UK Health Security Agency

European Spatial Data for PC-CREAM 08 and PACE

European Spatial Data for PC-CREAM 08 and PACE

J Smith, S Field, K Ramwell, T Charnock

Abstract

This report describes the methodology and data used to create data sets of spatial distributions of population and agricultural production in Europe. The data sets are used in the radiological impact assessment tools PC-CREAM 08 and PACE to calculate doses to members of the public. The population data set is the population including all age groups, but for dose assessment purposes it is usually assumed to be comprised entirely of adults. The agricultural production data sets cover the food types typical of a European diet and which are important in terms of radiological impact assessment.

Quality assurance

This work was undertaken under the Radiation Assessments Department’s Quality Management System, which has been approved by Lloyd's Register Quality Assurance to the Quality Management Standard ISO 9001:2015, Approval No: ISO 9001 - 00002655.

Contents

1. Introduction

PC-CREAM 08 (Smith and Simmonds, 2009) and PACE (Charnock and others, 2020) are tools developed by the Radiation Assessments Department (RAD) of the Radiation, Chemical and Environmental Hazards Division (RCEHD) of the UK Health Security Agency to estimate doses from releases of radioactive material into the environment. PC-CREAM 08 is applicable to planned continuous discharges from normal practices and PACE is used to determine the radiological impact of potential nuclear accidents.

Both PC-CREAM 08 and PACE use spatial data describing agricultural production and population distributions to calculate doses arising from atmospheric discharges. This report describes the data and methods used to create the required spatial data sets. The spatial data sets include the 28 countries that were member states of the European Union (EU28) between 1 July 2013 and 1 February 2020 as well as some additional countries and is referred to as EU+ (see Table 1). It should be noted that since the data was compiled the UK has left the European Union.

Table 1. Countries included in the EU+ spatial data sets

EU28 (1 July 2013 to 31 January 2020)	Additional countries
Austria	Albania
Belgium	Bosnia
Bulgaria	Iceland
Croatia	Macedonia
Cyprus	Montenegro
Czech Republic	Norway
Denmark	Serbia
Estonia	Switzerland
Finland	Turkey
France	
Germany	
Greece	
Hungary	
Ireland	
Italy	
Latvia	
Lithuania	
Luxembourg	
Malta	
Netherlands	
Poland	

EU28 (1 July 2013 to 31 January 2020)	Additional countries
Portugal	
Romania	
Slovakia	
Slovenia	
Spain	
Sweden	
United Kingdom[1]	

[1] The agricultural grids generated do not include production data for the Channel Islands or the Isle of Man. For PC-CREAM 08, the omission of these small regions will not be significant. For PACE it may be necessary to manually add estimates of production for these locations using the data in Appendix B.

2. Data requirements of PC-CREAM 08 and PACE

2.1 PC-CREAM 08

In PC-CREAM 08 the spatial data requirements depend upon the population for which the collective dose is to be calculated and the site where the release occurs. For example, to calculate the collective dose to the UK population following an atmospheric discharge the distribution of the UK population around the release point is needed, as well as the distribution across all countries of the agricultural production that is destined for consumption in the UK. Data sets for other sites and countries, and the aggregated region EU+, can also be created. The latter would include the population distribution of the EU+ countries around the release point and the distribution of agricultural production in all EU+ countries that is destined for consumption by the EU+ population. There is the potential to create many data sets for each site where a release occurs. For example, an agricultural production data set for Sizewell could be based on production in France that is consumed in the UK, or production in the UK that is consumed in France. Using the methodology described below a default collection of spatial data sets were created and others will be produced as and when they are needed.

The population and agricultural production data sets required by PC-CREAM 08 are in terms of quantities in each cell of a polar grid centred on the release point. The quantities are listed below. The exclusion of pig meat and chicken meat is because these animals are typically fed processed feeds that are not derived from the local area:

- population (number of people)
- cow milk (kg y^{-1})
- cow milk products (kg y^{-1})
- cow meat (kg y^{-1})
- cow liver (kg y^{-1})
- sheep meat (kg y^{-1})
- sheep liver (kg y^{-1})
- root vegetables (including potatoes) (kg y^{-1})
- green vegetables (including legumes) (kg y^{-1})
- fruit (hard fruit (sometimes called orchard fruit) and soft fruit) (kg y^{-1})
- cereals (kg y^{-1})

2.2 PACE

In PACE the population to be considered for the dose calculation determines the spatial data requirements. The data used to create the data sets for PC-CREAM 08 can be used in PACE provided the following modifications are made:

- cow milk products must be in terms of equivalent liquid milk (kg y^{-1})
- fruit is divided into soft fruit and hard fruit

In addition to the data used in the calculation of doses, PACE also requires the following spatial data for input to the economics calculations it carries out:

- milk producing cows (head)
- meat producing cows (head)
- meat producing sheep (head)
- grain producing area (hectares)
- potato producing area (hectares)
- sugar beet producing area (hectares)
- root vegetable producing area (hectares)
- green vegetable producing area (hectares)
- legume producing area (hectares)
- soft fruit producing area (hectares)
- hard fruit producing area (hectares)

3. Data sources

The principal sources used to develop the spatial data sets for agricultural production described in this report are Eurostat (Eurostat, 2018b), the Easy Comext trade database (Eurostat, 2018a) and FAOSTAT (FAO, 2014). The fundamental production data is based on FAOSTAT which publishes quantities of food specifically intended for human consumption and subdivides these into indigenous production and total imports and exports. FAOSTAT also publishes data on animal numbers and crop areas. However, FAOSTAT data are on a country by country basis and PC-CREAM 08 and PACE require a finer spatial resolution for dose calculation purposes. The disaggregation of agricultural production data from national to more local regions is carried out using Eurostat data. In addition, Eurostat data have been used to obtain values for the trade of agricultural products between EU countries and between EU countries and the rest of the world.

The Eurostat website holds agricultural production statistics for various Nomenclature of Territorial Units for Statistics (NUTS) levels. Data is available for all EU countries at a national level (NUTS 0), down to NUTS 2 level, the latter being broadly equivalent in size to a few UK counties. However, the level of detail available from this data set is not consistent across different foods, countries, NUTS levels and years. Consequently, an algorithm was used to select the NUTS level for use in the disaggregation process based on the completeness of the data set and a preference for the smaller NUTS regions where possible (refer to Section 4.2.9 for more information). Therefore, the effectiveness of the disaggregation of data from the national to the local scale varies. For this study the 2010 definition of the NUTS regions was used (Eurostat, 2011).

One of the important considerations in the development of spatial data sets for PC-CREAM 08 and PACE is to ensure that the total consumption of food at a national level, estimated from the data sets, is reasonable. This will ensure that the overall impact of the release is neither over nor under predicted. This is not considered in the Eurostat data set, which publishes agricultural production data reported by the member states and does not attempt to address omissions in the data. However, the FAOSTAT data is more complete in this regard because, where necessary, it includes estimates made by experts or using statistical methods to address gaps in the data sets. In addition, FAOSTAT includes countries that are outside of the EU28 but of interest to this project.

The European Environment Agency (EEA) website (European Environment Agency, 2017) provides a raster[2] map of agricultural land-use data, known as ‘CORINE land cover’, which is also used in the disaggregation process described in this report.

Data for population distributions is taken from the European Commission Global Human Settlement Population (GHS-POP) data source (see Section 4.1) in the form of a population density raster (European Commission, 2015; Florczyk and others, 2019).

The methodologies used to create the spatial data sets are described in the next sections and the implementation of these methodologies is described in Appendix A.

[2] Raster data is made up of pixels or grid cells with each pixel or grid cell having its own value.

4. Methodology for generating spatial data sets for PC-CREAM 08

This section describes the methodologies used to create population and food production data sets for EU+ countries as required by PC-CREAM 08. However, most of the data collected for PC-CREAM 08 can also be used for PACE. Details of the development of spatial data sets for PACE are presented in section 5.

4.1 Population

Population distributions in EU+ countries were derived from the European Commission Global Human Settlement Population (GHS-POP) data source (Florczyk and others, 2019). Files were downloaded from the GHS-POP website for the 2015 population at 1km resolution and based on the Mollweide coordinate system. The downloaded files were converted to the population in each cell of a 1 kilometre x 1 kilometre grid using ArcGIS Desktop™[3] software. The data is available for the whole world and population data sets can be created for all EU+ countries.

GHS-POP has been developed by disaggregating population from census or administrative areas to a grid using the density of built-up areas as provided by the Global Human Settlement Built-Up Layer (GHS-BUILT) data set. GSH-BUILT was developed using satellite imagery and describes the density of buildings in each grid square. Because of the sophisticated development process, no further disaggregation of the data for use in PC CREAM 08 and PACE is considered necessary and it is simply resampled onto the appropriate grids. Details of the processing steps used are given in Appendix A.

4.2 Agricultural production

This methodology is designed to be applicable to all foods but there are differences in the data used in the calculations because of what is available from Eurostat and FAOSTAT. The approach is intended to be robust in that final production totals for each country should not deviate significantly from the FAOSTAT values. The approach should also be repeatable in that the data sets can be updated in future to allow for changes in agricultural production. The intention is to calculate the human consumption of food within each country, taking into account both domestic and foreign production. The methodology is as follows.

The categories ‘production quantity’, ‘import quantity’ and ‘food’ were downloaded from commodity balance sheets in the ‘Food Balance’ section of the FAOSTAT Data web page for the foods of interest and for the years 2009 to 2011 (details are given for each food in sections 4.2.1 to 4.2.8). The FAOSTAT category ‘food’, also called ‘food supply quantity’, represents the amount of food consumed by the population of each country and is therefore most useful for the

[3] ArcGIS Desktop is trademark of ESRI (ESRI.com).

purposes of this study, although some manipulation is needed to determine where the food is produced. Using the FAOSTAT data, the home-grown food supply quantity for each EU+ country can be approximated using the following equation (FAOSTAT categories are given in single quotes):

$$\text{Home-grown food supply} = \text{Home-grown ratio} \times \text{Food supply quantity 'food'}$$

Where:

$$\text{Home-grown ratio} = \frac{\text{Production 'production quantity'}}{\text{Production 'production quantity'} + \text{Imports 'import quantity'}}$$

The ‘Home-grown food supply’ is the quantity of food consumed within a country that is produced within that country and it must be distributed appropriately. This is achieved using Eurostat data. This data may not represent the food item exactly but gives an indication of the spatial distribution of the food item. This is discussed further in Sections 4.2.1 to 4.2.8 but, using drinking milk as an example, FAOSTAT is used to obtain milk production for human consumption within each country and Eurostat provides the total production of liquid milk in the NUTS regions of each country. The latter can be used to estimate the spatial distribution of the former. Where possible the 10-year mean from 2005 to 2014 is calculated from the Eurostat data to provide a representative production distribution and to account for any discrepancies in the data.

The quantity of imported food consumed in an EU+ country is also required. This is calculated as follows:

$$\text{Imported food supply} = \text{Imported ratio} \times \text{Food supply quantity 'food'}$$

Where:

$$\text{Imported ratio} = \frac{\text{Imports 'import quantity'}}{\text{Production 'production quantity'} + \text{Imports 'import quantity'}}$$

The quantity of imported food must be allocated to the country of origin and this can be estimated using trade data available from Eurostat. To obtain a representative view of long-term trade a 10-year mean is calculated where possible using trade data from years 2005 to 2014. The reported trade data includes imports and exports for each EU28 country. Eurostat does not include import data for the additional countries listed in Table 1 but these can be estimated using the export data for the EU28 countries with which they trade. Imports between the countries of interest to this study are referred to as EU+ Imports.

It is also important to account for any imports of food that originate outside of the EU+ region as these are assumed to be uncontaminated. Imports originating outside the EU+ region are taken into account by adding together extra (transactions with all countries outside EU28) and intra

(transactions with all countries inside of the EU28) EU28 imports for each country (available from Eurostat), to get the total imports for that country, and subtracting the sum of all the imports to this country from the EU+ countries:

$$\text{Non EU+ imports} = (\text{Intra EU28 imports} + \text{Extra EU28 imports}) - \sum \text{EU+ imports}$$

It should be noted that if this calculation results in a negative value for Non EU+ imports then a value of zero is assumed. The total imports for each country are calculated by summing the imports received from other EU+ countries (Σ EU+ imports) and the Non EU+ imports. The fraction of imports derived from each trading partner is calculated. This ratio is applied to 'Imported food supply' to find out how much food consumed by one country is produced in another country. This production must then be distributed appropriately using Eurostat regional indicator data as described above.

The fraction of national production in each NUTS region is calculated using the following equation:

$$\text{Regional ratio} = \frac{\text{NUTS region 10 y mean for indicator data}}{\text{National 10 y mean for indicator data}}$$

The amount of home-grown food consumed from each NUTS region is:

$$\text{Home-grown food consumed from NUTS region} = \text{Home-grown food supply} \times \text{Regional ratio}$$

The amount of imported food consumed from each country is:

$$\text{Imported food from country Y} = \text{Imported food supply by X (FAOSTAT)} \times \frac{\text{Imports by X from Y (Eurostat)}}{\sum \text{imports by X (Eurostat)}}$$

The above equation is necessary because FAOSTAT total imports are not always equal to Eurostat total imports partly because of differences in the categorisation of traded products. The quantity of food originating from foreign NUTS regions can then be found:

$$\text{Imported food consumed from NUTS region in country Y} = \text{Imported food from country Y} \times \text{Regional ratio (for this NUTS region in country Y)}$$

As stated, this is a general overview of the methodology utilised; the exact methodology for each food type can differ slightly due to the availability of data. This is discussed further in sections 4.2.1 to 4.2.8.

For EU+ countries that are not part of EU28, Eurostat trade and production data can be incomplete across food types. To counter this, the following assumptions have been made.

Where insufficient trade data is available the imports to a non EU28 country are based solely on the exports from the EU28 to that country. Where a regional breakdown of production cannot be calculated, the production is assumed to be uniform across the country.

Finally, agricultural production data are allocated to appropriate production points based on the CORINE land cover raster (European Environment Agency, 2017). This is to ensure that production occurs at suitable locations and not, for example, in the middle of a city or wilderness. This process is described in Appendix A.

4.2.1 Cow's milk

This food category represents liquid cow's milk that is used for drinking. Data from FAOSTAT commodity balance sheets (Production Quantity, Import Quantity and Food) for 'Milk, Whole' has been used along with Eurostat data of regional collections of total liquid milk from farms and EU trade data. The general methodology described in section 4.2 was applied and details specific to this food type are presented here. The disaggregation of milk products to NUTS regions was carried out using total liquid milk production data from Eurostat. References to the data sources used are given in Table 2.

The annual consumption of cow's milk used for drinking by country MS that is produced in country MSX and NUTS region r, is calculated as follows (see Table 2 for explanation of terms): For all countries where consumption is considered, MS:

For all NUTS0, NUTS1 and NUTS2 regions r:
MSX = country to which this region r belongs
If MSX = MS (ie consumption of home-grown produce)
$ConReg_{MS,r} = (FoodSupply_{MS} \times ProdNat_{MS} / (ProdNat_{MS} + ImpNat_{MS})) \times MPReg_r / MPNat_{MS}$
Else (ie consumption of imported produce)
$ConReg_{MS,r} = (FoodSupply_{MS} \times ImpNat_{MS} / (ProdNat_{MS} + ImpNat_{MS})) \times (Imp_{MSXtoMS} / (ImpExtra_{MS} + ImpIntra_{MS})) \times MPReg_r / MPNat_{MSX}$

To provide some confidence in the data sets created, per caput intake rates have been calculated for every country. For the UK, the per caput intake rate calculated using this data set is 115 kg per year. This compares with a value of 95 kg per year from dietary surveys (Smith and Jones, 2003). The values compare reasonably well, and the difference can be attributed, at least in part, to wastage.

