an expansion in the area of production. Traditionally, field scale vegetables are grown in the South and East of England and the Reference run of the model produces just such a distribution of production. In the Scenario run, production does not expand markedly in these regions, but rather expansion is seen in other regions, most notably the midlands, particularly the East Midlands. Agronomically the South and East of England are most suited to horticultural production of this kind, but with the use of poly-tunnels and new cultivars it is very plausible that under such market conditions, production would expand in other regions. It is also possible that the model has distributed new production of field-scale vegetables to regions outside of the South and East in order to focus on expanding fruit production there, as both soft and top fruit have more stringent growing requirements than do most vegetables.

Figure 12. Change in field-scale vegetables area by region



As a consequence of increased demand, the areas of both top and soft fruit expand nationally, with increases in production projected for most regions (see Figures 13 and 14). The largest increases in production of both types of fruit are seen, as would be expected, in the South East, where growing conditions are best suited and where production and necessary skills are currently concentrated. The lack of expansion in East Anglia is likely due to a lack of land for additional crops - there is an expansion of the area of cereal and potatoes in this region. The increase in soft fruit in regions outside of the South East suggests increased use of poly-tunnels.

Figure 13. Change in top fruit area by region

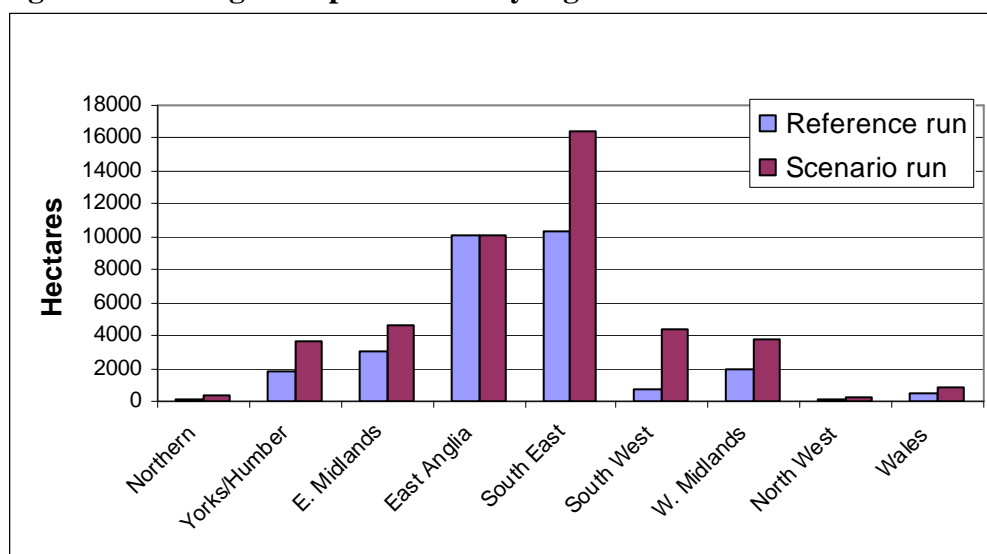


Figure 14. Change in soft fruit area by region

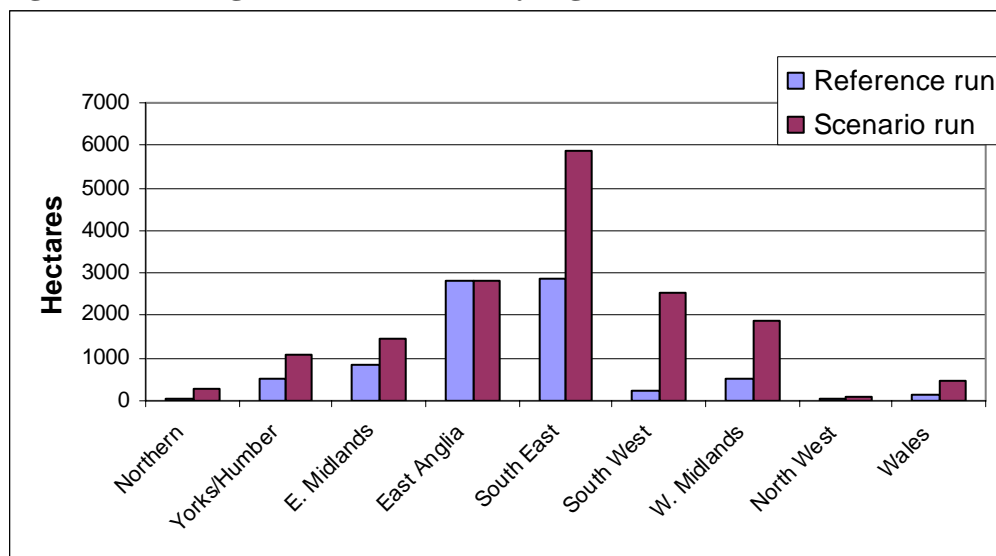
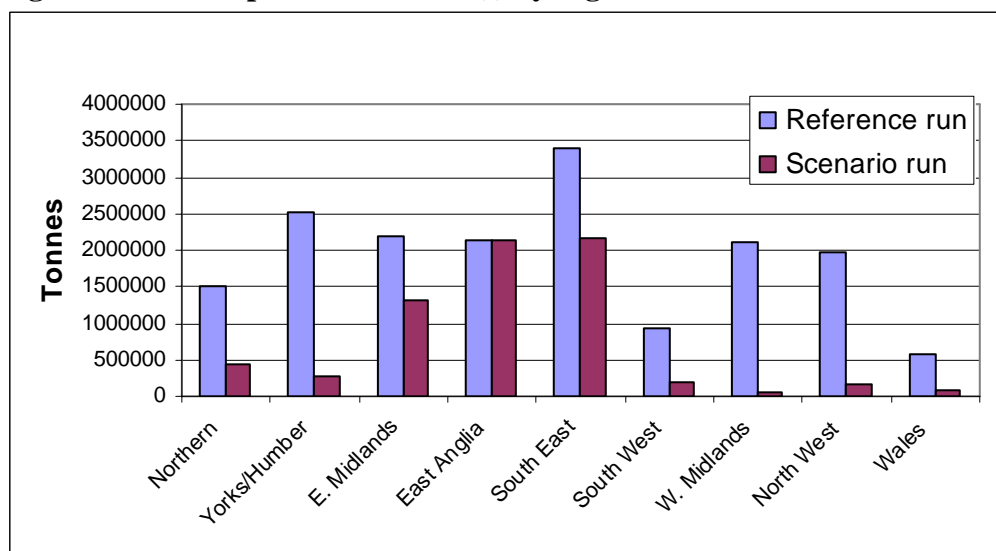


