Chapter 21:
UK Dependence on non-UK Ecosystem Services

Coordinating Lead Author: Tony Weighell

Key Findings*

The UK is increasingly drawing on the services of overseas ecosystems to support its own economic growth. The UK's landmass cannot provide all the ecosystem services required to support the national economy. Access to overseas ecosystem services, particularly for the supply of biomass (for food, fibre and bioenergy), is essential. This dependence makes the protection of the long-term functionality of these overseas ecosystems an economic imperative for the UK.

National consumption of minerals and fossil fuels reflects economic cycles. Domestic biomass consumption does not; its steady growth within the UK's economy over the last 40 years has primarily been related to population size[1]. With domestic production relatively stable, growth in the use of biomass by the UK's economy has been supported by a growth in imports, starting from 1980 and peaking in 2002[1]. Recently, imported biomass flow appears to have stabilised at approximately 50 million tonnes per year (t/yr), but population growth and the implementation of new bioenergy policies will increase future national demand for biomass, including imports.

[1] *well established*

Approximately one third of the biomass used by the UK comes from overseas according to Environmental Accounts prepared by the Office for National Statistics. This data indicates an annual biomass flow through the economy of 150 million tonnes based on domestic production of approximately 100 million tonnes (from agriculture, forestry and fisheries) and imports of 50 million tonnes. Exports are 20 million tonnes, so net annual biomass consumption by the UK economy is approximately 130 million t/yr, which is equivalent to 2.1 t/capita.

Total overseas land requirement for biomass exported to the UK was approximately 14 million hectares (ha) in 2008[2]. The domestic productive area in the UK is about 20 million ha. Provision of food (for human or animal consumption) and forest products (timber, pulp and paper) accounts for 90% of this land use impact and the remaining 10% is related to bioenergy crops.

[2] *established but incomplete evidence*

The majority of the overseas biomass utilised by the UK's economy comes from the Palearctic Realm (including the EU and wider Europe) and has a land requirement of 8.5 million ha[2]. In 2008, the estimated land requirement in the Neotropical Realm (South America) to supply biomass to the UK was approximately 2.4 million ha. Approximately 1.3 million ha was required in both of the Nearctic (North America) and Oceania Realms. Imports from the Afrotropical Realm (Sub-Saharan Africa) are relatively insignificant with a land use impact of only 300,000 ha in 2008.

[2] *established but incomplete evidence*

Approximately 10 million of the UK's 14 million ha of overseas land use impact can be assigned to four individual biomes[2]. Boreal Forest Taiga and Temperate Broadleaf and Mixed Forest biomes are key suppliers with a land use impact of approximately 3 million ha in each. Impacts in the Boreal Forest biome occur primarily through import of timber products; the impacts in the Temperate Forest biome are due to the provision of food chain biomass for human or animal consumption. Land use impact elsewhere affects less than 2 million ha in both the Temperate Grasslands of North and South America and Tropical/Sub-tropical Broadleaf Forests of South America and South East Asia.

[2] *established but incomplete evidence*

* Each Key Finding has been assigned a level of scientific certainty, based on a 4-box model and complemented, where possible, with a likelihood scale. Superscript numbers and letters indicate the uncertainty term assigned to each finding. Full details of each term and how they were assigned are presented in Appendix 21.1.

In 2008, almost 90% of domestic biomass consumption involved food chain material for human or animal use. Thus the national food requirement will be a key driver of future UK biomass demand as population continues to grow. If current consumption and waste patterns persist, and domestic production remains stable, food requirements will drive increased import demand for food chain biomass in direct proportion to population growth[2]. Food chain imports are likely to rise from the current 35 million tonnes to almost 50 million tonnes in 2030[2]. This demand is likely to be mitigated by waste reduction and increased domestic production[2]. Effective demand mitigation would stabilise the overseas land use requirement associated with UK food imports at the current level of approximately 10 million ha.

[2] *established but incomplete evidence*

As the UK implements renewable energy policies, biomass demand for heat and power production will increase significantly in the next decade, exceeding the UK's domestic biomass capacity before 2020[3]. As much as 27 million t/yr of additional biomass imports is very likely to be required to feed this one industry, potentially creating an additional overseas land requirement of 7–10 million ha by 2020, after which demand is very likely to stabilise if renewable targets remain unaltered[3].

[3] *competing explanations*

There is significant scope for moderating the UK's biomass import demand and its associated overseas impacts. A combination of increased domestic biomass production and food waste reduction could make significant contributions to reducing both. If biomass import demand is unmitigated by increased domestic production and reduced waste, the overseas land use requirement is likely to almost double from the current 14 million ha to 26 million ha by 2030, and continuing to increase with population growth thereafter[3]. Mitigated through increased domestic production and reduction in waste, this land use requirement could be limited to approximately 20 million ha, and potentially held at this level from 2020 onwards.