Table 2 Data sources for cow milk grid

Parameter	Description	Source
$ConReg_{MS,r}$	Annual consumption of milk used for drinking by country MS from production in NUTS region r. (kg y^{-1})	To be calculated
$ProdNat_{MS}$ $ImpNat_{MS}$ $FoodSupply_{MS}$	Domestic production of milk used for drinking in country MS Total national imports of milk by country MS Food supply quantity for milk used for drinking in country MS	FAOSTAT (Commodity Balances - Livestock and Fish Primary Equivalent) 2009 to 2011 mean Items: Milk, Whole; Milk, Skimmed Elements: Production quantity; Import quantity; Food Units: tonnes
$Imp_{MSXtoMS}$ $ImpExtra_{MS}$ $ImpIntra_{MS}$	Imports to country MS from country MSX $ImpExtra_{MS}$ imports to country MS from outside EU $ImpIntra_{MS}$ imports to country MS from inside EU	Eurostat Comext database – Imports DS-045409-EU Trade Since 1988 by HS2, 4, 6 and CN8 2005 to 2014 mean INDICATORS: QUANTITY_IN_100KG - QUANTITY_IN_100KG PRODUCT: 0401
$MPReg_r$ $MPNat_{MS}$ $MPNat_{MSX}$	Regional production of all milk on farms in country MSX National production of all milk on farms in country MS National production of all milk on farms in country MSX	Eurostat NUTS 2, database category = [agr_r_milkpr] 2005 to 2014 mean MILKITEM: Products obtained (1,000 t) DAIRYPROD: Raw cattles' milk from farm

4.2.2 Cow's milk products

For ingestion of cow's milk products, data from FAOSTAT commodity balance sheets (Food Supply Quantity, Production and Import Quantity) for 'Butter, Ghee, Cheese and Cream' has been used along with Eurostat data on regional collections of milk from farms and EU trade data. The general methodology described in section 4.2 was applied and details specific to this food type are presented here. The disaggregation of milk products to NUTS regions was carried out using total milk production data from Eurostat. References to the data sources used are given in Table 3.

The annual consumption of cow's milk products by country MS that is produced in country MSX and NUTS region r, is calculated as follows (see Table 3 for explanation of terms):

For all countries where consumption is considered, MS:

For all NUTS0, NUTS1 and NUTS2 regions r:
MSX = country for this region r
If MSX = MS
$ConReg_{MS,r} = (FoodSupply_{MS} \times ProdNat_{MS} / (ProdNat_{MS} + ImpNat_{MS})) \times MPReg_r / MPNat_{MS}$
Else
$ConReg_{MS,r} = (FoodSupply_{MS} \times ImpNat_{MS} / (ProdNat_{MS} + ImpNat_{MS})) \times (Imp_{MSXtoMS} / (ImpExtra_{MS} + ImpIntra_{MS})) \times MPReg_r / MPNat_{MSX}$

To provide some confidence in the data sets created, per caput intake rates have been calculated for each country. For the UK, the per caput intake rate calculated using this data set is 14.4 kg per year. This compares with a value of 20 kg per year for butter, cheese and other milk products from dietary surveys (Smith and Jones, 2003). The values compare reasonably well although in this case the intake rate based on survey data is higher than that based on production data. The probable reason is that the survey data include more milk products such as yoghurt. Consequently, there may be a slight underestimate in the quantities of milk products produced and any resulting doses calculated using this data set.

Table 3. Data sources for cow's milk products grid

Parameter	Description	Source
$ConReg_{MS,r}$	Annual consumption of milk products by country MS from production in NUTS region r. (kg y^{-1})	To be calculated
$ProdNat_{MS}$ $ImpNat_{MS}$ $FoodSupply_{MS}$	Domestic production of milk products in country MS Total national imports of milk products by country MS Food supply quantity for milk products in country MS	FAOSTAT (Commodity Balances - Livestock and Fish Primary Equivalent) 2009 to 2011 mean Items: Butter, Ghee; Cheese; Cream Elements: Production quantity; Import quantity; Food Units: tonnes
$Imp_{MSXtoMS}$ $ImpExtra_{MS}$ $ImpIntra_{MS}$	Imports to country MS from country MSX $ImpExtra_{MS}$ imports to country MS from outside EU $ImpIntra_{MS}$ imports to country MS from inside EU	Eurostat Comext database – Imports DS-045409-EU Trade Since 1988 by HS2, 4, 6 and CN8 2005 to 2014 mean INDICATORS: QUANTITY_IN_100KG - QUANTITY_IN_100KG PRODUCT: 0402, 0403, 0404, 0405 and 0406

Parameter	Description	Source
$MPReg_r$	Regional production of all milk on farms in country MSX	Eurostat NUTS 2, database category = [agr_r_milkpr]
$MPNat_{MS}$	National production of all milk on farms in country MS	2005 to 2014 mean MILKITEM: Products obtained (1,000 t)
$MPNat_{MSX}$	National production of all milk on farms in country MSX	DAIRYPROD: Raw cows' milk from farm

4.2.3 Cow and sheep meat (including liver)

For ingestion of cow and sheep meat, data from FAOSTAT commodity balance sheets (Food Supply Quantity, Production and Import Quantity) for 'Bovine Meat' and 'Mutton and Goat Meat' has been used along with Eurostat data on regional numbers of animals on farms and EU trade data. The general methodology described in section 4.2 was applied and details specific to this food type are presented here. The disaggregation of these animal products to NUTS regions was carried out using the number of live animals from Eurostat. References to the data sources used are given in Table 4.

For liver, the same methodology and data are used as for cow and sheep meat, but scaling factors are applied, one for cows and one for sheep, to account for the lower mass of liver compared to the whole carcass weight (Brown and Simmonds, 1995). The scaling factors are applied to the meat production quantities to calculate liver production quantities.

The annual consumption of meat or liver from cow or sheep by country MS that is produced in country MSX and NUTS region r, is calculated as follows (see Table 4 for explanation of terms):

For all countries where consumption is considered, MS:

For all NUTS0, NUTS1 and NUTS2 regions r:
MSX = country for this region r
If MSX = MS
$ConReg_{MS,r} = (FoodSupply_{MS} \times ProdNat_{MS} / (ProdNat_{MS} + ImpNat_{MS})) \times CNReg_r / CNNat_{MS}$
Else
$ConReg_{MS,r} = (FoodSupply_{MS} \times ImpNat_{MS} / (ProdNat_{MS} + ImpNat_{MS})) \times (Imp_{MSXtoMS} / (ImpExtra_{MS} + ImpIntra_{MS})) \times CNReg_r / CNNat_{MSX}$

To provide some confidence in the data sets created per caput intake rates have been calculated for each country. For the UK, the per caput intake rates for cow meat, cow liver, sheep meat and sheep liver calculated using these data sets are 18, 0.5, 4 and 0.2 kg per year, respectively. This compares with values of 15, 3 and 2 kg per year for cow meat, sheep meat and all offal from dietary surveys (Smith and Jones, 2003). The values compare reasonably well.

Table 4. Data sources for cow and sheep meat grids

Parameter	Description	Source
$ConReg_{MS,r}$	Annual consumption of meat or liver by country MS from production in NUTS region r. ($kg\ y^{-1}$)	To be calculated
$ProdNat_{MS}$ $ImpNat_{MS}$ $FoodSupply_{MS}$	Domestic production of meat products in country MS Total national imports of meat products by country MS Food supply quantity for meat products in country MS	FAOSTAT (Commodity Balances - Livestock and Fish Primary Equivalent) 2009 to 2011 mean Items: Bovine meat; or Mutton and Goat meat Elements: Production quantity; Import quantity; Food Units: tonnes
$Imp_{MSXtoMS}$ $ImpExtra_{MS}$ $ImpIntra_{MS}$	Imports to country MS from country MSX $ImpExtra_{MS}$ imports to country MS from outside EU $ImpIntra_{MS}$ imports to country MS from inside EU	Eurostat Comext database – Imports DS-045409-EU Trade Since 1988 by HS2, 4, 6 and CN8 2005 to 2014 mean INDICATORS: QUANTITY_IN_100KG - QUANTITY_IN_100KG PRODUCT: 0201 - MEAT OF BOVINE ANIMALS, FRESH OR CHILLED and 0202 - MEAT OF BOVINE ANIMALS, FROZEN or 0204 - MEAT OF SHEEP OR GOATS, FRESH, CHILLED OR FROZEN
$CNReg_r$ $CNNat_{MS}$ $CNNat_{MSX}$	Regional number of live bovine animals or sheep and goats on farms in country MSX National number of live bovine animals or sheep and goats on farms in country MS National number of live bovine animals or sheep and goats on farms in country MSX	Eurostat NUTS 2, database category = [agr_r_animal] 2005 to 2014 mean ANIMALS: Live bovine animals UNIT: Thousand head (animals) or ANIMALS: Live sheep UNIT: Thousand head (animals) and ANIMALS: Live goats UNIT: Thousand head (animals)

4.2.4 Potatoes

For ingestion of potatoes, data from FAOSTAT commodity balance sheets (Food Supply Quantity, Production and Import Quantity) for 'Potatoes and products' has been used along with Eurostat data for regional production of potatoes on farms and EU trade data. The general methodology described in section 4.2 was applied and details specific to this food type are presented here. The disaggregation of potatoes to NUTS regions was carried out using the harvested production of potatoes from Eurostat. References to the data sources used are given in Table 5.

For PC-CREAM 08 potato and root vegetable production are combined while PACE requires these to be separate.

The annual consumption of potatoes by country MS that is produced in country MSX and NUTS region r, is calculated as follows (see Table 5 for explanation of terms):

For all countries where consumption is considered, MS:

> For all NUTS0, NUTS1 and NUTS2 regions r:
> MSX = country for this region r
> If MSX = MS
> $ConReg_{MS,r} = (FoodSupply_{MS} \times ProdNat_{MS} / (ProdNat_{MS} + ImpNat_{MS})) \times AReg_r / ANat_{MS}$
> Else
> $ConReg_{MS,r} = (FoodSupply_{MS} \times ImpNat_{MS} / (ProdNat_{MS} + ImpNat_{MS})) \times (Imp_{MSXtoMS} / (ImpExtra_{MS} + ImpIntra_{MS})) \times AReg_r / ANat_{MSX}$

To provide some confidence in the data sets created per caput intake rates have been calculated for each country. For the UK, the per caput intake rate for potatoes calculated using this data set is 98 kg per year. This compares with a value of 50 kg per year for potatoes and potato products from dietary surveys (Smith and Jones, 2003). There is a factor of 2 between the estimates which is difficult to explain, but to some extent will be due to wastage.

Table 5. Data sources for potato grids

Parameter	Description	Source
$ConReg_{MS,r}$	Annual consumption of potatoes by country MS from production in NUTS region r. (kg y^{-1})	To be calculated
$ProdNat_{MS}$ $ImpNat_{MS}$ $FoodSupply_{MS}$	Domestic production of potatoes products in country MS Total national imports of potatoes products by country MS Food supply quantity for potatoes products in country MS	FAOSTAT (Commodity Balances - Crops Primary Equivalent) 2009 to 2011 mean Items: Potatoes and products Elements: Production quantity; Import quantity; Food Units: tonnes
$Imp_{MSXtoMS}$ $ImpExtra_{MS}$ $ImpIntra_{MS}$	Imports to country MS from country MSX $ImpExtra_{MS}$ imports to country MS from outside EU $ImpIntra_{MS}$ imports to country MS from inside EU	Eurostat Comext database DS-045409-EU Trade Since 1988 by HS2, 4, 6 and CN8 2005 to 2014 mean INDICATORS: QUANTITY_IN_100KG - QUANTITY_IN_100KG PRODUCT: 0701 - POTATOES, FRESH OR CHILLED
$AReg_r$ $ANat_{MS}$ $ANat_{MSX}$	Regional production area of potatoes on farms in country MSX National production area of potatoes on farms in country MS National production area of potatoes on farms in country MSX	Eurostat Crop statistics by NUTS 2 regions (from 2000 onwards), database category = [agr_r_acs] 2005 to 2014 mean CROPS: Potatoes (including seed potatoes) STRUCPRO: Harvested production (1,000 t)

4.2.5 Root vegetables

The FAOSTAT commodity balance sheets do not include a category representing human consumption of all the root vegetables of interest to this study. Key crops such as carrots, turnips and leeks are included in the general vegetable category. Therefore, the adopted approach is to use data from FAOSTAT commodity balance sheets (Food Supply Quantity, Production and Import Quantity) for the general 'Vegetable, other' category and determine how much of this can be allocated to root vegetables. This was estimated using the domestic production values for root vegetables and green vegetables and assuming the total food supply is broken down in the same ratio. Production data broken down by crop type is available from the FAOSTAT 'Production – Crops' data sets. This approach assumes that imports do not significantly affect the relative amounts of different vegetables in the food supply. The general

methodology described in section 4.2 is again applied to determine the fraction of the root vegetable food supply that is home grown and the fraction that is imported. The disaggregation of root vegetables to NUTS regions was carried out using the production area of fresh vegetables from Eurostat. References to the data sources used are given in Table 6.

As discussed in section 4.2.4, root vegetable and potato production are combined for PC-CREAM 08, while PACE requires these to be separate.

The annual consumption of root vegetables by country MS that is produced in country MSX and NUTS region r, is calculated as follows (see Table 6 for explanation of terms):

For all countries where consumption is considered, MS:

> For all NUTS0, NUTS1 and NUTS2 regions r:
> MSX = country for this region r
> If MSX = MS
> $ConReg_{MS,r} = (FoodSupply_{MS} \times ProdNat_{MS} / (ProdNat_{MS} + ImpNat_{MS})) \times FracRveg_{MS} \times AReg_r / ANat_{MS}$
> Else
> $ConReg_{MS,r} = (FoodSupply_{MS} \times ImpNat_{MS} / (ProdNat_{MS} + ImpNat_{MS})) \times FracRveg_{MS} \times (Imp_{MSXtoMS} / (ImpExtra_{MS} + ImpIntra_{MS})) \times AReg_r / ANat_{MSX}$

To provide some confidence in the data sets created per caput intake rates have been calculated for each country. For the UK, the per caput intake rate for root vegetables calculated using this data set is 19 kg per year. This compares with a value of 10 kg per year from dietary surveys (Smith and Jones, 2003). There is a factor of 2 difference in these results. Some of this can be accounted for by wastage, but it is also a very diverse group of vegetables which can introduce uncertainties in the categorisation.

Table 6. Data sources for root vegetable grids

Parameter	Description	Source
$ConReg_{MS,r}$	Annual consumption of root vegetable by country MS from production in NUTS region r. (kg y^{-1})	To be calculated
$ProdNat_{MS}$ $ImpNat_{MS}$ $FoodSupply_{MS}$	Domestic production of vegetables products in country MS Total national imports of vegetables products by country MS Food supply quantity for vegetables products in country MS	FAOSTAT (Commodity Balances - Crops Primary Equivalent) 2009 to 2011 mean Items: Vegetables, Other and Tomatoes and products Elements: Production quantity; Import quantity; Food Units: tonnes
$Imp_{MSXtoMS}$ $ImpExtra_{MS}$ $ImpIntra_{MS}$	Imports to country MS from country MSX $ImpExtra_{MS}$ imports to country MS from outside EU $ImpIntra_{MS}$ imports to country MS from inside EU	Eurostat Comext database DS-045409-EU Trade Since 1988 by HS2, 4, 6 and CN8 2005 to 2014 mean INDICATORS: QUANTITY_IN_100KG - QUANTITY_IN_100KG PRODUCT: 0703, 0706 (root vegetables)
$FracRveg_{MS}$	For each country sum all production of green vegetables and root vegetables. Calculate ratio of root vegetable to green vegetable production.	FAOSTAT (Production – Crops) 2009 to 2011 mean ItemName: all vegetables in ‘Vegetable, Other’ category ElementName: Production (tonnes)
$AReg_r$* $ANat_{MS}$* $ANat_{MSX}$*	Regional production area of fresh vegetables on farms in country MSX National production area of fresh vegetables on farms in country MS National production area of fresh vegetables on farms in country MSX	Eurostat Land-use number of farms and areas of different crops by agricultural size of farm (UAA) and NUTS 2 regions, database category = [ef_oluaareg] 2005, 2007, 2010 and 2013 mean INDIC_EF: ha Fresh vegetables, melons, strawberries AGRAREA: Total

* Eurostat regional statistics are very sparse for root vegetables and so data for green vegetables is used instead. The assumption being that the production of root vegetables and green vegetables have similar distributions.