Figure 15. Use of purchased feeds (t) by region

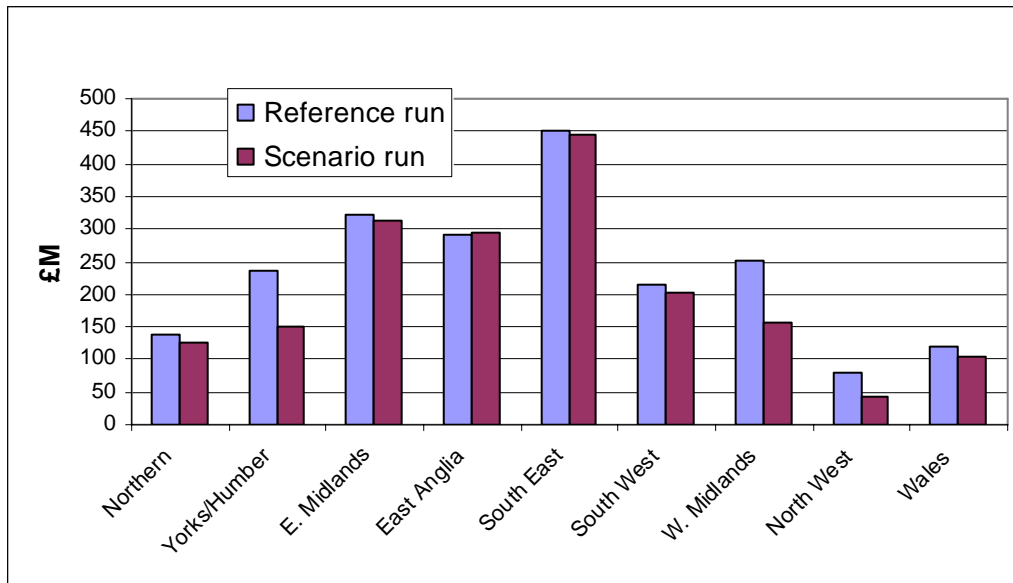


4.3 Farm labour

The cost of labour is £2,103.3M in the Reference run, falling to £1,835.7M (a drop of 12.7%) under the Scenario run. This fall must, in large part, be due to the significant reductions in the production of livestock, particularly dairy, as these are labour intensive enterprises. However, these figures reflect only regular hired labour and do not account for casual labour, which is traditionally treated in farm management accounting as a variable cost. Regular farm labour is treated as a fixed cost. The use of casual labour increases with the expansion of the horticulture sector. For the fruit sector, for example, the cost of casual labour increases from £105.9M in the

Reference case to £195.8M (+84.9%) under the Scenario run. Figure 16 shows change in the use of regular labour by region. As would be expected, labour use falls most significantly in regions which experience the heaviest loss of livestock production, particularly sheep and dairy and where there is limited scope for a compensatory increase in horticulture production.

Figure 16. Change in Labour use (volume, constant 2006 price) by region



4.4 Financial performance

The Gross Margin of England and Wales agriculture, excluding support payments under Pillar I and payments for agri-environment schemes, is £331.3M under the Reference run. This figure rises under the scenario conditions to £766.5M, an increase of 131.4%. The increase is largely due to the fact that the demand changes that drive the scenario cause a contraction in production of low margin enterprises such as beef and sheep and an increase in production (though not in the same geographical areas) of much higher margin enterprises. As these expanded horticultural enterprises tend to be concentrated in the South and East, the scenario will result in a geographical divergence in performance in England and Wales agriculture. The South and East will see farm incomes and labour use maintained and even rising, while the remaining regions of the country, particularly those regions, such as the South West, which traditionally depend on livestock rearing, will fare badly.