[3] *competing explanations*

The use of biomass Material Flow Analysis provides a framework for reporting on UK trends in biomass use: the measurement of pressures exerted on overseas ecosystems and the basis for formulating domestic and international policy initiatives. The framework allows identification and quantification of the UK's overseas biomass dependencies, including the spatial distribution of material sources. A suite of nationally important indicators can be used for reporting. The framework also identifies potential ecosystem impacts of imported biomass imports. The links between the indirect and geographically distant socioeconomic drivers of ecosystem change operating in the UK and the direct drivers of ecosystem change on the ground in countries supplying the UK economy are made explicit. The need for, and potential benefits arising from, domestic polices to minimise the overseas impacts of UK biomass consumption are made equally explicit.

Measuring the UK's use of biomass and combining these measurements with other data permits the drivers for national biomass consumption to be identified along with the global locations which supply this material. Empirical assessment of biomass flows and qualitative assessment of how and where pressures may be exerted does not, in itself, mean that negative ecosystem impacts are occurring, but serves to identity where and how they may occur. Detailed case-by-case sustainability analyses will be needed to determine if the pressures are acceptable on social, economic and ecological grounds, and if they are being effectively managed. Such analysis needs to be undertaken to determine the resilience of the ecosystems concerned and the appropriate thresholds below which we can safely continue to exploit specific systems. Given the economic dependence of the UK's economy on these overseas ecosystems, it is in the national interest to ensure that we, and other countries, identify and operate within these limits.

21.1 Scope and Purpose of this Chapter

The natural environment provides the UK's economy and population with food, energy, construction materials and water. These demands may cause ecosystem degradation and have the potential to impair long-term delivery of the ecosystem services on which the country depends. Current consumption patterns ensure that the landmass of the UK and the surrounding territorial waters cannot provide all of the services required to support the national economy. This is particularly true for the national consumption of biomass (food, fibre and bioenergy) where one third of the biomass utilised by the UK is currently sourced from outside the country. Access to the provisioning services of overseas ecosystems is, therefore, essential to ensure the security of food supply (Defra 2006, 2009), and will be necessary to meet the national renewable energy targets in the future.

The UK National Ecosystem Assessment (UK NEA) analyses historical trends and evaluates alternative futures for the landscape of the UK until 2060. This chapter uses an empirical approach to look at the dependence of the UK economy on imported biomass. This dependence is described and quantified in terms of the material goods imported into the UK from non-UK ecosystems. The source ecosystems are identified at the scale of Biogeographical Realm and Biome. Available knowledge on biomass flows and consumption and national population trends are combined with an empirical assessment of the future implications of new bioenergy policies to produce credible projections for national biomass consumption up to 2030. Secondary measurements of land and water requirement to produce specific biomass streams can be estimated and used to identify how the use of imported biomass may be translated into ecosystem impacts.

This focus on the UK's dependency on the provisioning services (tangible goods) provided by various biomass streams does not imply that the other services provided by non-UK ecosystems have no value. The UK's population makes use of the tourism and cultural benefits of overseas ecosystems, but these benefits do not represent an economic necessity or dependence. Nor are these services, or the climate regulation services upon which we are all dependent, amenable to straightforward measurement and impact assessment.

Measuring the UK's dependence on overseas ecosystems by analysing the material goods they provide does not mean that provisioning services can be valued directly on the basis of goods entering our national ports. The market price of these materials at their time of entry into the UK is not a true measure of the value of the ecosystem services underpinning the production of these goods (Bateman 2010). Therefore, this chapter does not attempt to value the goods and services provided by overseas ecosystems, but quantifies key dependencies on them, and identifies potential impacts that may arise from them. The Material Flow Analysis (MFA) techniques described and used in this chapter provide a general framework for sustainability analysis and policy development. These techniques have the capacity to enable the identification and development of effective policy responses to possible overseas ecosystem service degradation attributable to the UK's use of imported provisioning services.

Material Flow Analysis identifies where and how ecosystem dependencies exist (defining the eco-political context), and the *potential* scale and nature of impacts that may arise from such dependencies. Determining the *actual* scale and nature of these impacts will require location specific analysis. By describing and quantifying biomass flows from overseas ecosystems into the UK, MFA can, in this case, focus sustainability analysis in key areas of the world and in key ecosystems. The MFA framework also provides qualitative information on how ecosystem impacts may occur. These include pressure for land use change, water use, and pollution of water or soils. The quantitative and qualitative framework provides the basis for appropriate policy responses within the UK, both in the domestic and global context. To be effective in managing the UK's impact on overseas ecosystems, the level of deployment of these policies will be critical. Policies to comprehend and manage the UK's impact on overseas ecosystems need to be location-specific and designed to address particular impact categories.