4.2.6 Green vegetables

The FAOSTAT commodity balance sheets do not include a category representing human consumption of all the green vegetables of interest to this study. Key green vegetable crops are included in the general vegetable category. Therefore, the adopted approach is to use data from FAOSTAT commodity balance sheets (Food Supply Quantity, Production and Import Quantity) for the general 'Vegetable, other' category and determine how much of this can be allocated to green vegetables. This was estimated using the domestic production values for green vegetables and root vegetables and assuming the food supply is broken down in the same ratio. Production data broken down by crop type is available from the FAOSTAT 'Production – Crops' data sets.

This approach assumes that imports do not significantly affect the relative amounts of different vegetables in the food supply. The general methodology described in section 4.2 is again applied to determine the fraction of the green vegetable food supply that is home grown and the fraction that is imported. The disaggregation of green vegetables to NUTS regions was carried out using the production area of fresh vegetables from Eurostat. References to the data sources used are given in Table 7.

For both PC-CREAM 08 and PACE the green vegetable category includes leafy green vegetables and leguminous vegetables.

The annual consumption of green vegetables by country MS that is produced in country MSX and NUTS region r, is calculated as follows (see Table 7 for explanation of terms):
For all countries where consumption is considered, MS:

For all NUTS0, NUTS1 and NUTS2 regions r:
MSX = country for this region r
If MSX = MS
$ConReg_{MS,r} = (FoodSupply_{MS} \times ProdNat_{MS} / (ProdNat_{MS} + ImpNat_{MS})) \times FracGveg_{MS} \times AReg_{r} / ANat_{MS}$
Else
$ConReg_{MS,r} = (FoodSupply_{MS} \times ImpNat_{MS} / (ProdNat_{MS} + ImpNat_{MS})) \times FracGveg_{MS} \times (Imp_{MSXtoMS} / (ImpExtra_{MS} + ImpIntra_{MS})) \times AReg_{r} / ANat_{MSX}$

To provide some confidence in the data sets created per caput intake rates have been calculated for each country. For the UK, the per caput intake rate for green vegetables calculated using this data set is 56 kg per year. This compares with a value of about 40 kg per year from dietary surveys (Smith and Jones, 2003). These results are in reasonable agreement if factors such as wastage are considered.

Table 7. Data sources for green vegetables grids

Parameter	Description	Source
$ConReg_{MS,r}$	Annual consumption of green vegetables by country MS from production in NUTS region r. (kg y^{-1})	To be calculated
$ProdNat_{MS}$ $ImpNat_{MS}$ $FoodSupply_{MS}$	Domestic production of vegetables products in country MS Total national imports of vegetables products by country MS Food supply quantity for vegetables products in country MS	FAOSTAT (Commodity Balances - Crops Primary Equivalent) 2009 to 2011 mean Items: Vegetables, Other Elements: Production quantity; Import quantity; Food Units: tonnes
$Imp_{MSXtoMS}$ $ImpExtra_{MS}$ $ImpIntra_{MS}$	Imports to country MS from country MSX $ImpExtra_{MS}$ imports to country MS from outside EU $ImpIntra_{MS}$ imports to country MS from inside EU	Eurostat Comext database DS-045409-EU Trade Since 1988 by HS2, 4, 6 and CN8 2005 to 2014 mean INDICATORS: QUANTITY_IN_100KG - QUANTITY_IN_100KG PRODUCT 0702, 0704, 0705, 0707 and 0708 (green vegetables)
$FracGveg_{MS}$	For each country sum all production of green vegetables and root vegetables. Calculate ratio of green vegetable to root vegetable production.	FAOSTAT (Production – Crops) 2009 to 2011 mean ItemName: all vegetables in ‘Vegetable, Other’ category ElementName: Production (tonnes)
$AReg_{r}$ $ANat_{MS}$ $ANat_{MSX}$	Regional production area of fresh vegetables on farms in country MSX National production area of fresh vegetables on farms in country MS National production area of fresh vegetables on farms in country MSX	Eurostat Land-use number of farms and areas of different crops by agricultural size of farm (UAA) and NUTS 2 regions, database category = [ef_oluaareg] 2005, 2007, 2010 and 2013 mean INDIC_EF: ha Fresh vegetables, melons, strawberries AGRAREA: Total

4.2.7 Fruit

The FAOSTAT commodity balance sheets do not include a category representing human consumption of all the fruit crops of interest to this study. Therefore, the adopted approach is to use data from FAOSTAT commodity balance sheets (Food Supply Quantity, Production and

Import Quantity) for several fruit types (Table 8). The general methodology described in section 4.2 is applied to every fruit category and then the total home grown food supply and imported food supply are calculated by summing over the fruit types. The disaggregation of fruit to NUTS regions was carried out using the production area of permanent crops from Eurostat. Eurostat states that permanent crops mainly consist of fruit and berry trees, bushes, vines and olive trees. References to the data sources used are given in Table 8.

For PC-CREAM 08 the fruit category includes both soft fruit and hard fruit while PACE requires these to be separate.

The annual consumption of fruit by country MS that is produced in country MSX and NUTS region r, is calculated as follows (see Table 8 for explanation of terms):

For all countries where consumption is considered, MS:

For all NUTS0, NUTS1 and NUTS2 regions r:
MSX = country for this region r
If MSX = MS
$ConReg_{MS,r} = (FoodSupply_{MS} \times ProdNat_{MS} / (ProdNat_{MS} + ImpNat_{MS})) \times AReg_r / ANat_{MS}$
Else
$ConReg_{MS,r} = (FoodSupply_{MS} \times ImpNat_{MS} / (ProdNat_{MS} + ImpNat_{MS})) \times (Imp_{MSXtoMS} / (ImpExtra_{MS} + ImpIntra_{MS})) \times AReg_r / ANat_{MSX}$

To provide some confidence in the data sets created per caput intake rates have been calculated for each country. For the UK, the per caput intake rate for fruit calculated using this data set is 53 kg per year. This compares with a value of about 40 kg per year from dietary surveys (Smith and Jones, 2003). These results are in reasonable agreement if factors such as wastage are considered.

Table 8. Data sources for fruit grids

Parameter	Description	Source
$ConReg_{MS,r}$	Annual consumption of fruit by country MS from production in NUTS region r. (kg y^{-1})	To be calculated
$ProdNat_{MS}$	domestic production of fruit products in country MS	FAOSTAT (Commodity Balances - Crops Primary Equivalent)
$ImpNat_{MS}$	total national imports of fruit products by country MS	2009 to 2011 mean
$FoodSupply_{MS}$	food supply quantity for fruit products in country MS	

Parameter	Description	Source
		Items: Apples and products, Bananas, Citrus, Other, Dates, Fruits, Other, Grapefruit and products, Grapes and products (excluding wine), Lemons, limes and products, Olives (including preserved), Oranges, Mandarines, Pineapples and products and Plantains. Elements: Production quantity; Import quantity; Food Units: tonnes
$Imp_{MSXtoMS}$ $ImpExtra_{MS}$ $ImpIntra_{MS}$	imports to country MS from country MSX $ImpExtra_{MS}$ imports to country MS from outside EU $ImpIntra_{MS}$ imports to country MS from inside EU	Eurostat Comext database DS-045409-EU Trade Since 1988 by HS2, 4, 6 and CN8 2005 to 2014 mean INDICATORS: QUANTITY_IN_100KG - QUANTITY_IN_100KG PRODUCT 0803, 0804, 0805, 0806, 0807, 0808, 0809, 0810 and 0813 (fruit)
$AReg_r$ $ANat_{MS}$ $ANat_{MSX}$	regional production area of permanent crops on farms in country MSX national production area of permanent crops on farms in country MS national production area of permanent crops on farms in country MSX	Eurostat Permanent crops: number of farms and areas by size of permanent crop area and NUTS 2 regions, database category = [ef_popermreg] 2005, 2007, 2010 and 2013 mean CROPAREA: Total INDIC_EF: ha: Permanent crops

4.2.8 Cereals and rice

The FAOSTAT commodity balance sheets do not include a category representing human consumption of all cereal crops of interest to this study. Therefore, the adopted approach is to use data from FAOSTAT commodity balance sheets (Food Supply Quantity, Production and Import Quantity) for several cereal types (Table 9). The general methodology described in section 4.2 is applied to each cereal category and then the total home grown food supply and imported food supply are calculated by summing over the cereal types. The disaggregation of cereal to NUTS regions was carried out using the production area of wheat and rice on farms from Eurostat. References to the data sources used are given in Table 9.

The annual consumption of cereals by country MS that is produced in country MSX and NUTS region r, is calculated as follows (see Table 9 for explanation of terms):

For all countries where consumption is considered, MS:

For all NUTS0, NUTS1 and NUTS2 regions r:
MSX = country for this region r
If MSX = MS
$ConReg_{MS,r} = (FoodSupply_{MS} \times ProdNat_{MS} / (ProdNat_{MS} + ImpNat_{MS})) \times AReg_r / ANat_{MS}$
Else
$ConReg_{MS,r} = (FoodSupply_{MS} \times ImpNat_{MS} / (ProdNat_{MS} + ImpNat_{MS})) \times (Imp_{MSXtoMS} / (ImpExtra_{MS} + ImpIntra_{MS})) \times AReg_r / ANat_{MSX}$

To provide some confidence in the data sets created per caput intake rates have been calculated for each country. For the UK, the per caput intake rate for cereals and rice calculated using this data set is 111 kg per year. This compares with a value of about 50 kg per year from dietary surveys (Smith and Jones, 2003). The bulk of the cereal consumption in the UK is derived from wheat flour, and statistics (UK Flour Millers) show that in 2014 to 2015, 5.4 10^9kg of flour were produced of which the bulk (68%) was used for making white bread and 32% for food ingredients, starch manufacture and other purposes. If it is assumed that all this flour was consumed by the UK population then this suggests a per caput intake of about 80kg per year. If imports of wheat-based products are considered along with the consumption of other types of cereals then this value would increase, suggesting the value of 111 kg per year is not unreasonable. In addition, some food would be wasted between production and consumption.

Table 9. Data sources for cereal grids

Parameter	Description	Source
$ConReg_{MS,r}$	Annual consumption of cereals by country MS from production in NUTS region r. (kg y^{-1})	To be calculated
$ProdNat_{MS}$ $ImpNat_{MS}$ $FoodSupply_{MS}$	Domestic production of cereals products in country MS Total national imports of cereals products by country MS Food supply quantity for cereals products in country MS	FAOSTAT (Commodity Balances - Crops Primary Equivalent) 2009 to 2011 mean Items: Wheat and products, Barley and products, Maize and products, Cereals, other, Rice (Paddy Equivalent), Oats, Millet and products, Brans. Elements: Production quantity; Import quantity; Food Units: tonnes

Parameter	Description	Source
$Imp_{MSXtoMS}$ $ImpExtra_{MS}$ $ImpIntra_{MS}$	Imports to country MS from country MSX $ImpExtra_{MS}$ imports to country MS from outside EU $ImpIntra_{MS}$ imports to country MS from inside EU	Eurostat Comext database DS-045409-EU Trade Since 1988 by HS2, 4, 6 and CN8 2005 to 2014 mean INDICATORS: QUANTITY_IN_100KG - QUANTITY_IN_100KG PRODUCT: 1001, 1002, 1003, 1004, 1005 and 1006 (cereals)
$AReg_r$ $ANat_{MS}$ $ANat_{MSX}$	Regional production area of wheat and rice on farms in country MSX National production area of wheat and rice on farms in country MS National production area of wheat and rice on farms in country MSX	Eurostat Crop statistics by NUTS 2 regions (from 2000 onwards), database category = [agr_r_acs] 2005 to 2014 mean CROPS: C1110 common wheat and spelt, C1120 durum wheat, C1200 rye and winter cereal mixtures, C1300 barley, C1400 oats and spring cereal mixtures, and C1500 grain maize and corn cob mix. STRUCPRO: Harvested production (1,000 t)

4.2.9 Data manipulation and ArcGIS

The data sets described in sections 4.2.1 to 4.2.8 were input to ArcGIS where production was allocated to the relevant NUTS regions, and land-use types were taken into consideration. However, before this could be done the quality of the data used for disaggregation to NUTS regions was assessed because, as previously discussed, this data were incomplete for some countries and foods. This process was automated using a Python script to calculate the total production in each country based on disaggregation by NUTS 1 and NUTS 2 regions and compare these values with national production. If the total production based on disaggregation by NUTS 2 regions was within an acceptable tolerance of the national production value, then the regional breakdown by NUTS 2 regions was used. If this was not the case the total production based on the NUTS 1 regions was compared in the same way. If NUTS 1 regions could not be used, then the national production data was used and disaggregation at this stage was not possible. For each country, the Python script outputs the production data and corresponding NUTS regions for each food type. This data is then input to ArcGIS for further manipulation. This is described in more detail in Appendix A, but essentially involves the allocation of production data to appropriate NUTS regions while taking into account the type of land-use. The final step for data destined for use in PC-CREAM 08 is to allocate the production data to the sectors of a polar grid around the site of interest, that is, the point of discharge, this is also described in Appendix A.

5. Methodology for generating PACE spatial data

This section describes the methodologies used to create population and food production data sets required by PACE.

5.1 Population

The population data sets created for PACE are derived from the same data sources as used for PC-CREAM 08 (Section 4.1). Details of the processing steps used are given in Appendix A.

5.2 Agricultural production

The calculations of collective and per caput ingestion doses in PACE require data defining the amount and location of food produced for human consumption. This information is essentially the same as that derived for PC-CREAM 08 although there are some differences. For PACE the food groups are cow meat, cow liver, cow milk (total liquid for drinking and milk products), sheep meat, sheep liver, grain, green vegetables (including legumes), hard fruit, soft fruit, potatoes and, in a separate category, root vegetables. Therefore, the key differences to PC-CREAM 08 are the requirements to use total liquid milk from cows and to have separate categories for hard and soft fruit. The methods used to address these differences are described below.

5.2.1 Cow milk products

For PACE, cow milk products are calculated in the same way as described in Section 4.2.2 for PC-CREAM 08 except that the mass of the liquid milk used to manufacture the milk products is needed. This is calculated assuming the following conversion factors forkg of liquid milk perkg of product: 20 for butter and ghee, 10 for cheese and cream (Defra, 2019). This reference assumes 2 litres of cream are required to make 1 kg of butter, if it is then assumed that about 10 litres of whole milk are required to make 1 litre of cream (whole milk is about 3.5% fat and cream is about 35% fat) the whole milk to butter conversion factor is 20. Based on this approach the total quantity of liquid milk used in the manufacture of milk products that are consumed in the UK is estimated to be about 1.1 10^{10} kg y^{-1}. In the UK in 2013 about 6.2 10^{9} kg of domestically produced liquid milk were used in the manufacture of milk products (Defra and others, 2018). However, FAOSTAT data indicates that almost half of the butter and cheese consumed in the UK was imported and hence the value of 1.1 10^{10} kg y^{-1} quoted above seems reasonable.