5. DISCUSSION AND CONCLUSIONS

The model results show the impact of the scenario conditions on land use in England and Wales. The comparison with the Reference run, which reflects the future based on current policies, permits the isolation of the marginal effects of the scenario alone. Looking at the Reference run in isolation, it is apparent that some significant land use changes are already in the pipeline, notably an expansion of sheep production on the better lowland pastures of England, at the expense of upland production, particularly in Wales. In response to this, the model chooses the replacement of sheep with extensive beef production. The expansion of sheep in lowland regions is plausible, as lowland livestock producers would look to find alternatives to using their grass which is lost from beef production. However, the substitution of beef for sheep in Wales is somewhat counter-intuitive and may be occurring for no other reason than that the LUAM is constrained to use all land for something and it has only a limited set of available enterprises. It is likely that with falling demand for beef, production will be maintained in the regions with the best margins, i.e. the lowlands. If the model were not constrained to use all land, it is possible that significant areas of upland pasture in Wales would fall idle. In the real world land abandonment is unlikely, but land prices in more remote regions may fall to the point where large scale extensive ranching becomes the only economically feasible option.

In both the Reference and Scenario runs the model supplies all enterprises up to the maximum permissible. The model is not constrained to produce any minima. This suggests that it is profitable to produce all enterprises under at least some conditions. If enterprises were loss making in a particular Land Class, it is possible that the model might still produce them there, as a means to ensuring that all land in that Land Class was used. However, this outcome is unlikely to be extensive, as the model has considerable flexibility in the generation of solutions. The observed scenario solution may also be impacted by the assumption that England and Wales agriculture maintain its current proportionate market share of fruit and vegetable production, in the face of increased domestic demand. There are no agronomic reasons why all of this increased demand might not be met by domestic producers (except in the case of citrus fruits and other exotic food of course). In these circumstances, producers in regions beyond the current horticulture heartlands (East and South East England) would also benefit, as there would be insufficient suitable land in the East and South East to meet total

demand. Any attempt to do so would, in the absence of significant yield increases, lead to the export of the production of broad-acre crops like wheat to other regions.

Because the model does not capture likely future technological change, it is possible that the scenario outcomes underestimate the loss of production (in area or LSUs terms) in some cases. This might be particularly true in the case of dairying, where loss of demand for milk and milk products is accompanied by a significant cut in price (due to CAP reform). It would be expected that tighter margins would lead to a drive for greater efficiency and this would be reflected in the concentration of production on fewer, larger holdings and an increase in average yield per cow. In the longer term, the same might be true of sugar beet, which sees a 36% cut in price under CAP reform.

Regions more heavily dependent on beef and sheep production would be the hardest hit as a consequence of the changes in consumer demand envisioned in the Scenario run. However, the problem for these regions is not confined to the loss of demand for livestock, it is compounded by several other factors. First, there would be increased competition for market share from lowland dairy producers who are, according to the model results, taking up alternative livestock enterprises, particularly sheep, to make use of slack pasture. Second, these more remote, pasture dominated regions are not well suited to the production of arable crops, especially fruit and vegetables, and so alternatives to livestock production are very limited. Existing arable production in these regions tends to be dominated by feed crops, eg. forage maize or, more importantly, wheat and barley for animal feeds. These areas will thus not benefit from growth in demand for cereals, which is confined to milling varieties. As the model is not constructed to distinguish between the different types of cereals, e.g. milling and feed varieties, or winter and spring sown crops, the Scenario run results perhaps overestimate likely levels of cereals production in livestock producing regions, especially the South West.

The headline story that comes from these model runs is that the margin of England and Wales agriculture would rise as a consequence of the public switch to a health conscious diet due to increased production of high market value and high margin crops. However, large parts of British agriculture, i.e. livestock producers and

agronomically less-favoured regions, would not be able to capitalise on these opportunities and they would experience loss of markets for existing enterprises and low prices. Structural change in these areas would likely be extreme, with declines in the number of farm businesses and average farm sizes increasing. If land prices fell far enough, it would be economical for land to be bought for extensive livestock production, i.e. ranching. However, it is also possible that land prices would remain high due to demand for land from urban dwellers for hobby farming and lifestyle reasons. Under these circumstances, existing farmers would be priced out of the market and the farming landscape would become very fragmented, with large numbers of small non-commercial holdings. Loss of farm labour in these areas would have significant detrimental effects on local rural economies and migration pressure to more prosperous regions would increase.

The effects of these changes would be felt not only on agriculture but also upstream industries, particularly feed suppliers. With fewer livestock to feed it will be feasible to introduce more grass-based production systems, particularly in the South West and Wales, where stocking rates will have to decline, unless very large areas of land fall out of agriculture. There may be environmental gains arising out of lower stocking rates, but in more marginal upland areas and on calcareous grasslands in southern regions, problems may arise due to a lack of grazing management. Environmental gains are unlikely in the East and South East, where intensive horticulture will expand, together with the use of poly-tunnels and irrigation.

APPENDIX A. THE CEH LAND CLASSIFICATION SYSTEM

A.1 Introduction

The Centre for Ecology and Hydrology (CEH) LCS forms the backbone of the national-level agricultural impact analyses. It is an objective framework used to categorise land use in Great Britain allowing it to be ‘sampled efficiently to provide estimates of *land* cover types and the distribution of landscape elements’ (Barr *et al.*, 1993⁷). Key variables (listed in Table A.1) were subjectively identified and recorded before an objective mathematical technique derived from multivariate clustering techniques was employed to group characteristic land areas into one of 32 classes. This method produces a general purpose classification that can be used as a basis for predicting a variety of related parameters. The CEH LCS was last revised in 1996 (Bunce *et al.*, 1996a⁸ & b⁹). It contains more than 240,000 1 km grid squares of which some 155,000 fall within the boundaries of England and Wales. For a brief history of the LCS's development see Parry *et al.* (1999)¹⁰ and CEH (1998)¹¹.