Material Flow Analysis does not provide a direct measure of specific impacts of the UK's economy on overseas ecosystems. In its review of UK material flows the Office for National Statistics (ONS) reflects that: "There is increasing policy interest in the relocation of production as it disguises the global impact of the UK economy" (ONS 2005). What MFA does is to define where in the world these impacts are being relocated to, and how they are may be expressed if not properly managed. Defining these global pressure points is the essential first step to developing and promoting policies to avoid, or mitigate, these impacts.

Projections beyond 2030 have not been attempted in this chapter because the numerical basis for such projection (particularly population trends and the consequences of policies governing biomass supply and demand) cannot be reasonably extended beyond this date. However, the projections presented suggest that the next 20 years are critical in terms of the policy actions needed to ensure sustainable use of overseas ecosystems. If current policy initiatives are successful, the UK's use of provisioning services from non-UK systems could be stabilised by 2030. Subsequent economic and population growth could be detached from a continued growth in demand for overseas biomass supplies and the associated impacts. If these policies fail, our inability to ensure efficient biomass use within the UK's economy, coupled with continued population growth, will lead to an unsustainable growth in demand for imported biomass. The overseas ecosystems upon which we currently rely, and others which may come 'on stream' in the future, are unlikely to cope with this demand from the UK and other global economies. The chapter presents:

- a description of the data available on biomass flow through the UK's economy and how this can be used to analyse imports flows;
- a baseline position using 2008 data to describe and quantify the nature of biomass imported into the UK, its

geographical and ecosystem origins, and an estimated land use requirement;
- an historical analysis of biomass imports to identify trends and socio-economic drivers of biomass use;
- projections of future biomass use by the UK's economy up to 2030, and the potential associated overseas land use impacts.

21.2 Imported Biomass: Quantifying the Dependency Between Domestic and Global Ecosystems

The national environmental accounts published by ONS quantify material flows through the economy using a set of high level indicators that reflect domestic production of raw materials (fossil fuels, minerals and biomass), imports, and national consumption (ONS 2010). Set alongside indicators of total material use are a complimentary set of biomass measurements (**Table 21.1**), which can be used to quantify biomass flows through the economy including monitoring of biomass imports.

21.2.1 Imported Biomass

Over one third of the 150 million tonnes of biomass available to the UK economy is imported. Trade data (gathered by HM Revenue & Customs) provide the basis for a set of indicators to quantify and map the biomass links between the UK and overseas ecosystems. These include potential 'primary' and 'secondary' indicators. Primary indicators are direct measurements that form part of the existing national statistical database, can be used in an unmodified form, and have long-term value for monitoring trends. Secondary indicators are derived directly from primary statistical data through some form of transformation, or are primary statistics judged to have less value (due to special considerations) for long-term trend analysis.

21.2.2 Mass (Weight) of Imported Biomass as a Primary Indicator

Trade statistics provide the basis for:
- the quantification of the long-term contribution of imported biomass to the UK's economy in relation to domestic production and exports;
- the identification and quantification of the UK's main imported biomass commodities and development of a 'profile' of the UK's biomass imports;
- and profiling of the UK's regional suppliers of biomass at the global level to identify and quantify regional suppliers of key commodities.

Trade data (**Box 21.1**) provides a set of robust numerical indicators to monitor the UK's use of primary production sourced from overseas ecosystems. Gathered according to standard international procedures, this data can be used to identify long-term trends in national use of all forms of biomass, and to identify and monitor key commodity flows (see Giljum 2009 for a European perspective). It can also be combined with other information to project future use. Spatial analysis is possible through the use of this data to identify national or regional suppliers of biomass to the UK and the ecosystems that are providing this service.

21.2.3 Secondary Measurements: Land Use, Water Use and Monetary Value

Secondary biomass indicators based on the UK's national trade data are:
- *Land requirement to produce imported biomass*—by recording mass, commodity type and country of origin, trade data can be combined with country-specific crop yield data to estimate the land area required to produce imported biomass commodities. This is distinct from ecological footprinting which integrates biomass and energy demands with waste generation to estimate total land requirements for production and disposal (WWF 2010). Ecological footprinting reports using a standardised unit:the global hectare. Land requirement is reported in actual hectares (ha).
- *Biomass market price*—the UK's Overseas Trade Statistics report the recorded monetary value of imported biomass in Pounds Sterling Biomass value is regarded as a secondary measurement because the changing value of Sterling and commodity prices through time make it less valuable as a long-term indicator than mass (weight) data. This data does, however, provide a useful economic dimension to this form of analysis, emphasising the economic importance of imported biomass, and, by extension, the source ecosystems, to the UK economy. In 2008 the total value of these imports was approximately £50 billion (HMRC 2010a).
- *Embedded (virtual) water associated with biomass imports*—primary data on biomass weight and type permits the calculation of the amount of water required to produce biomass supplied to the UK through imports (Hoekstra & Chapgain 2008). This measurement is linked directly to the primary statistics on import mass, but is a derivative of this data and is, therefore, of limited use for long-term analysis. Approximately 66% of the UK's water demand is met by overseas sources, three quarters of which is due to the production of agricultural biomass (WWF 2008; **Box 21.2**).