5.2.2 Soft fruit

For soft fruit the approach is to use data from FAOSTAT commodity balance sheets (Food Supply Quantity, Production and Import Quantity) for category ‘Fruit, other’ which includes soft

fruit as well as a variety of other fruit types. The general methodology described in section 4.2 is applied to this fruit category. However, to determine the quantity of this category that is comprised of soft fruit an additional scaling factor is applied. This scaling factor is calculated using the FAOSTAT 'Production – Crops' data set, which is available for a range of soft fruit categories namely: Berries nes (not elsewhere specified), Currants, Gooseberries, Raspberries, Strawberries, Cranberries and Blueberries. The production of these fruits is summed and divided by the production of the 'Fruits, other' category to obtain the required ratio. The trade data is again taken from Easy Comext (Eurostat, 2018a) but is only for the soft fruit category and data used to disaggregate national production by NUTS region is the same as that used for total fruit, that is, the production area of permanent crops (Section 4.2.7). References to the data sources used are given in Table 10.

The annual consumption of soft fruit by country MS that is produced in country MSX and NUTS region r, is calculated as follows (see Table 10 for explanation of terms):

For all countries where consumption is considered, MS:

For all NUTS0, NUTS1 and NUTS2 regions r:
MSX = country for this region r
If MSX = MS
$ConReg_{MS,r} = (FoodSupply_{MS} \times ProdNat_{MS} / (ProdNat_{MS} + ImpNat_{MS})) \times (ProdNatB_{MS} / ProdNat_{MS}) \times AReg_r / ANat_{MS}$
Else
$ConReg_{MS,r} = (FoodSupply_{MS} \times ImpNat_{MS} / (ProdNat_{MS} + ImpNat_{MS})) \times (Imp_{MSXtoMS} / (ImpExtra_{MS} + ImpIntra_{MS})) (ProdNatB_{MSX} / ProdNat_{MSX}) \times AReg_r / ANat_{MSX}$

To provide some confidence in the data sets created per caput intake rates have been calculated for each country. For the UK, the per caput intake rate for soft fruit calculated using this data set is 3.5 kg per year. This compares to a value of about 2.3 kg per year in 2015 for the 2 dominant soft fruits, strawberries and raspberries (Defra, 2017).

Table 10. Data sources for fruit grids

Parameter	Description	Source
$ConReg_{MS,r}$	Annual consumption of soft fruit by country MS from production in NUTS region r. (kg y^{-1})	To be calculated

Parameter	Description	Source
$ProdNat_{MS}$ $ImpNat_{MS}$ $FoodSupply_{MS}$	Domestic production of fruit products in country MS (or MSX) Total national imports of fruit products by country MS Food supply quantity for fruit products in country MS	FAOSTAT (Commodity Balances - Crops Primary Equivalent) 2009 to 2011 mean Items: Apples and products, Bananas, Citrus, Other, Dates, Fruits, Other, Grapefruit and products, Grapes and products (excluding wine), Lemons, limes and products, Olives (including preserved), Oranges, Mandarins, Pineapples and products and Plantains. Elements: Production quantity; Import quantity; Food Units: tonnes
$Imp_{MSXtoMS}$ $ImpExtra_{MS}$ $ImpIntra_{MS}$	Imports to country MS from country MSX $ImpExtra_{MS}$ imports to country MS from outside EU $ImpIntra_{MS}$ imports to country MS from inside EU	Eurostat Comext database DS-045409-EU Trade Since 1988 by HS2, 4, 6 and CN8 2005 to 2014 mean INDICATORS: QUANTITY_IN_100KG - QUANTITY_IN_100KG PRODUCT 0810
$ProdNatB_{MS}$	Domestic production of berries in country MS (or MSX)	FAOSTAT ‘Production – Crops’ data set Production Berries nes Production Currants Production Gooseberries Production Raspberries Production Strawberries Production Cranberries Production Blueberries Units: tonnes
$AReg_r$ $ANat_{MS}$ $ANat_{MSX}$	Regional production area of permanent crops on farms in country MSX National production area of permanent crops on farms in country MS National production area of permanent crops on farms in country MSX	Eurostat Permanent crops: number of farms and areas by size of permanent crop area and NUTS 2 regions, database category = [ef_popermreg] 2005, 2007, 2010 and 2013 mean CROPAREA: Total INDIC_EF: ha: Permanent crops

5.3 Economics spatial inputs

PACE uses the model COCO-2 (Higgins and others, 2008) to estimate the economic consequences of an accident including consequences to agricultural activity. For these agricultural consequences, PACE uses data that is not required by PC-CREAM 08. This data is in terms of the number of head of livestock or the number of hectares of crops. The food groups are cow meat, cow milk, sheep meat, grain, green vegetables (excluding legumes), legumes, hard fruit, soft fruit, potatoes, root vegetables and sugar beet.

FAOSTAT is a useful source for this data on a national level and disaggregation to smaller regions could be carried out using data from Eurostat as described above. However, PACE also requires spatial data representing industrial, commercial and tourism activities. Such data is not readily available, and therefore, to ensure that the economics data used in PACE is consistent across all activities, the agricultural data set used to determine economic consequences has not been updated.

6. Output

6.1 PACE

This section compares some of the revised population and agricultural production data sets with those previously used in PACE.

Figure 1 shows the new population data for Europe described in Section 4.1 plotted as a map to illustrate the coverage and resolution. The distribution is as expected and major conurbations such as London, Paris and Madrid can be seen clearly. In the far north of the UK, in Sweden and in Estonia there are unexpected zones of low but uniform population. These artifacts are present in the underlying GHS-POP data set and is likely to represent lack of spatial resolution in the underlying census or administrative units from which population numbers are drawn. Typically, where population is low, such units are large to preserve anonymity. A similar effect can be seen in Iceland but on a larger scale and may be due to the same issues or, because GHS includes remote sensed imagery to define human settlements, it is possible that process is mis-classifying the large areas of bare rock as settlements. Whatever the reason, it is judged that these regions are sufficiently remote, and the population numbers low, that these artifacts are not important for PACE or PC-CREAM 08.

Figures 2 to 4 are examples of the new agricultural production data sets to illustrate the coverage and resolution. Figures 2 and 3 show, respectively, the quantities of cow's milk used for drinking and green vegetables that are produced in the EU+ countries for consumption in EU+ countries. Figure 4 shows the quantities of grain that are produced in EU+ countries for UK consumption, the predominance of UK production for UK consumption is clear.

Figure 1. Population density (2015) derived from GHS-POP and reformatted for PACE on a 1 km square grid

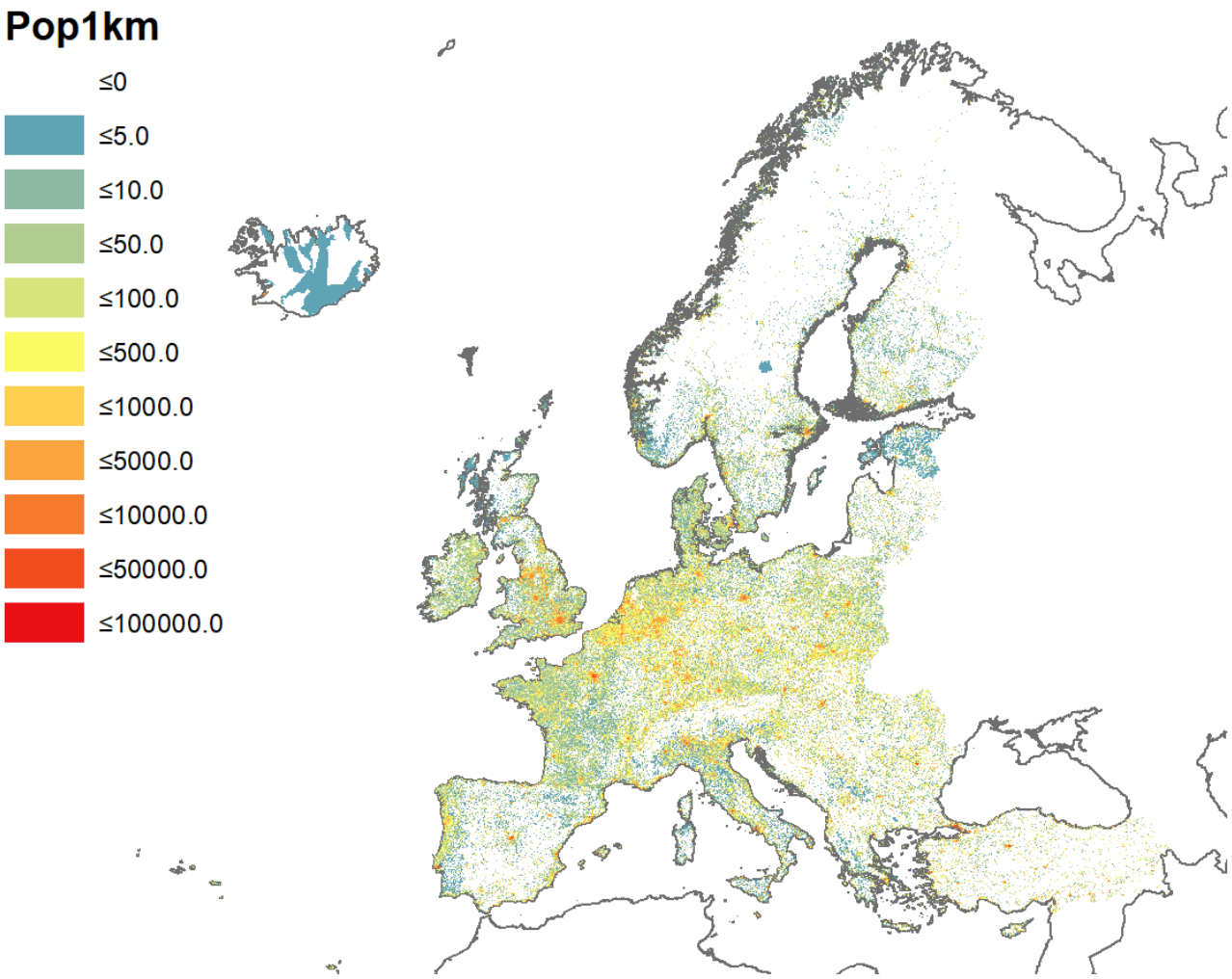


Figure 2. Milk used as drinking milk kg km^{-2} (EU+ produced, EU+ consumed) reformatted for PACE on a 2 km square grid

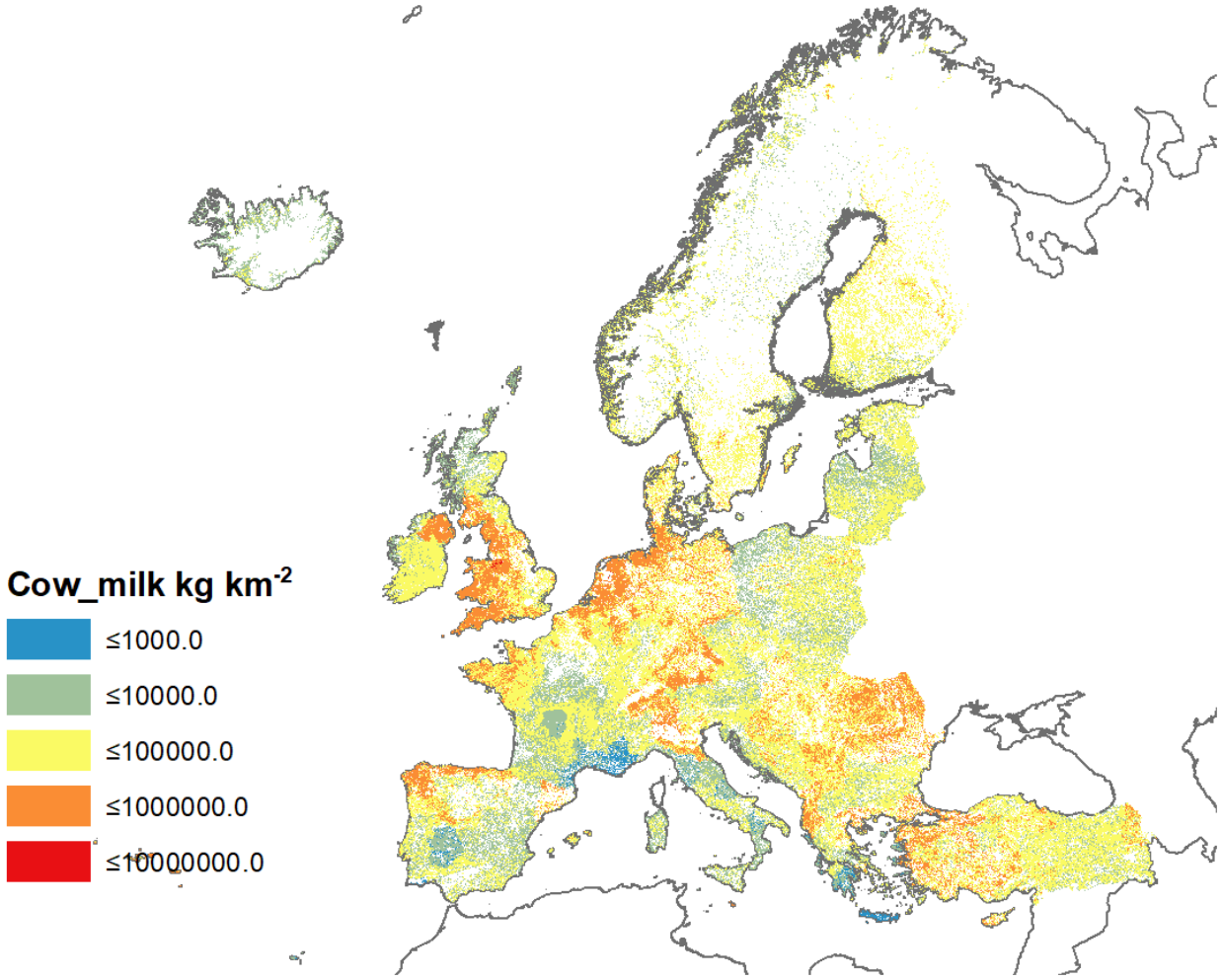


Figure 3. Green vegetable production kg km^{-2} (EU+ produced, EU+ consumed) reformatted for PACE on a 2 km square grid