A.2 Application of the LCS within the LUAM

The LCS was the ideal basis for structuring the land resource of the LUAM as it provided the best available medium through which the environmental and ecological consequences of various agricultural policies could be projected. The LCS describes and delineates the land surface of England and Wales and its ecological characteristics, and it enables the agricultural components of the LUAM to be linked with this database, thus forming the basis for all distribution analyses. It also allows the results of the LUAM to be ‘raised’ or ‘lowered’ to various geographical scales. A summary description of the LUAM Land Classes can be found in Table A.2 with a

⁷ Barr, C.J., Bunce, R.G.H., Clarke, R.T., Fuller, R.M., Furse, M.T., Gillespie, M.K., Groom, G.B., Hallam, C.J., Hornung, M., Howard, D.C. and Ness, M.J. 1993. *Countryside Survey 1990. Main Report*. Department of the Environment, London.

⁸ Bunce, R.G.H., Barr, C.J., Clarke, R.T., Howard, D.C. and Lane, A.M.J. 1996a. Land Classification for Strategic Ecological Survey. *Journal of Environmental Management*, 47, 37-60;

⁹ Bunce, R.G.H., Barr, C.J., Clarke, R.T., Howard, D.C. and Lane, A.M.J. 1996b. ITE Merlewood Land Classification of Great Britain. *Journal of Biogeography*, 23, 625-634.

¹⁰ Parry, M.L., Carson, I., Rehman, T., Tranter, R.B., Jones, P.J., Mortimer, D., Livermore, M.T.J. and Little, G.P.J. (1999) *Economic Implications of Global Climate Change on Agriculture in England and Wales*. Research Report No.1. Jackson Environment Institute, University College London.

¹¹ CEH (1998) <http://www.ceh.ac.uk/products/publications/documents/13bio1.pdf>

broad description of the locations of such Land Classes and the farming typical of these areas.

Table A.1. List of variables and formats used in the CEH LCS

Type of variable	Variable	Format
Coastal	Cliff, sand, shingle, rock, mud, tidal	P
	Island	P
	Sea	V
Topography	Height of hill behind	V
	Distance to hill behind	V
	Height of valley behind	V
	Distance to valley behind	V
	Mean altitude	V
	Slope (length and gradient)	V
	Distance to south coast	V
	Distance to west coast	V
Human Geography	Towns	V
	Villages	V
	Roads (A, B, Minor, Motorways)	V
	Railways	V
	Canals	V
	Woodlands	V
Climate	Mean minimum January temperature	B
	Mean hours of sunshine in year	B
	Mean days with snow laying	B
Geology	Solid geology	N
	Drift	N

P - presence/absence

V - variable

B - banded variable

N - presence of one of a number of values

Source: Bunce *et al.*, 1996b¹².

¹² Bunce, R.G.H., Barr, C.J., Clarke, R.T., Howard, D.C. and Lane, A.M.J. 1996b. ITE Merlewood Land Classification of Great Britain. *Journal of Biogeography*, 23, 625-634.

Table A.2. Summary of LUAM Land Classes

Land Class	Description
1	<u>England, Central South downs.</u> Gently rolling country with moderate relief. Rich farmland, both pastoral and arable.
2	<u>England, South-east downs.</u> Long rounded slopes, particularly associated with chalk downs.
3	<u>East Anglia central plains.</u> Almost flat plain with extensive arable farming.
4	<u>East Anglia marginal plains.</u> Intensively farmed arable; flat featureless plain.
5	<u>England, central plains.</u> Undulating landscape with many hedges; mainly pastoral, often with heavy soil.
6	<u>England, South-west lowlands.</u> Low emphasis relief with local variation. Predominantly pastoral agriculture.
7	<u>England/Wales, coastal.</u> Widely variable with estuaries, cliffs or steep slopes and associated lowland land, occasionally marsh or dunes.
9	<u>Midlands and North Wolds of England.</u> Undulating land mainly with arable valleys and slopes.
10	<u>North-east Wolds of England.</u> Undulating land, predominantly pastoral and woodland.
11	<u>England, Midlands plains.</u> Gently undulating land with intensive arable farming, except on heavy soils.
13	<u>England, North-West Midlands and North Lowlands.</u> Level featureless alluvial plains and coastal sites with mud flats. Intensive arable agriculture.
15	<u>Lowlands of Wales and Northern plains of England.</u> Intensively farmed flat land, inland from coasts.
17	<u>Wales, central uplands.</u> Gently undulating hills with moderate relief. Mainly pastoral agriculture.
19	<u>Northern England.</u> Somewhat steeper slopes and higher altitudes than 17 above. Less farmed land available; some forestry.
25	<u>East lowlands of England.</u> Intensively farmed pasture; gently rolling slopes with some upland influence.

APPENDIX B. LUAM DATA SOURCES

LUAM data was derived from a number of different data sources, published in a number of different media, according to need. The following is a list of the data requirements of the LUAM, with the data sources used to meet these requirements detailed under each header.