Trade data on UK biomass imports provides a suite of potential indicators for mass flow, economic analysis and the assessment of potential ecosystem impacts of biomass production overseas. These indicators can be utilised for time-series or geographical analysis. This chapter presents a new analysis of the overseas land use requirement arising from biomass imports, but only summarises already published assessments of the UK overseas water requirement. The value of land and water use indicators is their relevance to the provision of ecosystem goods and services, and to specific drivers of biodiversity loss such as land use change and increased water stress.

Table 21.1 Material and Biomass Flow Indicators. Source: ONS (2005, 2010b)

Total material flow indicator	Equivalent biomass flow indicator
Domestic Extraction—the sum of materials (minerals, fossil fuels, biomass) taken from the UK environment.	**Domestic Biomass Extraction**—the sum of primary biomass taken from the UK marine and terrestrial environment.
Direct Material Input—primary resources extracted from the UK environment plus imports. Direct Material Input represents the *gross* use of raw materials by the UK economy.	**Domestic Biomass Input**—biomass extracted from the UK environment plus biomass imports.
Domestic Material Consumption—is Direct Material Input less the mass of goods exported from the UK.	**Domestic Biomass Consumption**—Domestic Biomass Input less biomass exported.
Imported Material—mass of primary resources (minerals, fossil fuels, biomass) imported into the UK.	**Imported Biomass Input**—mass of biological material imported into the UK. Can be used at aggregated level (total imported biomass) or for specific commodity groups.

Box 21.1 Imported biomass: data available, data codes and import profiling.

Reporting on UK import flows follows international guidelines and employs a hierarchical coding system that allows biomass imports to be classified and recorded on the basis of a single to eight digit coding system. Single digit codes provide a high level summary; eight digit coding provides very specific commodity data. For example, code 15111010 represents the precisely defined *'Crude palm oil for technical or industrial uses (excluding for manufacture of foodstuffs)'.*

The UK HM Revenue & Customs database records commodity code, commodity type, volume (kilogrammes), value (Pounds Sterling) and country of dispatch for each import category. Detailed coding provides the ability to analyse import data for specific commodities of interest.

This chapter focuses on the use of five trade data groups defined by single digit codes and 26 associated (two digit) commodities. Two digit coding classifies biomass imports into the following groups:

- **Food and live animals** (Code 0)—over 50% of UK biomass imports fall into this category including meat, cereal, animal feedstuffs and vegetable commodities.
- **Beverages and tobacco** (Code 1)—a minor commodity group within which only tobacco is classed as biomass for this analysis.
- **Crude materials** (Code 2)—includes the oilseeds, wood pulp and cork/wood commodities.
- **Animal and vegetable oils and fats** (Code 4)—includes palm oil, soya and rapeseed oils.
- **Manufactured goods** (Code 6)—a miscellaneous group of processed biomass commodities, paper products being most significant.

Taken together, these groupings provide the basis for high level analysis of import flows in this chapter, including the graphical profiling of the UK's biomass imports in terms of volume and category (**Figure 1**).