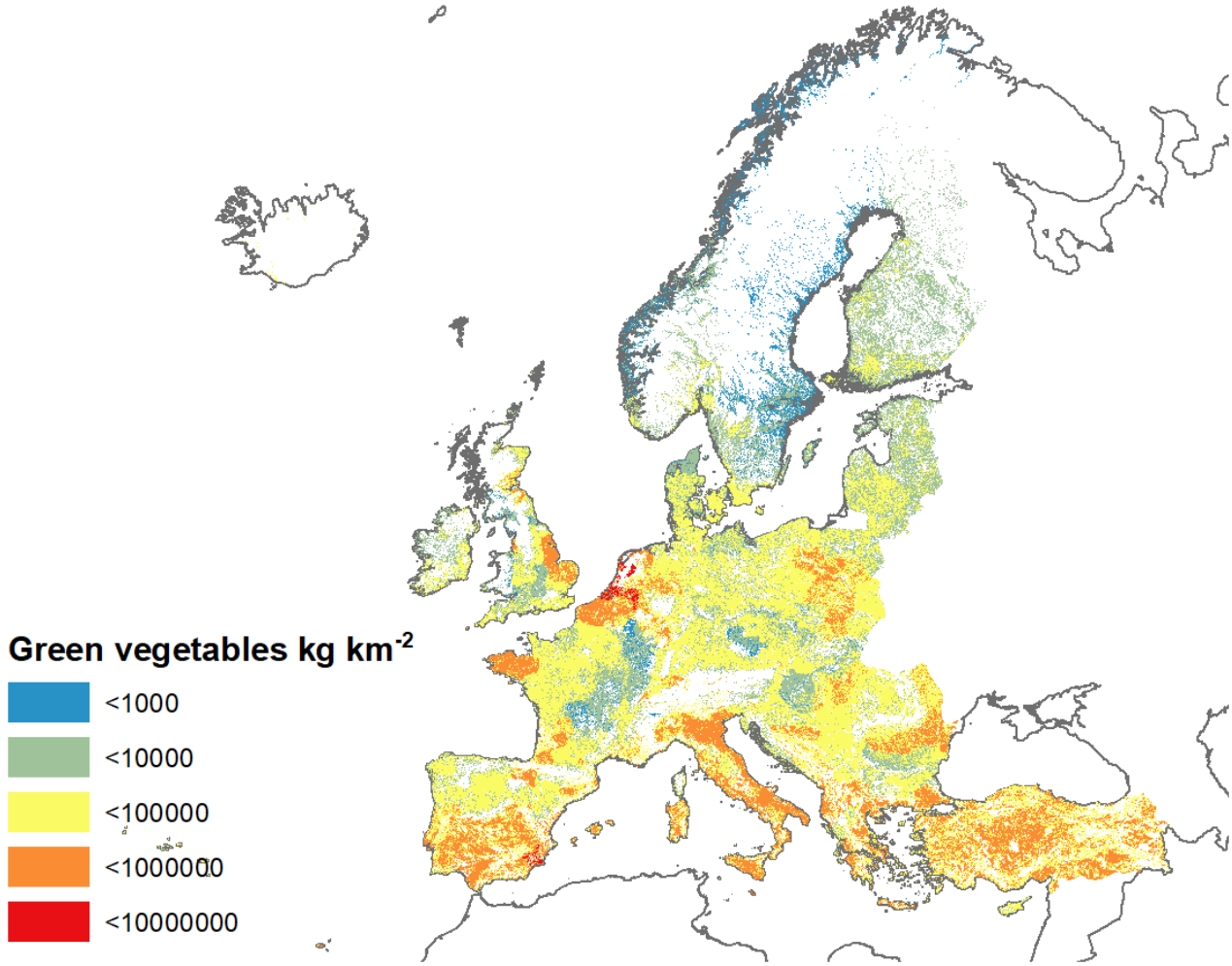


Figure 4. Grain production kg km^{-2} (EU+ produced, UK consumed) reformatted for PACE on a 2 km square grid

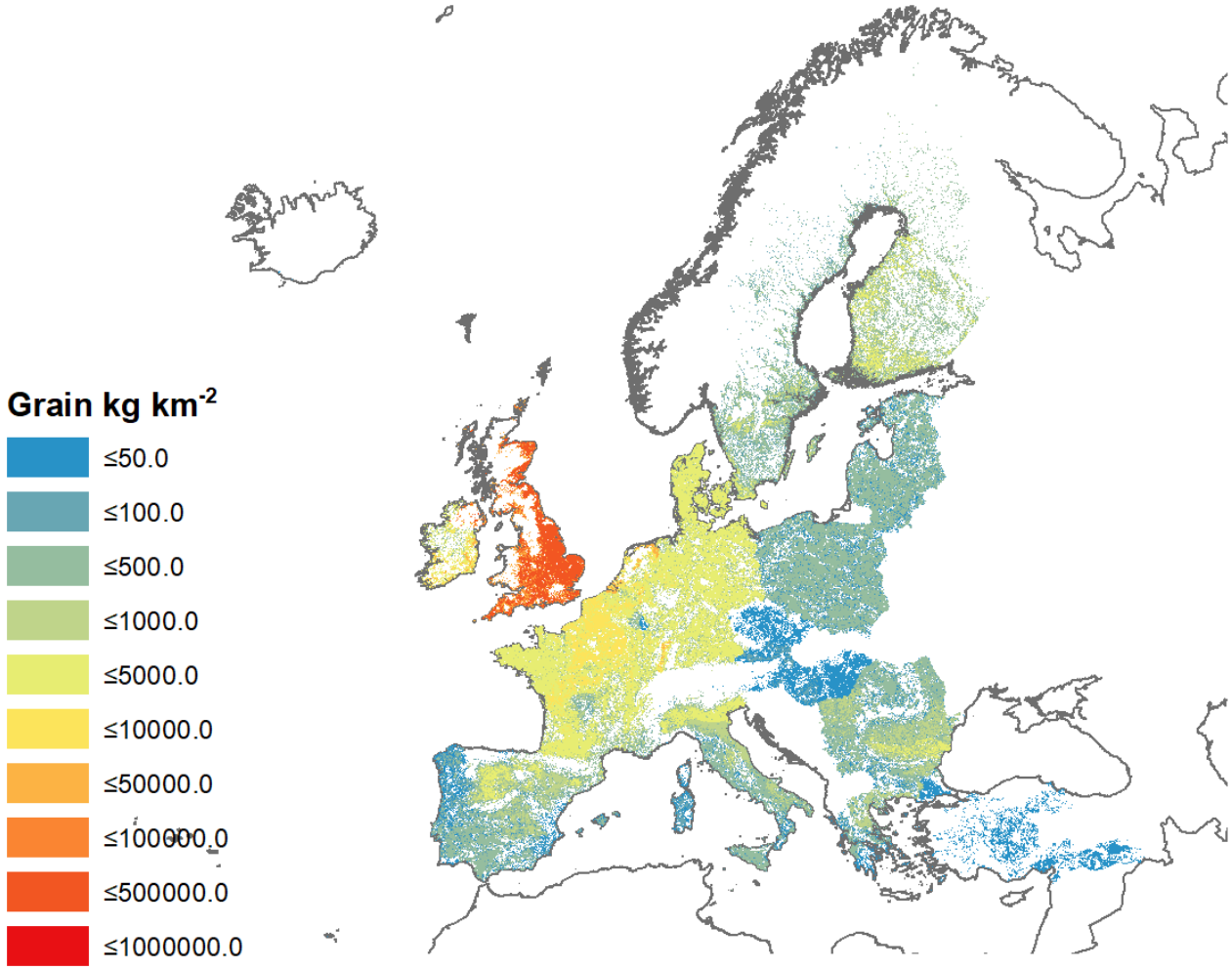


Table 11 compares the UK population and agricultural production from the existing and revised data sets used in PACE. Although both data sets are based on the UK agricultural census, differences are expected because the underlying methodologies used to interpolate the raw data are different, as are the time periods and regions represented.

The previous agricultural production data set is derived from agricultural information compiled by the EDINA National Data Centre at Edinburgh University for 2003 and does not include Northern Ireland but is augmented with data for the Channel Islands. It includes production in the UK that is consumed in the UK. The revised data set described in this report represents the period 2009 to 2011 and includes Northern Ireland but not the Channel Islands. Neither set includes the Isle of Man. Appendix B gives suitable data from other sources for the Isle of Man and Channel Islands that could be incorporated. There are 2 variants to the new data set, one giving the UK production that is consumed in the UK (UK - UK), and the other giving the EU+ production that is consumed in the EU+ countries (EU+ - EU+). For the purposes of the comparison in Table 11 the UK production has been extracted from the (EU+ - EU+) data set to produce the UK production that is consumed in the EU+ countries (UK - EU+).

Generally, the agreement is good, and it can be seen in Table 11 that the majority of UK production is for domestic consumption. The largest apparent increases in production are for cow meat and cow liver. Some of this difference is due to the contribution from Northern Ireland which is not present in the previous data set. However, this only accounts for about 15% of the revised UK production estimate. Another reason for the difference is that the meat and liver production values for the previous data set were derived from herd numbers which introduced uncertainties into the calculations because the number of animals being slaughtered annually and the yield of product from each animal had to be estimated. Therefore, the FAOSTAT data for UK cow meat production is considered more robust and are supported by calculations of per caput intake rates which compare well with national diet surveys (Section 4.2.3). There are also notable differences in the total production of root vegetables and soft fruit which have changed by factors of about 0.5 and 2, respectively. One reason for the difference in root vegetable production is that sugar beet was included in the previous data set but has been omitted from the revised one because this crop is mainly used for animal feed or refined for sugar. For fruit, the difference is partly due to a recognised increase in soft fruit production in the UK between 2003 and 2013 of about 40% (FAO, 2014). The per caput intake rates derived from the FAOSTAT data suggest the new data set is a good representation of UK agricultural production for root vegetables and soft fruit (Sections 4.2.5 and 5.2.2).

The original population data set is from the National Population Database, developed by the HSL on behalf of HSE (HSE, 2005), and is based on the 2001 UK Census. The new population data set uses the 2011 census and other information to give an estimate adjusted for 2015. Both sets include Northern Ireland, the Isle of Man, and the Channel Islands. The increase seen in the new data reflects the increase in the UK population between 2001 and 2015.

Table 11. Comparison of UK agricultural production between previous and revised PACE data sets. The factor is calculated as revised or previous

EDINA Agcensus		**New FAO Stat derived data**				
Field	**(kg)**	**Field**	**UK-UK (kg)**	**Factor**	**UK-EU+ (kg)**	**Factor**
D_Cow_Milk_Drink	$6.26\ 10^{9}$	Cow_milk	$6.97\ 10^{9}$	1.1	$7.02\ 10^{9}$	1.1
D_Cow_Milk_ Products	$6.24\ 10^{9}$	Cow_milk_product_ liquid	$5.50\ 10^{9}$	0.88	$6.23\ 10^{9}$	1.0
D_Cow_Meat	$2.79\ 10^{8}$	Cow_meat	$7.30\ 10^{8}$	2.6	$7.82\ 10^{8}$	2.8
D_Cow_Liver	$1.12\ 10^{7}$	Cow_liver	$1.90\ 10^{7}$	1.7	$2.04\ 10^{7}$	1.8
D_Sheep_Meat	$2.10\ 10^{8}$	Sheep_meat	$2.30\ 10^{8}$	1.1	$2.98\ 10^{8}$	1.4
D_Sheep_Liver	$1.12\ 10^{7}$	Sheep_liver	$1.02\ 10^{7}$	0.91	$1.32\ 10^{7}$	1.2
D_Grain	$6.94\ 10^{9}$	Grain	$5.73\ 10^{9}$	0.83	$6.18\ 10^{9}$	0.89
D_Potato	$4.36\ 10^{9}$	Potato	$4.96\ 10^{9}$	1.1	$5.27\ 10^{9}$	1.2
D_Root_Veg	$1.23\ 10^{9}$	Root_veg	$6.36\ 10^{8}$	0.52	$6.65\ 10^{8}$	0.54
D_Green_Veg_and_Legume	$1.04\ 10^{9}$	Green_veg	$1.30\ 10^{9}$	1.3	$1.36\ 10^{9}$	1.3
D_Soft_Fruit	$7.17\ 10^{7}$	Soft_fruit	$1.31\ 10^{8}$	1.8	$1.39\ 10^{8}$	1.9
D_Hard_Fruit	$3.34\ 10^{8}$	Hard_fruit	$2.63\ 10^{8}$	0.79	$4.61\ 10^{8}$	1.4
NPD 2001		**GHS-POP 2015**				
Population	$5.90\ 10^{7}$	Population	$6.41\ 10^{7}$	1.1		

Figures 5 to 8 compare the distribution of population and agricultural production across the UK for the previous and revised PACE data sets. Figure 5 shows that the overall distribution pattern of the UK population is similar although the low population areas in the previous data set appear smoother than the revised data set which has a more speckled appearance.

Figure 6 compares drinking milk production data, and the distribution patterns look similar but, in this case, the revised data set is smoother in the low value areas. Figure 7 shows green vegetable production. The smoothing in the revised data set is even more pronounced and the underlying NUTS 2 regions from which the new green vegetable production distribution was derived can be seen in the East Midlands and East Anglia. The same NUTS 2 regions were the basis of the disaggregation of the data in Figure 6 and so the fact that this data is less smeared than the green vegetable data is due to the application of different land use categories.

Figure 8 compares the previous and revised UK cow meat production data. At first viewing they look quite different, but the underlying pattern of high and low production areas match reasonably well. However, as Table 11 indicates, there is an overall increase in UK cow meat production in the revised data set by a factor of almost 3, for reasons described above. Therefore, the differences apparent in Figure 8 are real and not an effect of greater smoothing in the previous data set.

Figure 5. Population density a) revised 2015 data set and b) previous 2001 data set

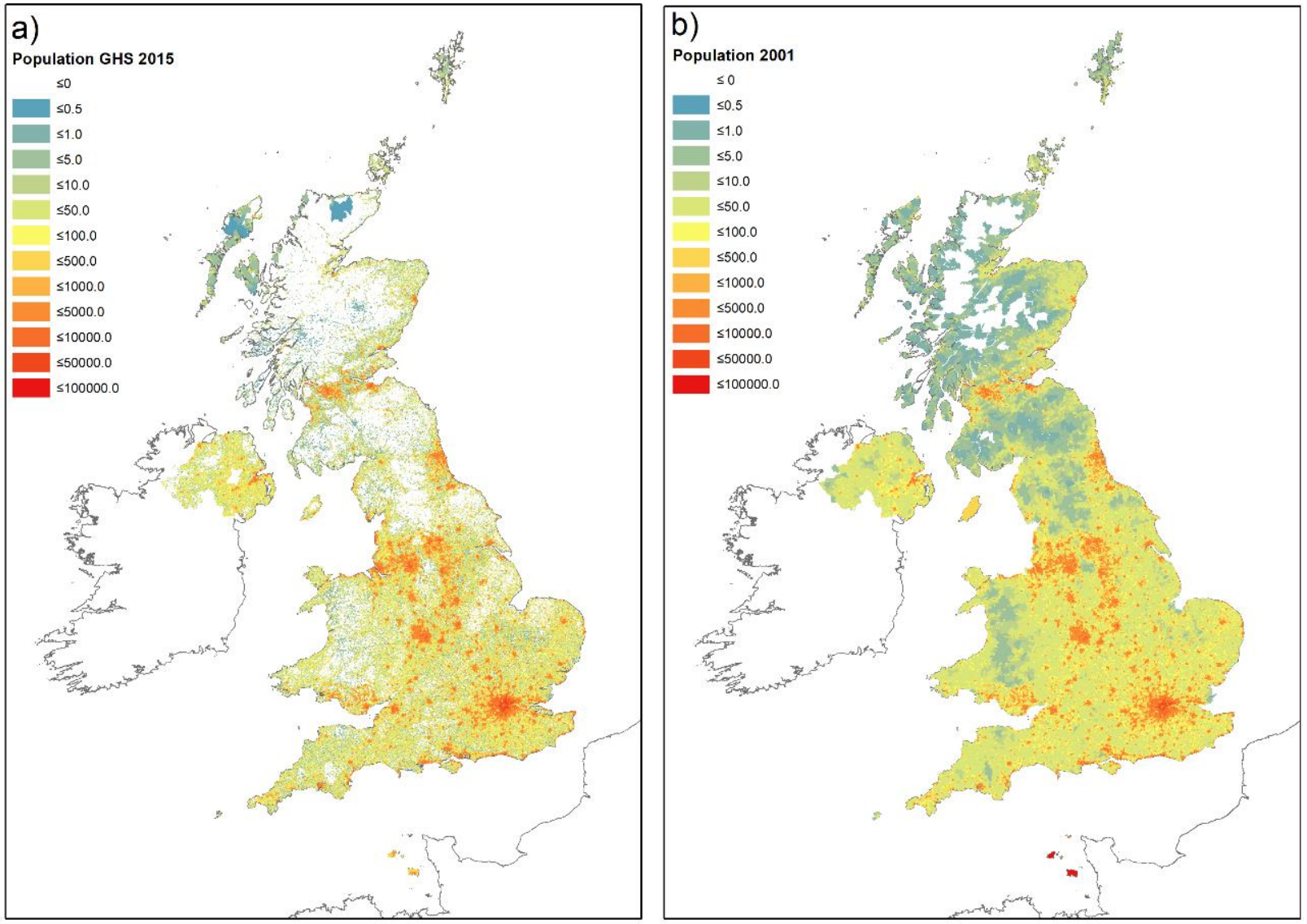


Figure 6. Production of cow milk for drinkingkg km^2 a) FAOSTAT/Eurostat 2009 to 2015 (UK produced, UK consumed), b) derived from EDINA data 2003