B.1 Crop areas and livestock numbers

Published data are required to calibrate the model to ensure that it is grounded in reality at a fixed point in time. Data on the available arable area, the areas of the different arable crops and livestock numbers were derived from the June Agricultural Census for 2004.

http://statistics.defra.gov.uk/esg/statnot/june_eng.pdf

<http://new.wales.gov.uk/docrepos/40382/40382313/statistics/agriculture/734522/sdr89-2004.pdf?lang=en>

B.2 Grassland areas

Grassland in the LUAM takes one of three forms: Ley (defined by Defra as grasses under 5 years old), permanent pasture (grasses over 5 years old) and Rough Grazing. Estimates of the areas of these three types of grassland were derived from the CEH Land Classification system. The advantages of deriving estimates from this source are: first, data are available on a Land Class basis and second, as the CEH distinguishes Leys and Permanent pasture on the basis of species composition this is a better indicator of yield than the age of the grassland.

http://www.cs2000.org.uk/CIS_files.htm

B.3 Input - output data

B.3.1 Crop and livestock yields

Crop and livestock yields are derived from Defra's Farm Business Survey for 2004. Published farm management data are also available that would serve the same purpose, but these are only readily available at the national level. Use of the Farm Business Survey data permits the capture of regional differences in yield and farming

practice. Because individual farms, for confidentiality reasons, cannot be precisely located and for that reason cannot be identified with Land Classes, data are averaged over Government Office Regions. These GOR values are subsequently re-attributed to Land Classes using a set of coefficients reflecting the area of each Land Class in each GOR.

National FBS data were obtained, with Defra's permission, from the UK ESRC Data Archive.

B.3.2 Input use

The Farm Business Survey provides data on agricultural input use only on a per farm basis. It would have been possible to allocate this whole-farm data to individual enterprises using econometric techniques, but this process is both time consuming and somewhat unreliable. Consequently, the following published farm management standards data were used instead:

The Agricultural Notebook, 19th Edition. Oxford, Blackwell Science.

The Farm Management Pocketbook, 36th Edition. University of London, Imperial College, Wye.

B.4 Prices

The following sources were used to provide input and output prices, so that the quantities specified in the model could be specified as values. All prices specified were based on 2006, i.e. the most recent year for which market data were available.

Index of the purchase prices of the means of agricultural production, Defra.
<http://statistics.defra.gov.uk/esg/statnot/apinotice.pdf>

Index of producer prices of agricultural products (UK), Defra.
<http://statistics.defra.gov.uk/esg/statnot/apinotice.pdf>

The Farm Management Pocketbook, 36th Edition. University of London, Imperial College, Wye.

Average earnings index: all employee jobs by industry (not seasonally adjusted).
www.statistics.gov.uk

APPENDIX C. THE KEY PROVISIONS OF THE FISCHLER REFORMS OF THE CAP

C.1 UK implementation of the reform of the CAP (1 January 2005)

C.1.1 The basics

Separate CAP reform arrangements were negotiated for England by the Westminster Government and the devolved administration in Wales, with both being implemented from 1 January 2005. There was no delayed implementation in either case, although there will be a phased implementation between 2005 and 2012. The following is a summary of the provisions of the reform as they apply to England. A statement of differences in the implementation in Wales is also presented.

All major subsidy payments that were coupled to production were fully decoupled as of 1 January 2005, with a SFP now being made on a flat rate basis. There are a few very small schemes that are not decoupled, i.e. for peas and hops. The SFP is now made on the basis of the 'eligible area' available to farmers in 2005 - with buildings, forestry and permanent crops areas excluded. Some land not previously registered for payment is now eligible to receive it, e.g. land previously used for horticulture.

For the purpose of administering the scheme, England has been divided into three regions, each with different payment rates per hectare of eligible land:

- Moorland within SDA;
- Non-moorland within SDA; and
- All other land.

Upon implementation of the SFP, the following schemes were withdrawn:

- Arable Area Payments Scheme
- Beef Special Premium Scheme
- Extensification Payment Scheme
- Sheep Annual Premium Scheme

- Suckler Cow Premium Scheme
- Slaughter Premium Scheme
- Veal Calf Premium Scheme
- Dairy Premium
- Dairy Additional Payments

C.1.2 Rates of payment

Rates of payment per hectare have been decided by a top-down formula, in which the total aggregate payments in England, for each of the three regions in the reference period (2000-2002), were divided by the total declared eligible area, where this includes areas previously not classed 'eligible land', i.e. land previously used for non-supported crop and livestock enterprises such as pigs and poultry. At time of modelling, payment rates per hectare for the three regions by 2012 were, before deductions:

- SDA moorland - £24
- SDA non-moorland - £175
- The rest - £215

Source: Nix, J. (2005); *Farm Management Pocketbook*, 36th edition, Imperial College London: Wye Campus.

C.1.3 Modulation

Under the reformed CAP, modulation has two components in the UK: a mandatory EU modulation rate of 5% by 2007, plus a national voluntary rate of 6% by 2006. The terminal rate of modulation by the end of the transition period in England will be around 11%. The first €5,000 of payment is not subject to the EU modulation component, but is subject to the UK voluntary component. A further 3% deduction in rates of payment will be made for the national reserve - designed to assist new entrants to farming and compensate farmers who bought land in the reference period and where the vendor has been awarded the entitlements - making the terminal modulation rate around 15% (this assumes a further 1% reduction for financial discipline, i.e. a claw-back mechanisms designed to prevent the EU budget being exceeded).

The UK voluntary modulation rate in 2003 was 3.5% and it was proposed under Agenda 2000, i.e. prior to the new rates declared in the Fischler reforms, that the rate would rise to 4.5% from 2006.

C.1.4 Cross-compliance

Under the reformed CAP, certain agricultural and environmental prescriptions have to be met for SFP payments to be paid.

There are two components to cross-compliance: Statutory Management Requirements (SMR) and maintenance of land in Good Agricultural and Environmental Condition (GAEC).