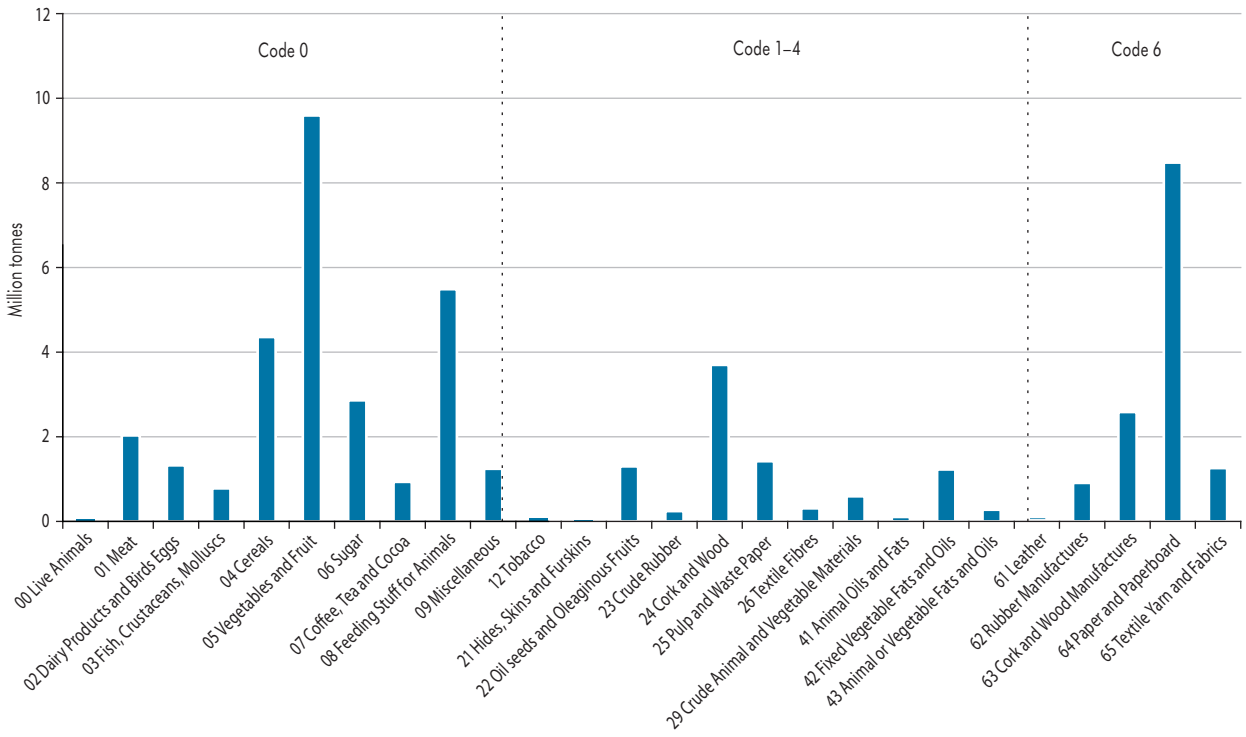


Figure 1 Commodity profile of UK biomass imports in 2008. Source: data from HMRC (2010b).

21.3 Domestic Pressures on Global Ecosystems

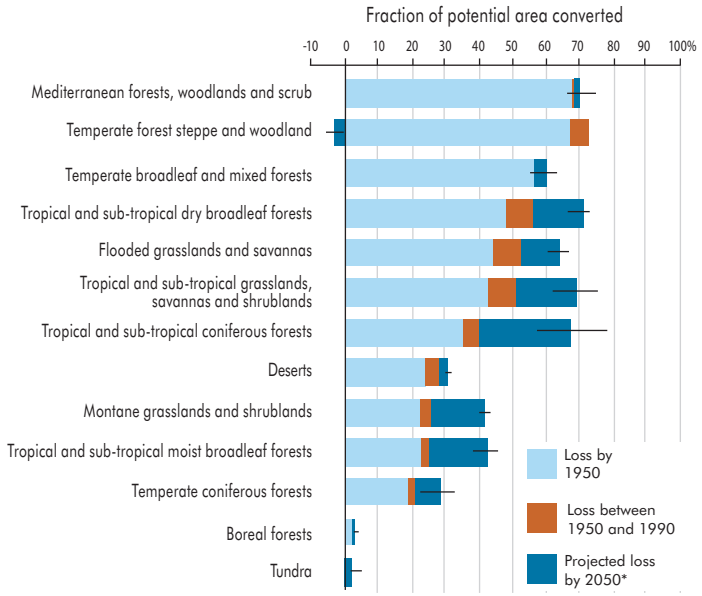
The link between the UK's economy and the provision of biomass from overseas ecosystems can be quantified and analysed in an eco-political context (described in terms of ecological and political boundaries). Dependencies can be defined, and the ways in which the UK is adding to pressures on specific global ecosystems can be identified, providing a framework for developing appropriate domestic and international policies to eliminate or manage these pressures.

21.3.1 Ecosystems

Spatial patterns of biodiversity can be expressed in varying levels of geographical and ecological detail. This chapter follows the approach adopted by the Millennium Ecosystem Assessment (MA 2005a) and uses 'Biogeographical Realms' and 'Biomes' as the geographical units for analysis of the UK's links to overseas ecosystems. These ecological units fall within political boundaries, so a useful framework for policy development requires an eco-political analysis.

The geographical analysis presented in this chapter is designed to provide this eco-political context and is undertaken on three levels, two biogeographical and one political:

- The Biogeographic Realm, the eight large spatial regions in which ecosystems share broadly similar characteristics and evolutionary history and roughly correspond to the continents (**Figure 21.1**). Global Biogeographic Realms display variations in the extent of the change to their component ecosystems, face different drivers for change and may be amenable to different strategies for managing these drivers.
- The Biome, the 13 major terrestrial global biological communities (**Figure 21.2**) classified according to the predominant vegetation, and characterised by adaptations of organisms to that particular environment.
- National sources of biomass imports, as recorded in the UK trade database (HMRC 2010b), allowing specific trade partners to be identified and categorised according to biomass trade relationships. Any international UK policies to manage the overseas impacts of its material consumption will be implemented at a national level and will be deployed in the context of agricultural, environmental and other frameworks.