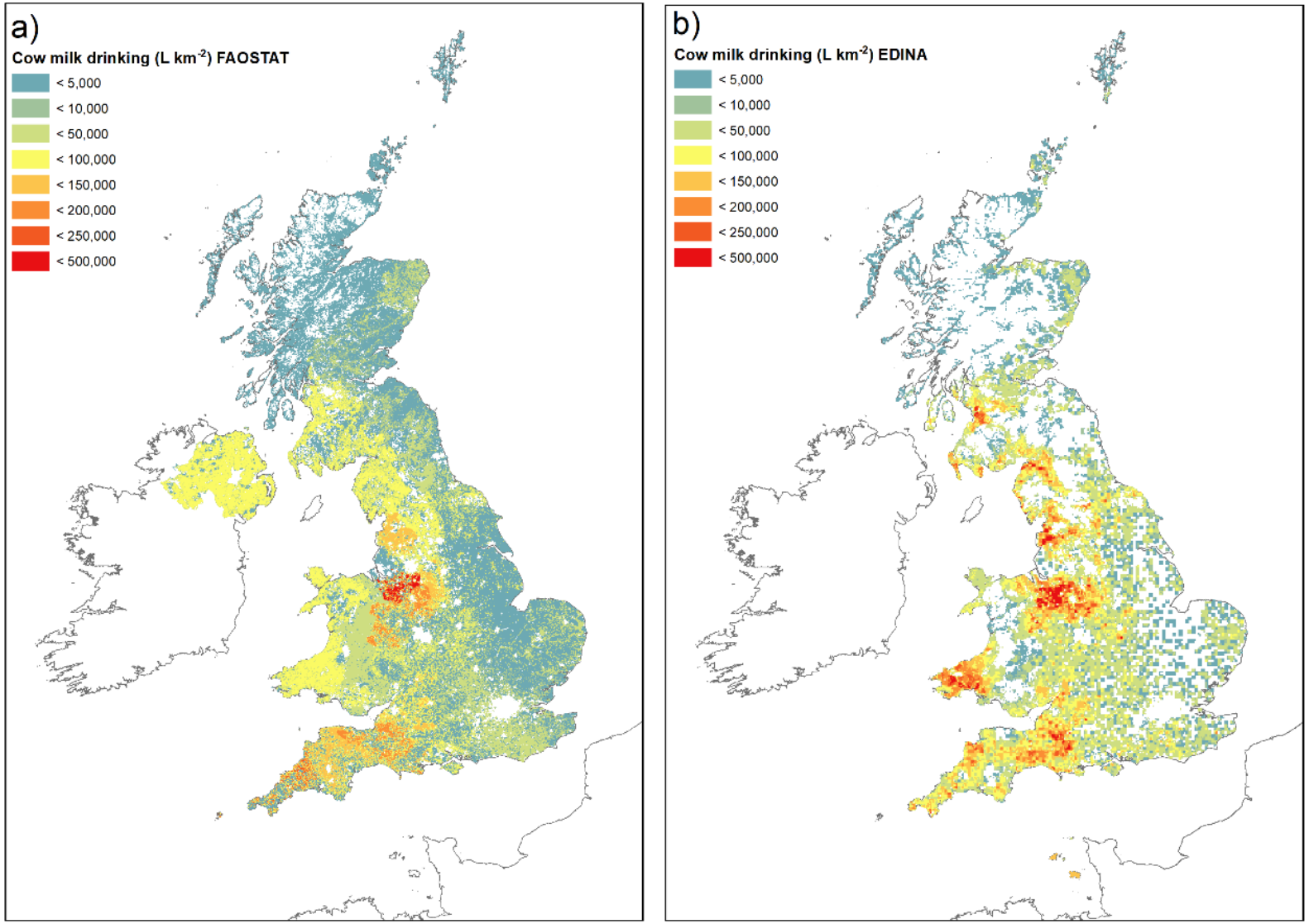


Figure 7. Production of green vegetables kg km^2 a) FAOSTAT/Eurostat 2009 to 2015 (UK produced, UK consumed), b) derived from EDINA data 2003

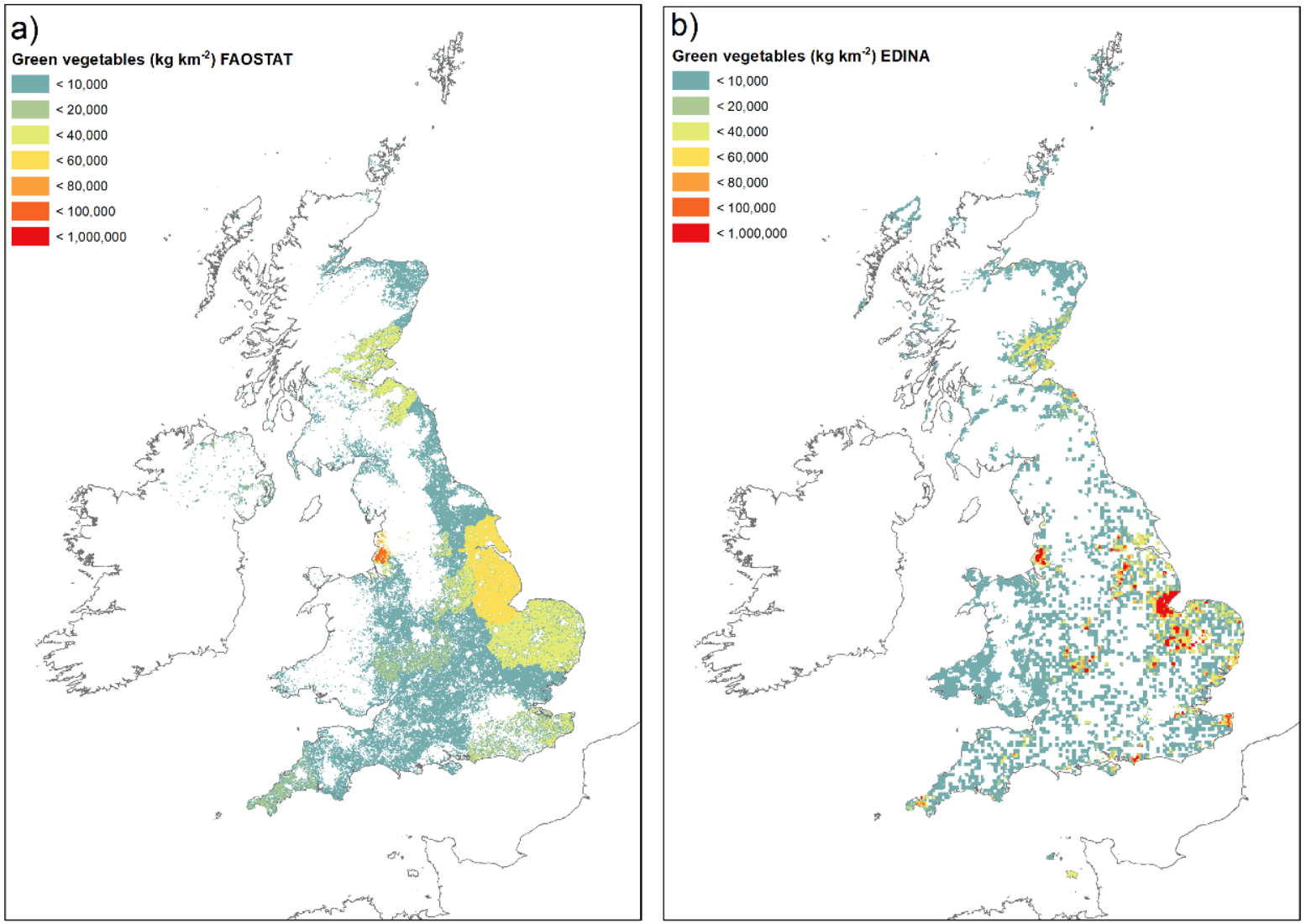
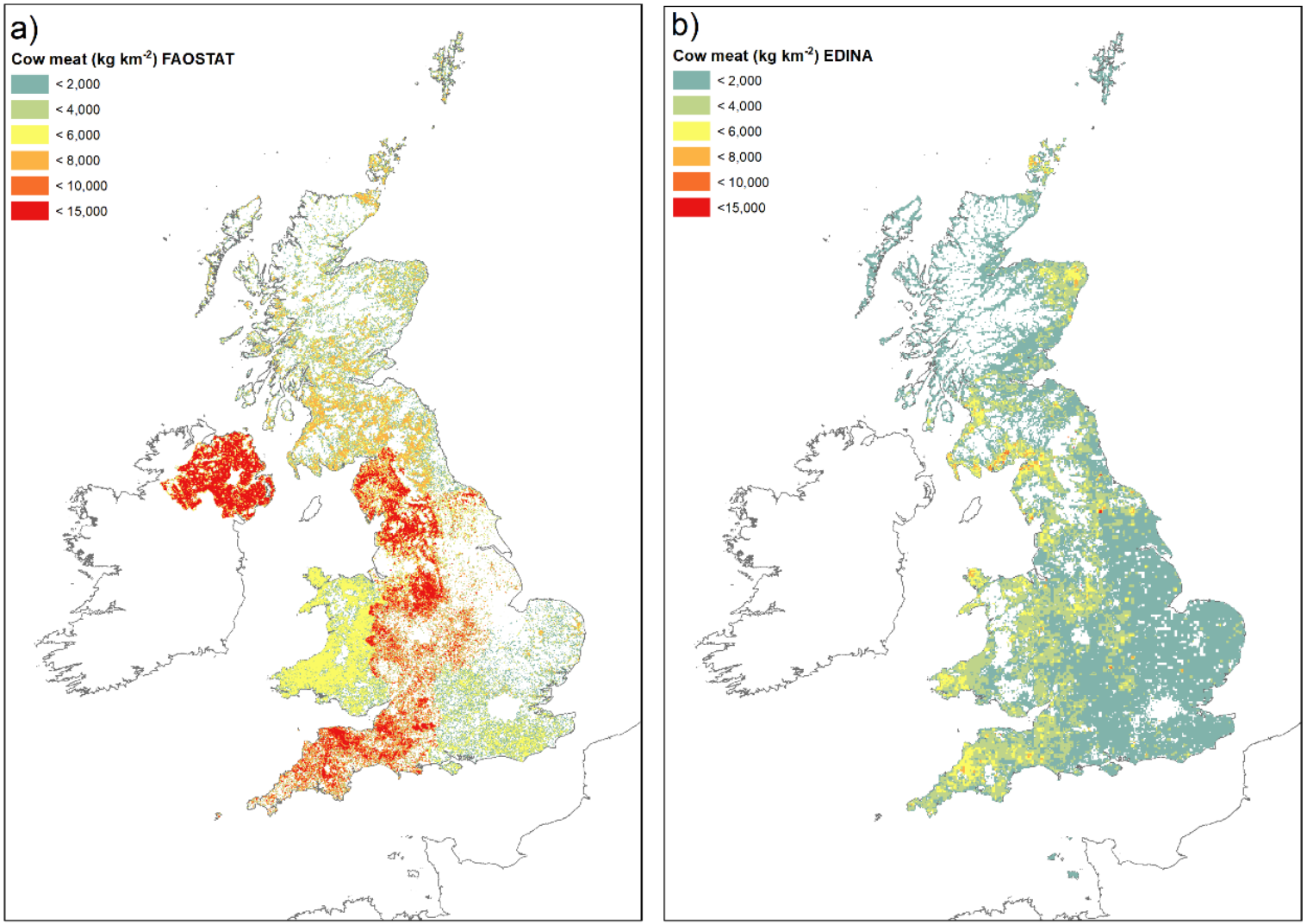


Figure 8. Production of cow meat kg km^2 a) FAOSTAT/Eurostat 2009 to 2015 (UK produced, UK consumed), b) derived from EDINA data 2003



6.2 PC-CREAM 08

A comparison was made of the previous PC-CREAM 08 population and agricultural production polar grids with revised polar grids for the UK and Europe. Tables 12 and 13 present the values calculated for the 2 data sets for UK and Europe, respectively. For the UK, the most significant difference is for cow's milk. This is due to this category being used for total liquid milk in the existing data set but only for drinking milk in the revised data set. There are greater differences in the European data sets which are partly due to the larger area covered by the existing data set. The existing data set includes all regions within a 3,000km radius of Sizewell, whereas the revised data set is for the EU+ countries only (Table 1).

Table 12 Comparison of previous and revised data sets used in PC-CREAM 08 for UK (kg y^{-1} or number of people)

Category	Previous data set (circa 1980s)	Revised data set (2015)
Cow meat	$5.66\ 10^{8}$	$7.27\ 10^{8}$
Cow liver	$2.26\ 10^{7}$	$1.90\ 10^{7}$
Cow milk	$1.56\ 10^{10}$	$6.95\ 10^{9}$
Cow milk prod	-	$4.41\ 10^{8}$
Sheep meat	$2.17\ 10^{8}$	$2.29\ 10^{8}$
Sheep liver	$1.16\ 10^{7}$	$1.02\ 10^{7}$
Grain	$5.76\ 10^{9}$	$5.72\ 10^{9}$
Green veg	$1.51\ 10^{9}$	$1.30\ 10^{9}$
Root veg	$5.47\ 10^{9}$	$5.59\ 10^{9}$
Fruit	-	$3.94\ 10^{8}$
Population	$5.51\ 10^{7}$	$6.47\ 10^{7}$

Table 13 Comparison of previous and revised data sets used in PC-CREAM 08 for Europe (kg y^{-1} or number of people)

Category	Previous data set (extends 3,000 km from Sizewell) (circa 1980s)	Revised data set for EU+ (2015)
Cow meat	$9.46\ 10^{9}$	$8.81\ 10^{9}$
Cow liver	$3.00\ 10^{8}$	$2.32\ 10^{8}$
Cow milk	$7.61\ 10^{10}$	$4.99\ 10^{10}$
Cow milk prod	$5.54\ 10^{10}$	$1.31\ 10^{10}$
Sheep meat	$1.17\ 10^{9}$	$1.39\ 10^{9}$
Sheep liver	$7.34\ 10^{7}$	$6.16\ 10^{7}$
Grain	$2.18\ 10^{11}$	$7.69\ 10^{10}$

Category	Previous data set (extends 3,000 km from Sizewell) (circa 1980s)	Revised data set for EU+ (2015)
Green veg	$3.84\ 10^{10}$	$6.34\ 10^{10}$
Root veg	$1.36\ 10^{11}$	$4.93\ 10^{10}$
Fruit	-	$5.45\ 10^{10}$
Population	$6.77\ 10^{8}$	$6.14\ 10^{8}$

7. Conclusions

This report describes the methodology and data used to create data sets of spatial distributions of population and agricultural production in Europe. The data sets are designed for use in radiological impact assessment tools PACE and PC-CREAM 08. The population data set includes all age groups but for dose assessment purposes is generally assumed to be comprised entirely of adults. The agricultural production data sets cover the food types typical of a European diet.

The data is sourced from internationally recognised organisations and is subject to quality control procedures by those organisations. It is anticipated that this methodology will remain broadly applicable for any revised data sets, even if there are future changes in the format and the coverage of the data.

Validation of the data sets was carried out through visualisations of the distributions, comparison of national totals with the raw data and calculation of per caput ingestion rates.