SMR

Complying with regulations stemming from the 19 EC Directives of Regulations covering: wildlife, pollution, animal and public health and welfare etc. These are due to be implemented in stages from 1 January 2005, but all are due to be fully implemented by 2007.

GAEC

Compliance with 11 ‘standards and requirements’. There are a large number of these provisions and because the LUAM model is a simplified representation of reality, it is not possible to reflect all of them due to structural and data limitations. However, a sample of the provisions are listed below:

- Overgrazing to be prevented by appropriate management of stocking levels.
- Permanent pasture as a national resource must not be reduced to less than 95% of the 2003 levels.
- Land not wholly in agricultural production must be kept clear of invasive plant species and establishment of scrub vegetation prevented.

The default set aside rate was fixed under Agenda 2000 at 10% of eligible land (although this rate did vary in practice in some years) and this level prevailed until 2005. Under the new scheme, more land now becomes eligible for payments and so

the set aside area reduces as a proportion of the total eligible area. Farmers in England will now have to set land aside at a rate of 8% of the area of eligible hectares with the following exceptions:

- Farmers wholly within the moorland SDA (no set aside requirement)
- Farms within non-moorland SDA will set aside 1.3% of eligible land
- Farms with no eligible hectares
- Small producers (in England this is fixed at farms with arable areas of less than 15.62 ha)

It is the case that farmers can vary their set aside area by selling their set aside entitlements (i.e. entitlement to set aside payments is based on historic areas, but entitlements once allocated are tradeable).

C.1.5 Commodity regimes

Milk

There are few adjustments proposed under the Fischler reforms for commodity regimes. The exception is the milk regime.

The Mid Term Review reforms have been overlaid onto the earlier Agenda 2000 reforms to the commodity regimes, i.e. those Agenda 2000 regime reforms that had been completed by 1 January 2005 remain in place. However, the Agenda 2000 reform of the milk regime was postponed to 2005, at which point a phased implementation over the three years 2005/6 - 2007/8 was proposed. This involved the following:

Table C.1. Cut in guide price (%) for milk products under the reformed CAP

Milk product	2005/06 %	2006/07 %	2007/08 %
Butter	-5.0	-5.0	-5.0
Skimmed milk powder (SMP)	-5.0	-5.0	-5.0

In compensation for the above, milk quota was set to increase by 0.5% per year for each of the three years. There were also associated increases in direct payments through the introduction of a new dairy premia payment, paid on the basis of quota entitlement (owned and used, plus leased in, less owned and leased out).

These provisions have been revised by the Mid Term Review. Over the three years to 2008 the butter guide price is to be cut by 25%, while the 15% cut in SMP price is retained. The direct payments (the dairy premia), estimated at 2.45 pence/litre from 2006 onwards, are to be rolled into the SFP and paid on a per hectare basis. Milk quotas are retained until 2014/15 and are set to increase by 1.5% in total (as proposed under Agenda 2000).

C.1.6 Wales

The implementation of the CAP reforms in Wales does vary from the implementation in England. However, because the effective differences are so small, for modelling purposes these are treated as being the same.

C.2 UK implementation of the reform of the EU sugar regime (December 2005)

Sugar regime reforms were agreed in November 2005. The thrust of this reform involves a cut of 36% in the sugar price (implemented over 4 years), compensated by direct payments, which amount to 60% of the lost revenue from sales (due to the price cuts). There are buyout schemes for quota holders. The sugar direct payments will be added to the SFP, but not confined to sugar producers, i.e. they will add a very small amount to the average SFP for all farmers.

C.3 Implementation of CAP reform in the model

C.3.1 The Reference Run

The Reference Run reflects the CAP situation after all transitional phases have been completed. This involves the following:

- Milk price cut of 18%
- Milk quota entitlement as per the Base Run
- Set aside at 8% of eligible land (for modelling purposes this constitutes all land except Permanent Pasture and Rough Grazing)
- Cut sugar price by 36%
- Sugar compensation payments per hectare are likely to be a negligible amount so for our purposes have been ignored.

- SFP payments not included in the model.

The following constraints are applied to reflect GAEC cross-compliance conditions:

- to prevent overgrazing the model incorporates stocking rate limits of 2.0 LSU per hectare over all forage areas within each Land Class.
- the national area of permanent pasture cannot fall below 95% of the calibration area.
- Land cannot be abandoned, i.e. it must be used for something, and on grassland a minimum stocking rate of 0.5 LSU per hectare applies.

C.3.2 Price support measures

Although there have been discussions and some general agreements on future EU-level changes to intervention regimes, export refunds and import tariffs at time of modelling, no time-table for these have been agreed. Therefore, the Scenario Run assumes that all these price support mechanisms remain in place. It is further assumed that these mechanisms are actively used to ‘manage’ EU prices for commodities such that they reflect the institutional price guides set for them in the Agenda 2000 reform package and the Mid Term Review dairy regime reforms, i.e. there is perfect price transmission.

APPENDIX D. IMPROVING THE SPATIAL RESOLUTION OF LUAM OUTPUT

Any assessment of the impacts of alternative policy scenarios on biodiversity and landscape first requires geographically explicit data on the major land use and landscape changes that result from the implementation of those scenarios. Although the LUAM generates this data, the model outputs are currently of relatively low geographical resolution, due to the fact that the model is based on the CEH Land Classification System (LCS), where land use changes cannot be identified with specific sites within Land Classes. Moreover, the spatial level of the LUAM output is not appropriate for the evaluation of biodiversity changes, given the type and resolution of distribution data on species occurrence and abundance.