*According to the four MA scenarios. For 2050 projections, the average value of the projections under the four scenarios is plotted and the error bars (black lines) represent the range of values from the different scenarios.

Figure 21.2 Principal global biomes and their status. Source: MA (2005a).

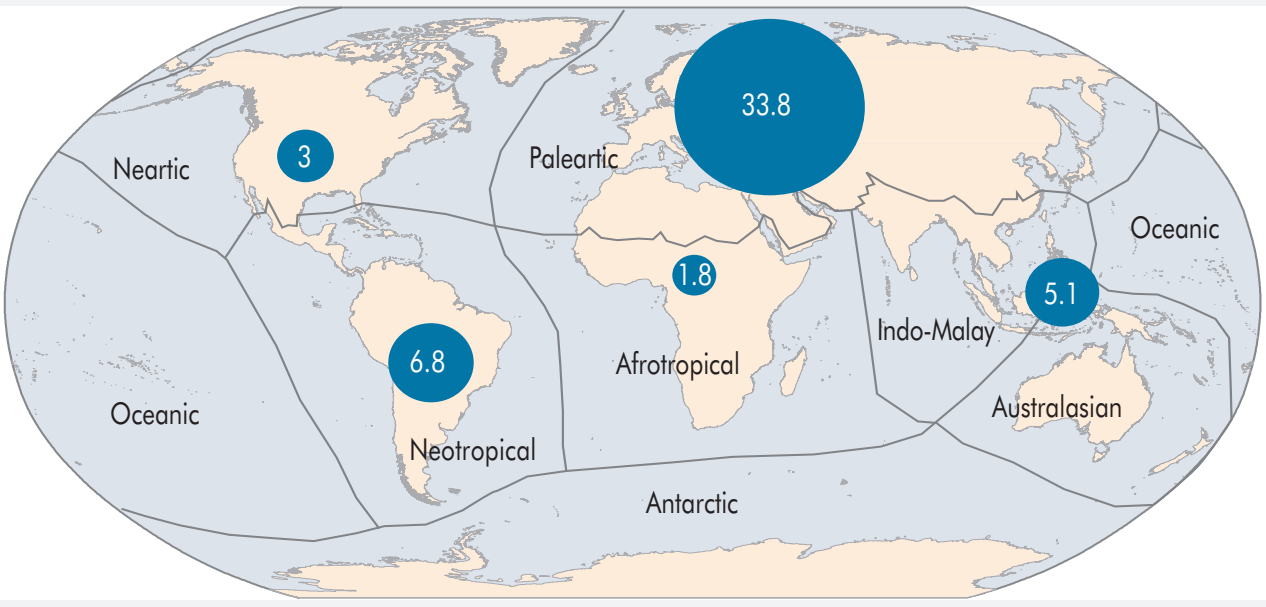


Figure 21.1 Source of biomass (millions of tonnes) imported into the UK by Biogeographical Realms in 2008. Source: data from HMRC (2010b); underlying map based Olson *et al.* (2004).

21.3.2 Pressures and Drivers

Changes within global ecosystems are primarily a result of indirect anthropogenic drivers, the most significant of which are related to demographic and economic changes. Population growth and relocation (urbanisation) are major factors, along with changing consumption patterns associated with increasing per capita income. These indirect drivers have resulted in an absolute increase in global consumption of ecosystem services and goods, and also an increase in per capita consumption. These indirect drivers are linked to a set of direct drivers of ecosystem degradation (and biodiversity loss) which include habitat change, climate change, impacts of invasive alien species, overexploitation and pollution.

The original extent of many of the terrestrial global biomes (on which this chapter focuses) is uncertain because of deforestation, agricultural expansion and urbanisation. The original boundaries can be estimated by reference to soil and climate conditions, the results of which infer significant changes in all of the major biomes: 20–50% of nine out of the 14 biomes have been converted to croplands (MA 2005a; **Figure 21.2**). This pressure for conversion is increasing as global demand for food and other biomass rises, emphasising the role of provisioning services at the expense of the other ecosystem services and biodiversity. The MA predicts that habitat loss due to land use change will cause continued decline in local and global taxa, and states that this decline is a cross-border issue driven by both local and global pressures. The expected increase in the UK's use of global ecosystem services, particularly its use of biomass, will add to these pressures.