8. References

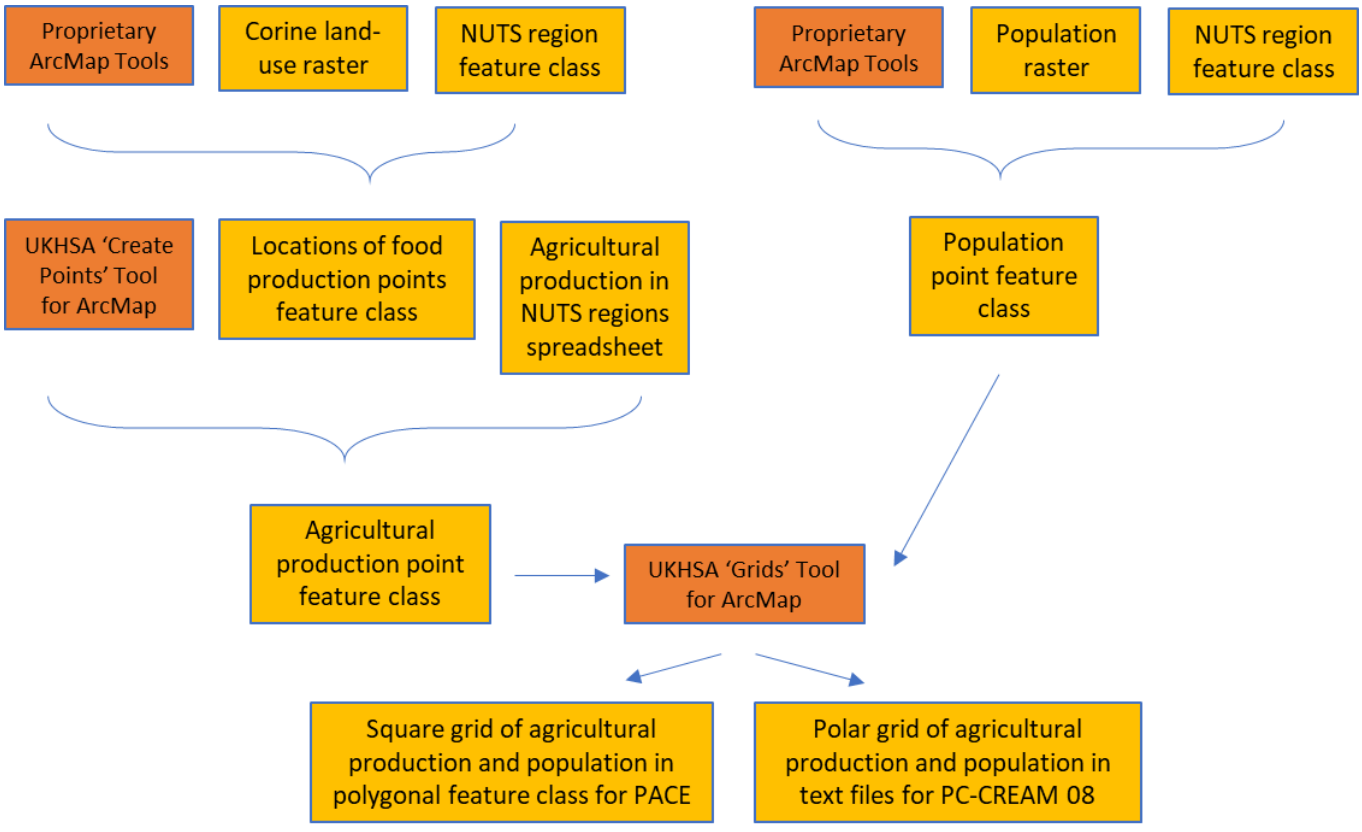
1. Brown J and Simmonds JR (1995). 'Farmland: a dynamic model for the transfer of radionuclides through terrestrial foodchains'. NRPB, Chilton (UK), NRPB-R273
2. Charnock TW, Bexon AP, Sherwood J, Higgins NA, Field S, Smith J and Brown IK (2020). 'The Probabilistic Accident Consequence Evaluation (PACE) software methodology for version 3.3.2' Public Health England, CRCE-RAD-006-2020
3. Defra (2017). Horticulture Statistics 2016 (accessed 2020)
4. Defra (2019). Usage of milk by dairies in the United Kingdom – December 2018. (accessed 2020)
5. Defra, DAERA (NI), Welsh Assembly and Scottish Government (2018). Agriculture in the United Kingdom 2017.
6. European Commission (2015). GHSL - Global Human Settlement Layer (accessed 2020)
7. European Environment Agency (2017). Corine Land Cover 2006 raster data - Version 18.5 (accessed 2017)
8. Eurostat (2011). 'Regions in the European Union. Nomenclature of territorial units for statistics'. NUTS 2010/EU-27. Publications Office of the European Union, Luxembourg
9. Eurostat (2018a). Easy Comext (international trade data) (accessed 2018)
10. Eurostat (2018b). Eurostat database (accessed 2018)
11. FAO (2014). FAOSTAT (accessed 22 October 2014)
12. Florczyk AJ, Corbane C, Ehrlich D, Freire S, Kemper T, Maffenini L, Melchiorri M, Pesaresi M, Politis P, Schiavina M, Sabo F and Zanchetta L (2019). GHSL Data Package 2019. JRC 117104/EUR 29788 EN
13. Higgins NA, Jones C, Munday M, Balmforth H, Holmes W, Pfuderer S, Mountford L, Harvey MP and Charnock TW (2008). 'COCO-2: a model to assess the economic impact of an accident'. Health Protection Agency, Chilton (UK), HPA-RPD-046
14. HSE (2005). A national population data base for major accident hazard modelling. HSE, Norwich, Research Report 297
15. Smith JG and Simmonds JR (2009). 'The methodology for assessing the radiological consequences of routine releases of radionuclides to the environment used in PC-CREAM 08'. Health Protection Agency, Chilton (UK), HPA-RPD-058
16. Smith KR and Jones AL (2003). 'Generalised habit data for radiological assessments'. National Radiological Protection Board, Chilton (UK), NRPB-W41
17. UK Flour Millers (accessed 2021)

Appendix A. Creating geospatial data sets for use in PACE and PC-CREAM 08

A1. Overview

This appendix outlines the processing steps used to create geospatial data sets for PACE and PC-CREAM 08. The agricultural production data was allocated to NUTS regions as described in the main text but was further manipulated (see Section A2) to take account of land-use data, before being reformatted for use in PACE and PC-CREAM 08 (Section A4). The population data was also processed for input into PACE and PC-CREAM 08 (Section A3). Figure A1 provides an overview of the process, which is essentially carried out in 2 main steps: the production of agricultural and population point feature classes (described in detail in sections A2 and A3) and the creation of inputs for PC-CREAM 08 and PACE (see section A4).

Figure A1. Overview of the process to create input data for PACE and PC-CREAM 08



A2. Creating points feature classes of agricultural production

The main text explains the method for calculating the amount of food produced in every NUTS region. However, some of the NUTS regions are quite large and it makes sense to use high resolution land-use data to improve the spatial resolution of agricultural production.

The 2 main steps of this process are to:

1. Calculate the number of non-null food production points in every NUTS region for every food type.
2. Divide the quantity of food in a NUTS region by the number of food production points for that food in that NUTS region and assign the average value to each point in the region.

The CORINE land-use data set (European Environment Agency, 2017) is available as a 250 m x 250 m resolution raster which is used to determine which food types can be grown at which locations. Every food type was allocated to a grid code (Table A1) which defines the CORINE land-use class in which they can be produced. The allocation is as follows:

1. Fruit, soft fruit (grid codes 12, 15 to 17 and 19 to 22).
2. Grain (grid codes 12 to 14 and 19 to 22).
3. Green veg, root veg and potatoes (grid codes 12 to 13 and 19 to 22).
4. Cow – for cow meat, cow liver, cow milk, cow milk products and liquid cow milk products (grid codes 18, 20 to 22 and 26).
5. Sheep – for sheep meat and sheep liver (grid codes 18, 20 to 22 and 26 to 29).

Table A1. Food types and associated CORINE land-use types

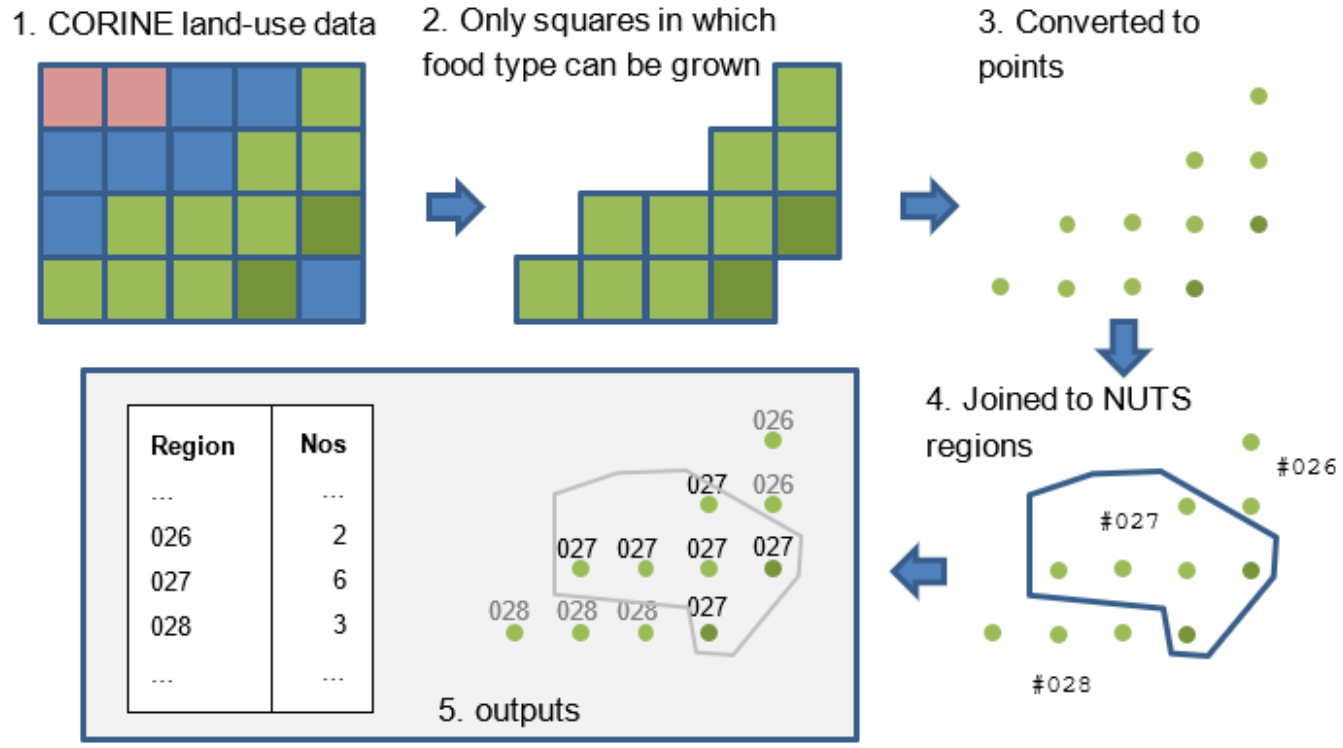
Food type	Land-use type	Grid code
Green vegetables, Root vegetables, Potatoes, Grain, Fruit	Non-irrigated arable land	12
Green vegetables, Root vegetables, Potatoes, Grain	Permanently irrigated land	13
Grain	Rice fields	14
Fruit	Vineyards	15
Fruit	Fruit trees and berry plantations	16
Fruit	Olive groves	17
Cow, Sheep	Pastures	18
Green vegetables, Root vegetables, Potatoes, Grain, Fruit	Annual crops associated with permanent crops	19

Food type	Land-use type	Grid code
Green vegetables, Root vegetables, Potatoes, Grain, Fruit, Cow, Sheep	Complex cultivation patterns	20
Green vegetables, Root vegetables, Potatoes, Grain, Fruit, Cow, Sheep	Land principally occupied by agriculture, with significant areas of natural vegetation	21
Green vegetables, Root vegetables, Potatoes, Grain, Fruit, Cow, Sheep	Agro-forestry areas	22
Cow, Sheep	Natural grasslands	26
Sheep	Moors and heathland	27
Sheep	Sclerophyllous vegetation	28
Sheep	Transitional woodland-shrub	29

The points data sets were created as follows. The CORINE land-use raster data and the NUTS regions polygon data set[4] are added to ArcGIS. The land-use raster is then resampled to a 500 metres by 500 metres resolution to make it more manageable and reclassified for every food type so that it only gives a value where food production occurs as specified in Table A1. The raster is then converted to a points data set using ArcGIS tools, and XY coordinates are added to the points. The points are then assigned to the NUTS region in which they are located. The resulting data set is very large and is split into multiple data sets to avoid problems with computer memory. The smaller split data sets are processed one at a time by the 'Create Points' tool developed at UKHSA. Summaries are created containing the total number of agricultural production points in every NUTS region for every food type. This process is illustrated in Figure A2.

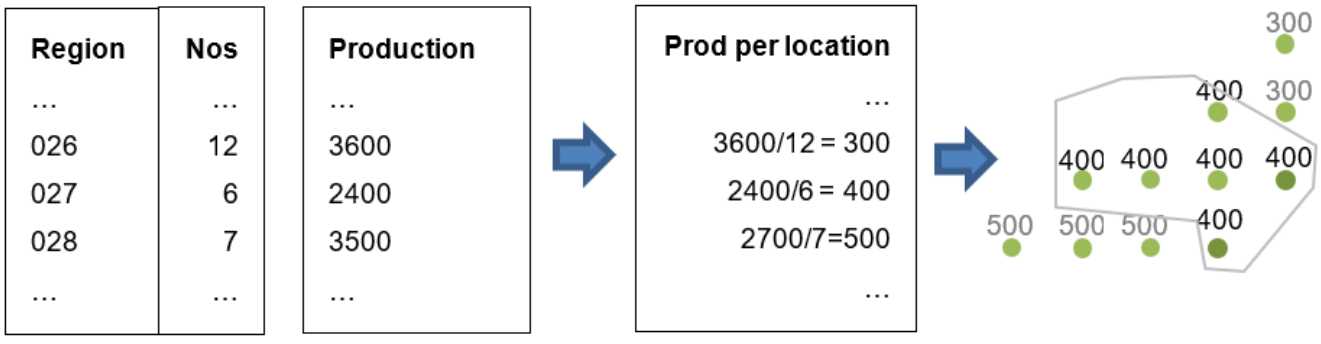
[4] Polygon data sets are based on vectors (x, y coordinates) with lines connecting the vertices and the first and last coordinates pairs being the same in order to create a bounded area.

Figure A2 Overview of the one-off process to identity locations of food type production and assign them to a NUTS region



This completes the one-off process of creating the agricultural production points data sets. The main outputs from the process are data sets containing the 'locations of food production' for every food type (See Figure A1). The points represent the locations of production for the food type considered. A summary containing the number of food production points in every NUTS region is also output for every food type.

Figure A3. Overview of process of disaggregating food production from NUTS regions to locations



The points and summaries are then used in combination with food production data in NUTS regions (see Section 3) to estimate the quantity of food produced at each point. This is achieved using the 'Create Points' tools developed at UKHSA. The Create Points tool creates point data sets of agricultural production by allocating an equal portion of the production in a NUTS region to all the production points within that region. The output from this step is an 'agricultural

production' points data set for each food type, which contains estimates of food production for the food type in the 500 m by 500 m square that surrounds each point. This process is illustrated in Figure A3.