Therefore, as part of this project, it has been necessary to increase the spatial resolution of LUAM output in order to enable a GIS analysis of predicted land use changes and to facilitate the geographically explicit representation of those changes across England and Wales. This was achieved by a two-stage methodological improvement of the LUAM modelling process. The first stage (i) refers to an amendment of the model structure itself to incorporate a set of enterprise weights and the second (ii) involves a separate GIS-based ‘treatment’ of the model output.

(i) The economic rationale for adopting this approach has been outlined at Section 2.3 above. Here, the benefits in terms of environmental interpretation are explained and more detail on the methodology is provided. Environmental interpretation of LUAM outputs has, in the past, been hampered by the model’s generation of perceived ‘unlikely’ re-distributions of enterprises between Land Classes. This limitation of the model stems from the fact that in allocating land to enterprises, the model makes no reference to past practice and does not account for a range of factors that hold production of enterprises in certain geographical zones, factors such as the capital costs of enterprise establishment for example. Such problems were less apparent in previous modelling exercises, where model results were presented at levels of aggregation above that of the Land Class, e.g. Government Office Region. However, one of the requirements of the current study is that model results be interpreted, in terms of their environmental impacts,

at levels below that of the Land Class. At this level the effect of this model limitation becomes very much apparent. Conversion of the model to a multi-objective format, by the introduction of enterprise weights reflecting past land use practice, produces a much more realistic Land Class distributions of land uses, making it possible for the first time to attempt the interpretation of model outputs at below this level of aggregation. The weights were based on a GIS analysis of the Defra June Census data for the 10 year period 1988-1997. For a range of key land uses, coefficients were generated representing the percentage share of total agricultural area (in percentage terms), in every 10 km grid square across England and Wales, averaged over the 10 year period 1988-1997. These 10 km² values were then aggregated to the Land Class level for inclusion in the model. This was done by weighting the coefficient for each 10 km square by the area of agricultural land within that block that lies within the Land Class. Table D.1 below shows the data generated at this point. Before entry into the model, the coefficients were rebased such that they averaged to 1 over the 15 Land Classes.

(ii) The second stage of methodological improvement involves a GIS-based refinement of the LUAM output in two separate stages: an improvement of the spatial interpretation of (a) the Reference run and (b) Scenario run outputs, as indicated below (a separate report of these activities, which have taken place under Workpackage 5, sub-task 3 will shortly be produced).

(a) This first step involves a disaggregation of the Land Class-based results of the Reference run to smaller geographically explicit units that can be more readily identified with specific landscape types and habitats. This involves applying to the model outputs a set of coefficients that capture the historical area and persistence of enterprises in all 10 km squares within each Land Class, i.e. the same set of coefficients that formed the basis of the Land Class-based set presented in Table D.1. Essentially, Land Class based results are disbursed over 10 km squares using a set of decision rules that seek to place enterprises in squares that have traditionally shown the greatest percentage coverage and persistence. This operation is spreadsheet

based. This mapping of land use at the 10 km square level is the Reference position against which scenario changes are mapped.

- (b) Having generated a 10 km square Reference run map, the next step is to decide where model scenario projections of change at the Land Class level are going to occur within the Land Class. For this purpose a second set of 10 km square coefficients are generated, reflecting the tendency of the area of enterprises within each 10 km square to follow general land use trends, in this case, national variation in crop areas and livestock numbers. The coefficients are derived from a GIS analysis of the June Agricultural Census data for the 10 year period 1988-1997. Coefficients are estimated by generating a coefficient of variation for each land use in each 10 km square and then comparing this with the national change in this land use over the same period. Based on this new set of coefficients, the changes projected by the model in each Land Class are allocated to 10 km grid squares, i.e. on the basis of observed likelihood of change.

Table D.1 – Land use coverage (as a percentage of total agricultural area), by CEH Land Class, averaged over the period 1988-1997

Land use	Land Class														
	1	2	3	4	5	6	7	9	10	11	13	15	17	19	25
cereals	16.09	14.28	16.35	37.32	19.21	7.58	47.71	24.18	20.32	22.36	18.66	19.08	2.50	3.26	6.55
Potatoes	1.08	0.54	2.71	7.29	2.11	0.92	8.21	3.39	3.06	3.23	2.96	2.45	0.36	0.32	1.39
Peas / beans	1.24	1.18	1.58	3.06	0.93	0.33	2.89	1.64	1.31	2.02	1.04	0.86	0.11	0.07	0.64
Oilseeds	1.96	2.05	2.14	4.65	1.45	0.58	5.39	3.23	3.08	3.70	1.88	2.26	0.20	0.32	2.80
Sugar beet	0.22	0.13	1.75	4.27	0.42	0.01	2.95	1.26	1.19	1.91	0.81	0.59	0.06	0.02	0.22
Cattle	33.79	19.86	11.24	29.36	78.27	34.85	71.89	26.81	26.41	9.88	45.47	43.71	21.25	28.11	45.53
Sheep	7.68	4.01	3.33	6.25	27.29	10.14	22.07	9.41	8.02	2.53	12.56	22.38	21.40	28.12	24.50
Pigs	4.54	3.48	3.55	9.89	5.09	1.62	10.90	4.96	4.56	3.65	4.84	4.73	1.67	2.80	5.91
Poultry	4.99	3.57	3.48	7.17	6.71	2.26	8.03	3.76	3.18	2.65	5.22	3.94	1.79	2.40	3.09

APPENDIX E. SCENARIO 1: DATA SOURCES AND METHODOLOGY

The first modelling scenario posits changes to the pattern of food consumption in the UK to approximate SACN/WHO/FAO guidelines for healthy eating. A full report on the sources of data used in specifying this scenario, together with a full methodological description of their use, can be found at:

<http://www.relu.rdg.ac.uk/Working%20Papers%20and%20Reports/WP1%20Guidelines%20Report1June06.pdf>, pp.12-13).