The MA highlights the potential for socioeconomic factors (consumption patterns, population changes, policies and economic cycles) to have positive or negative effects on the functioning of ecosystem provisioning services and on the supporting services underpinning them. The capacity of these socioeconomic drivers to impact on ecosystem function reinforces the need to understand the nature of these links and to formulate policies accordingly.

The UK contributes to global ecosystem pressures through the following socioeconomic drivers:

- *Economic growth*—although UK domestic material consumption appears detached from economic growth (as measured by GDP) the economy has grown through use of overseas resources (ONS 2010).
- *Increasing population*—over the past 30 years, increased UK biomass consumption has been closely related to population growth.
- *Changing patterns of biomass consumption*—currently the main use of biomass by the UK economy is for food (either directly or through contributions to the animal food chain). The pattern of biomass consumption within the UK's economy is changing as a result of new policies on recycling and waste reduction (reducing demand) and use of renewable energy sources (increasing demand).

The capacity to measure UK economy biomass use, combined with other data examining the drivers for national biomass consumption, allows an assessment to be made of the effects of these UK domestic drivers on overseas ecosystems. Population growth and changes in national wealth and patterns of biomass use can be translated into a strategic overview of where (in which countries and ecosystems) these pressures will be felt and through what specific mechanisms. Empirical assessment of biomass flows and qualitative assessment of how and where pressures may be exerted does not, in itself, mean that negative ecosystem impacts are occurring, but serves to identity where and how they may occur. Detailed sustainability analysis on a case-by-case basis will be needed to determine if the pressures within the identified ecosystems are acceptable on social, economic and ecological grounds, and if they are being effectively managed. Such analysis needs to be undertaken to determine the resilience of the ecosystems concerned and appropriate thresholds below which we can safely continue to exploit specific systems (Bateman 2010; Turner 2007).

The MFA approach used here provides a framework for such sustainability work by providing:

- *An eco-political location (in terms of country and ecosystem) where pressures are occurring*—demonstrating the UK's dependencies on specific regions/countries and the need to focus sustainability analysis on these areas.
- *The basis for a numerical measure of land and water requirements for biomass production in each eco-political region*—permitting quantification of pressure exerted through these demands, indicating the scale of potential associated impacts and the extent to which pressure is being exerted on individual ecosystems.
- *A strategic overview of the mechanisms through which ecosystem impacts may occur in specific regions*—analysis of commodity types originating from individual regions permits specific associated environmental pressures to be identified, providing a screening mechanism to direct sustainability analysis.

21.4 Imported Biomass in the UK's Economy: 2008 as a Baseline

This chapter looks at the historical use of biomass by the UK's economy, and makes some basic forward projections in terms of biomass requirements and their potential overseas impacts. The year 2008 provides a convenient point from which to look back on historical trends and project these into the future.

21.4.1 Characterising Biomass Import Flows

According to the ONS analysis (ONS 2010), approximately 52 million tonnes of biomass were imported in 2008, representing one third of the 154 million tonnes of the total biomass input into the economy (**Figure 21.3**). Data available from HM Revenue & Customs allows UK biomass imports to be profiled according to their characteristics. Imports cover the full range of biomass groups from unprocessed raw materials (primarily foodstuffs) to highly

processed items such as textiles and manufactured wood products. Almost 70% of imported biomass is food chain material, either for direct human consumption or animal feed, with fruit and vegetables, animal feed and cereals dominating (**Box 21.1**; **Figure 21.4**). Non-food imports are primarily forest products such as cork, wood and paper.

21.4.2 Biofuels: a Special Case

To comply with the EU Renewable Energy Directive, the UK will need to achieve a 10% substitution of transport fuels with biofuels by 2020. The UK used approximately 1 million tonnes of biofuels in 2008. Over 80% of this fuel was biodiesel sourced from soya, oilseed rape and palm oil (RFA 2009), the remainder being bioethanol primarily sourced from sugarcane.

Trade data on biomass does not directly record biofuel imports, which are described under several industrial classifications and customs codes, but the UK Renewable Fuels Agency (RFA) monitors the use of biofuels in the UK, including imports. Currently, most biofuels used in the UK come from primary crops, rather than recycled materials, so have a land use requirement. With over 80% of biofuels being imported (RFA 2010), much of this requirement falls overseas: the total overseas land use requirement for the UK's use of biofuels was estimated at 1.3–1.4 million ha in 2008 (RFA 2009; JNCC 2009). In addition to volumetric data, the RFA records data on source country and crop, allowing source biome to be deduced for most of the imported supply (JNCC 2009).

The bias towards biodiesel use by the UK transport sector skews overseas land use impacts to those areas producing oilseed rape, palm oil and soya: Germany, Malaysia and Indonesia, and the Americas respectively. Plant oil and, therefore, biofuel yield per hectare varies considerably for the three principal biodiesel source crops. Soya is the most important single biodiesel feedstock for the UK. It has the lowest yield per hectare, however, so the high relative use of this crop results in over 60% of the land use pressure arising from UK biofuels use occurring in the 'Americas', specifically the USA, Argentina and Brazil.