A3. Creating points feature class of population

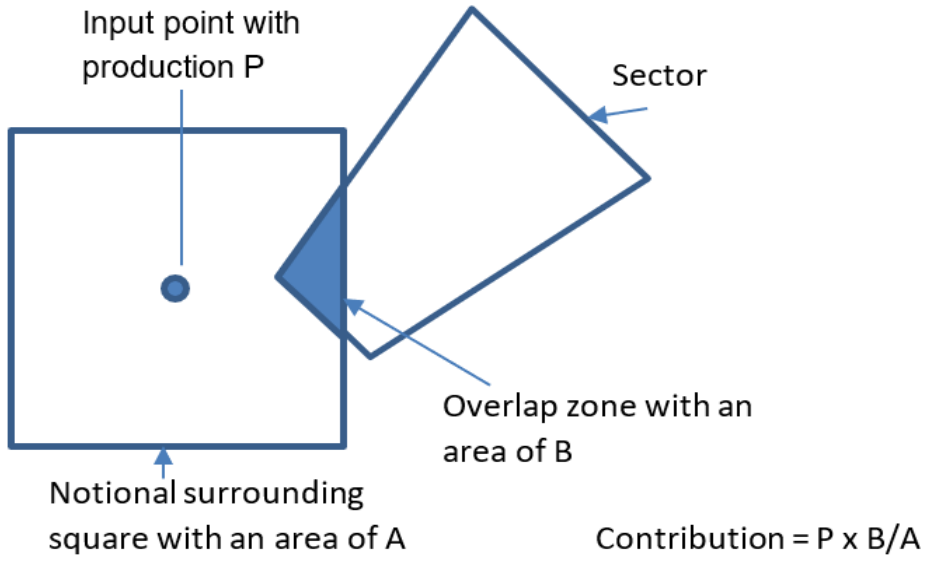
Population data is available from the European Commission Global Human Settlement Population (GHS-POP) in the form of a 1 km resolution raster. This is converted to a population points data set using proprietary ArcGIS tools. This feature class contains a set of points covering the EU+ countries and the population at each point. Each point, with its associated population, represents an area of 1 km^2. If the population of a single country or NUTS region is required, this can be extracted from the population points data set.

A4. Creating inputs for PC-CREAM 08 and PACE

The points data sets of agricultural production and population created in sections A2 and A3 must be further processed for input to PACE and PC-CREAM 08. An ArcGIS toolbox called 'Grids' was developed to do this. The purpose of the Grids toolbox is to resample the points data sets into either a square grid required by PACE or a polar grid required by PC CREAM 08. Different approaches to resampling are adopted for PACE and PC CREAM 08 input data.

For PACE, it is assumed that the agricultural production or population at a point is entirely allocated to the grid square in which it is located. For PC-CREAM 08, it is assumed that a notional grid square surrounds each production or population point. The contribution of agricultural production or population at a point to the total production in a PC-CREAM 08 polar grid sector is derived based on the fraction of the surrounding notional square that overlaps with the sector (Figure A4). The total production in a sector is the sum of contributions from all the overlapping notional grid squares.

Figure A4. Resampling of an input point to a polar grid sector

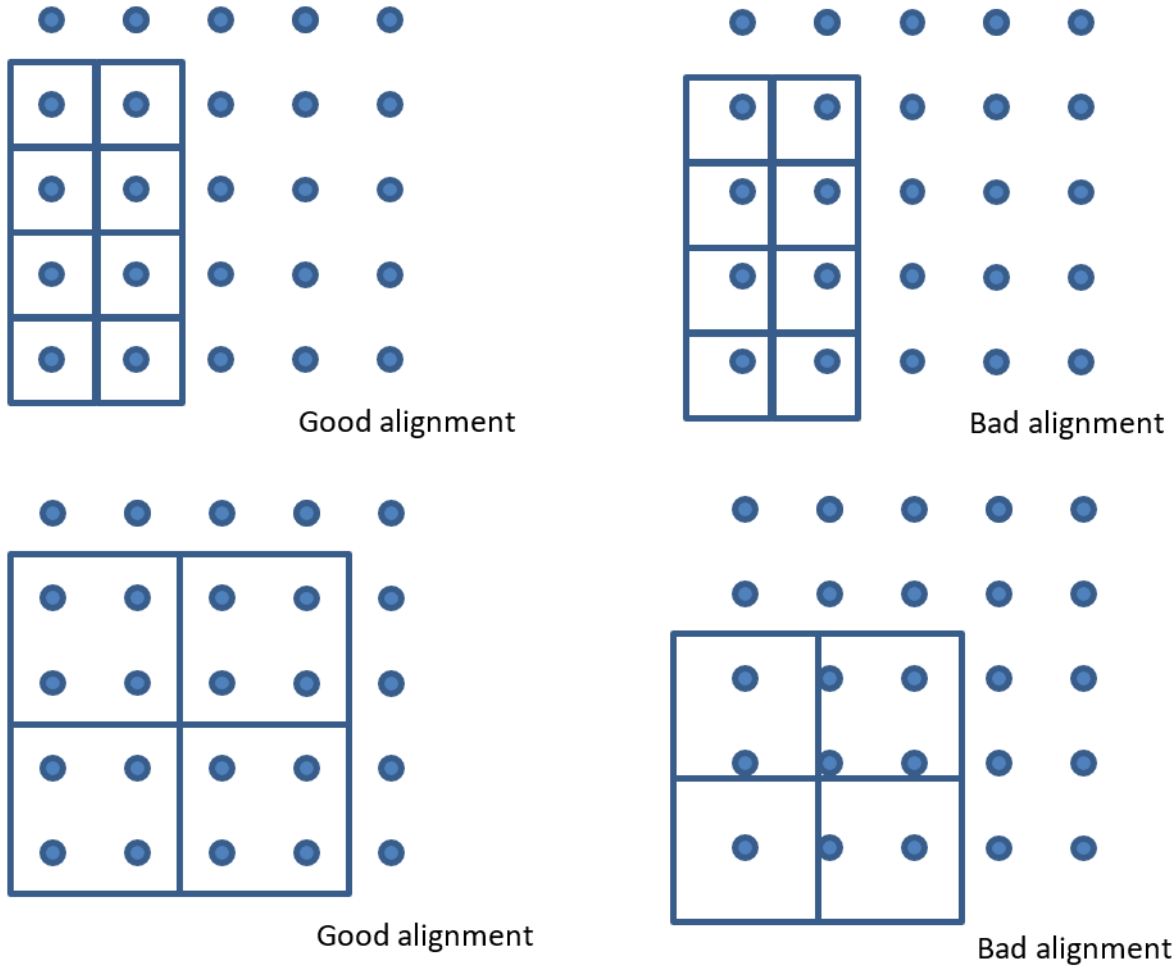


A4.1 Output grid definition

For PACE, the output grid can be defined in one of 2 ways, either using the extent of the set of input points or using a user-defined grid.

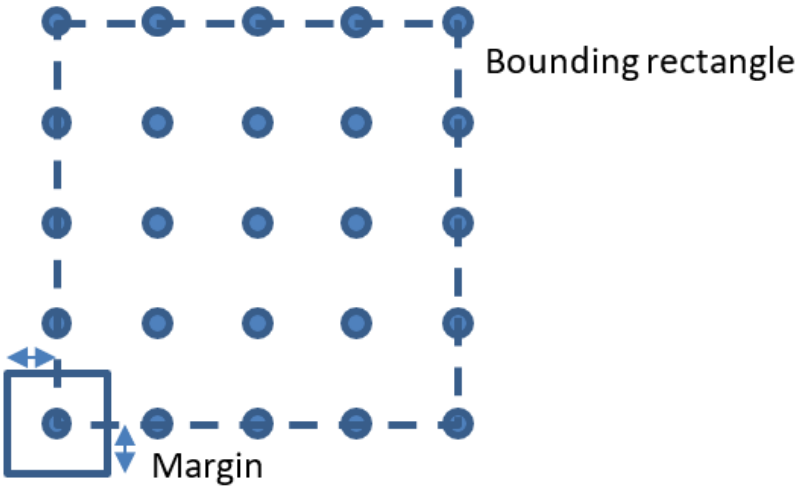
If a user-defined grid is used, then the user specifies the coordinates of the lower left corner of the lower left grid square of the output grid (Figure A5). The number of columns and rows in the output grid, and the X and Y resolution, must be specified. Because a point is assumed to contribute all the production to the output grid square in which it resides, it is important that the lower-left corner coordinates and resolution are chosen carefully so that the output grid is in good alignment with the points.

Figure A5. Output grid for PACE defined by the user



If the user chooses to use the input extent, then the output grid is partially defined using the bounding rectangle of the points (Figure A6). The lower left corner coordinates of the lower left grid square are calculated from the bounding rectangle coordinates minus a user-defined margin to properly position the grid. As before the user must specify an output resolution, from which the number of columns and rows will be calculated. The margins should be chosen to ensure good alignment and so will generally be half the vertical and horizontal distances between the points. A grid square is omitted from the output feature class if there are no input points within the grid square.

Figure A6 Output grid for PACE defined by the extent of the set of input points

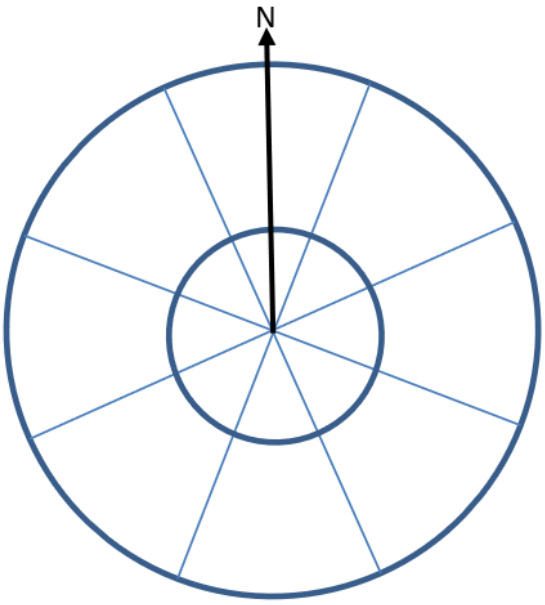


For PC-CREAM 08, the output grid is in the form of a polar grid (Figure A7) which is defined by the user based on the following parameters:

- coordinates of the centre
- a set of sector distances
- number of sectors
- number of smoothing points

The sector directions are constrained such that the last sector symmetrically straddles the north line. ArcGIS does not allow curved lines, so the curved sector edges are represented by several straight lines, the number being controlled by the number of smoothing points. Generally, 3 points are sufficient for a visually smooth curve.

Figure A7. Output grid for PC-CREAM 08 defined by the user



A4.2 Spatial reference or projection

For PACE, the Grids toolbox requires the spatial reference or projection of the data-frame (the ArcMap map window) to be in the same projection as the input point data. The output gridded data is in the same projection.

For PC-CREAM 08, the spatial reference of the data-frame is not important. The Grids toolbox constructs the polar grid in latitude and longitude coordinates using non-planar trigonometry and a destination-point calculation. The notional grid square is constructed around the point in its native projection and re-projected into latitude and longitude coordinates in order to calculate the areas of overlap with the polar grid.

A5. Reference

European Environment Agency (2017). Corine Land Cover 2006 raster data - Version 18.5 (accessed 2017)

Appendix B. Agricultural production data for Channel Islands and Isle of Man

B1. Introduction

Agricultural production data for the Channel Islands and the Isle of Man is not available from FAOSTAT therefore other sources were used to obtain this information. These sources and the derived production data are detailed below. The production data can be allocated to a single production point within each island and included in the production grids used in PC-CREAM and PACE if required.

B2. Channel Islands

The data collected for the Channel Islands was taken from a previous unpublished study and covers the years 2012 and 2013. The Channel Islands are divided into 2 governing bodies called Bailiwicks. Data was only collected for islands of a significant size and habitation, namely Jersey, which falls under the Bailiwick of Jersey, and Guernsey, Sark and Alderney, which fall under the Bailiwick of Guernsey.

For Jersey, the local government publishes an annual report called the Agricultural Statistics report (Government of Jersey, 2012) which includes much of the information needed. The data selected was for 2012 and, although there is some annual variation in production, it does not seem to be significant. In addition to the report, the Jersey Government were able to provide additional information such as the fraction of potatoes grown for human consumption.

There is no annual report on agricultural statistics for the Bailiwick of Guernsey and so all data came from correspondence with the local government.

For both Bailiwicks, production data is available in terms of crop areas and animal numbers. Crop areas were scaled by UK average crop yields, and animal numbers by UK average milk and meat yields, to estimate production quantities. In some cases, production quantities were also available, for example, for litres of milk, and these were used in preference to the scaled values. The results are presented in Table B1.

Validation of the results was carried out by calculating per caput consumption rates and comparing these with UK national values. In general, the comparisons suggest that significant amounts of most food types are imported to the islands. The exceptions are potatoes and milk, which are known to be exported in significant quantities from Jersey and Guernsey to the UK.

Table B1. Agricultural production data for Channel Islands

Food	Annual production Jersey (2012) (kg)	Annual production Guernsey (2013) (kg)	Annual production Alderney (2013) (kg)	Annual production Sark (2013) (kg)
Grain	0	0	0	0
Potato	$5.1\ 10^{7}$	$3.1\ 10^{6}$	0	0
Root vegetables	$2.4\ 10^{6}$	0	0	0
Green vegetables	$3.3\ 10^{6}$	$3.8\ 10^{5}$	0	0
Soft fruit	$1.2\ 10^{5}$	0	0	0
Hard fruit	$4.9\ 10^{5}$	0	0	0
Cow meat	$9.0\ 10^{4}$	$3.0\ 10^{4}$	$7.5\ 10^{3}$	0
Cow liver	$3.6\ 10^{3}$	$1.2\ 10^{3}$	$3.0\ 10^{2}$	0
Cow milk total (litre)	$1.3\ 10^{7}$	$8.0\ 10^{6}$	$2.2\ 10^{5}$	$1.1\ 10^{5}$
Cow milk drinking (litre)	-	-	-	-
Cow milk products	-	-	-	-
Sheep meat	$6.0\ 10^{3}$	$4.5\ 10^{3}$	0	$3.0\ 10^{3}$
Sheep liver	$3.2\ 10^{2}$	$2.4\ 10^{2}$	0	$1.6\ 10^{2}$

B3. Isle of Man

For the Isle of Man, the primary source of agricultural production data is the annual agricultural and horticultural census conducted by the Isle of Man Department of Environment, Food and Agriculture (DEFA, 2018). Areas of crop production were taken from the 2018 census report and combined with standard crop yields to estimate annual production of potatoes, green vegetables and soft fruit. Data for milling wheat and animal products was provided through personal communication with DEFA. Production data for hard fruit and root vegetables was not available and so this was estimated using UK production ratios of hard fruit to soft fruit, and root vegetables to potatoes, respectively. The results are presented in Table B2.

Validation of the results was carried out by calculating per caput consumption rates and comparing these with UK national values. In general, there was good agreement except for green vegetables and fruit which were underestimated, probably because significant quantities of these foods are imported to the Isle of Man.

Table B2. Agricultural production data for Channel Islands

Food	Annual production (mean 2015 to 2018) (kg)
Grain	$2.0\ 10^6$
Potato	$3.3\ 10^6$
Root vegetables	$4.2\ 10^5$
Green vegetables	$2.3\ 10^5$
Soft fruit	$2.4\ 10^3$
Hard fruit	$4.8\ 10^3$
Cow meat	$1.3\ 10^6$
Cow liver	$5.0\ 10^4$
Cow milk total (litre)	$3.1\ 10^7$
Cow milk drinking (litre)	$6.3\ 10^6$
Cow milk products	$2.2\ 10^6$
Sheep meat	$7.8\ 10^5$
Sheep liver	$4.2\ 10^4$

B4. References

- DEFRA (2018). Agricultural and Horticultural Census 2018. Isle of Man
- Government of Jersey (2012). Agricultural Statistics for 2012. Jersey

About the UK Health Security Agency

UKHSA is responsible for protecting every member of every community from the impact of infectious diseases, chemical, biological, radiological and nuclear incidents and other health threats. We provide intellectual, scientific and operational leadership at national and local level, as well as on the global stage, to make the nation heath secure.

UKHSA is an executive agency, sponsored by the Department of Health and Social Care.

Version 1.0

Report number: UKHSA-RCE-003

Published: June 2022
Publishing reference: GOV-12207