For convenience, Table E.1 below (replicating data from the above report) shows percentage changes in the national consumption of basic agricultural products under this scenario. The percent changes shown in Table E.1, with some minor modification (See Table 2 in the main report), were used in specifying the scenario in the model. As the model does not reflect all the agricultural outputs reflected here, some data were aggregated, i.e. where UK production of products exists, and some data were ignored, where there is no UK production of products.

Table E.1 – Estimation of change in consumption of basic food products under the scenario

		Existing ('000 tonnes)			Target ('000 tonnes)			Percent change
		England	Wales	Total	England	Wales	Total	
Dairy & Meat	Milk (million litres)	10198.82	582.68	10781.51	5898.19	333.64	6231.83	-0.42
	Beef - Veal	559.96	35.09	595.05	473.24	29.79	503.03	-0.15
	Mutton - Lamb	163.65	10.03	173.68	117.50	7.28	124.78	-0.28
	Pork	550.60	34.18	584.78	451.13	27.06	478.19	-0.18
	Poultry	680.32	39.33	719.65	745.76	44.50	790.26	0.10
	Misc. meats	150.34	11.09	161.42	111.90	8.30	120.20	-0.26
Eggs	Egg (billion)	23.27	1.32	24.58	21.00	1.22	22.22	-0.10
Cereals	Wheat	2414.75	148.68	2563.43	3111.89	197.28	3309.17	0.29
	<i>of which non Pasta</i>	2201.58	137.35	2338.92	2794.24	179.68	2973.93	0.27
	<i>of which Pasta</i>	213.17	11.34	224.51	317.65	17.60	335.24	0.49
	Barley	113.08	6.77	119.85	115.21	6.84	122.06	0.02
	Rye Flour	14.04	0.69	14.73	23.03	1.17	24.20	0.64
	Oats	153.90	8.46	162.35	183.76	10.19	193.94	0.19
	Rice	366.29	15.79	382.08	485.51	21.90	507.41	0.33
	Maize	82.67	4.27	86.94	104.92	5.54	110.46	0.27
Misc.	Sugar	830.32	55.90	886.21	572.26	35.90	608.16	-0.31
	Oils & Fat	419.71	29.64	449.35	397.27	28.52	425.79	-0.05
	Potato	3744.88	240.47	3985.35	4608.92	309.21	4918.13	0.23
	Fish	348.35	17.85	366.20	471.44	26.16	497.59	0.36
	Honey	10.40	0.61	11.01	15.13	0.94	16.07	0.46
	Green Veg.	Cabbages	116.98	6.74	123.72	235.43	13.51	248.94
Brussels sprouts		38.99	1.69	40.68	78.47	3.38	81.85	1.01
Cauliflower		207.97	9.80	217.77	418.28	19.64	437.93	1.01
Salads		171.57	8.43	180.00	249.57	12.94	262.51	0.46
Peas		157.02	10.17	167.19	269.54	17.79	287.32	0.72
Beans		288.04	17.19	305.23	387.32	23.15	410.47	0.34
Other Green Veg.		246.96	13.53	260.49	271.33	14.73	286.06	0.10
Other Veg.	Carrots	262.56	15.63	278.19	528.28	31.32	559.60	1.01
	Turnips & Swede	57.19	5.36	62.55	115.10	10.74	125.85	1.01
	Other Root Veg.	64.99	3.98	68.97	130.80	7.98	138.78	1.01
	Onions, Leeks, Shallots	252.16	14.71	266.87	437.09	26.01	463.10	0.74
	Cucumbers	111.78	5.52	117.30	162.58	8.43	171.01	0.46
	Mushrooms	96.19	4.90	101.09	193.57	9.82	203.40	1.01
	Tomatoes	485.61	24.01	509.61	736.37	36.51	772.88	0.52
	Misc. Veg.	480.93	23.48	504.41	687.92	32.23	720.15	0.43
	Fruit	Oranges	171.57	8.12	179.69	297.35	14.36	311.71
Other citrus fruits		236.57	10.11	246.68	388.14	17.09	405.23	0.64
Apples		444.53	25.58	470.12	729.07	43.25	772.32	0.64
Pears		128.73	7.69	136.42	220.55	13.45	234.00	0.72
Stone fruit		196.32	9.22	205.54	228.19	10.99	239.18	0.16
Grapes		142.98	7.51	150.49	227.93	12.40	240.33	0.60
Other soft fruit		80.59	4.14	84.72	162.19	8.29	170.48	1.01
Bananas		561.52	29.72	591.24	849.88	47.03	896.91	0.52
Melons		101.39	3.68	105.06	147.46	5.64	153.10	0.46
Pineapple		9.15	0.64	9.79	13.31	0.98	14.29	0.46
	Misc. Fruits	364.31	20.42	384.73	414.67	22.73	437.40	0.14