21.4.3 UK Biomass Imports: Sources and Land Requirements

The UK's biomass imports, including bioethanol and biodiesel fuels, amounted to approximately 52 million tonnes of primary materials in 2008. As agricultural or forest products, or their derivatives, these imports can be expected to have a land use requirement for their production. More than 98% of these imports are sourced from five Biogeographical Realms (**Figure 21.1**; **Table 21.2**), with an estimated total land use footprint of 14 million hectares. Of this footprint, 90% arises from the provision of agricultural products for food and forest products, and the remaining 10% from bioenergy crops.

The UK's trade relationships are dominated by its links to the EU which, along with Russia and other European neighbours, supplied 34 million tonnes of biomass to the UK economy in 2008: 65% of the country's total biomass imports. Therefore, the majority of the land use footprint associated with biomass imports (approximately 8.5 million ha) falls in the Palearctic Realm (**Figure 21.1**).

Tropical regions provide a further 26% of the UK's biomass imports, with the remaining material coming from North America. The Neotropical region of South America provides 2.4 million ha of land to support UK biomass consumption, which is approximately equal to the total contribution from the Nearctic (North American) and Oceania Realms combined (**Box 21.3**). In addition to its land demand, the UK also has a significant South American water footprint (**Box 21.2**).

Analysed at the global biome level, approximately 10 million ha of land use footprint can be assigned to five individual biomes (**Table 21.3**): Boreal Forest Taiga, Temperate Broadleaf and Mixed Forest, Temperate Grasslands, Mediterranean Forest and Tropical/Sub-tropical Broadleaf Forest. The processed nature of some of the biomass imported into the UK prevents simple analysis of source biome and land use requirements, and the estimates presented here represent minimum figures. European Boreal Forest Taiga and Temperate Broadleaf and Mixed Forest biomes are key providers, the former for timber products and the latter for food chain biomass. Outside these areas,

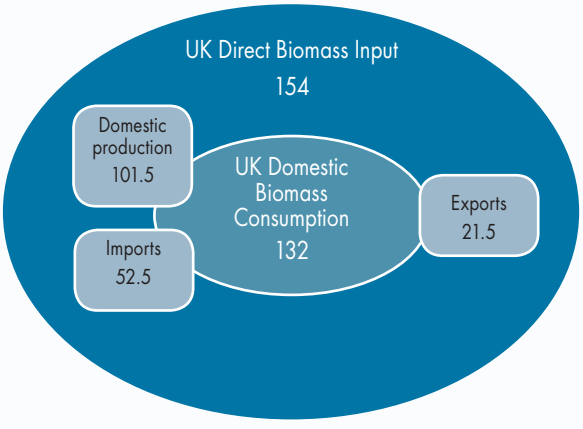


Figure 21.3 UK biomass balance for 2008 in millions of tonnes. Source: data from ONS (2010b).

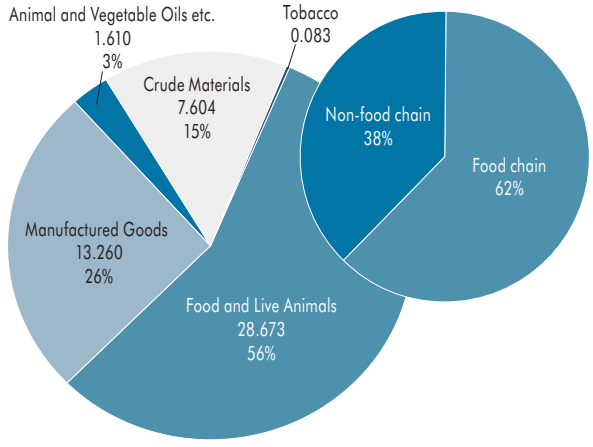


Figure 21.4 Commodity profile of UK biomass imports (millions of tonnes/percentage) in 2008. Source: data from HMRC (2010b).

Table 21.2 Estimated land requirement (in millions of ha) in global Biogeographical Realms to provide biomass imported to the UK. Land area estimates based on detailed analysis of imported biomass commodity flows, country/region- and crop-specific biomass yields. Due to rounding of numbers column totals may not match cell figure totals. See JNCC (2009) for details of biofuels analysis.

Realms	Agricultural and forest products area	Biofuels area	Total area
Palearctic	8.3	0.2	8.5
Nearctic	0.7	0.6	1.3
Oceania	1.3	0.0	1.3
Neotropical	1.9	0.5	2.4
Afrotropical	0.3	0.0	0.3
Total	**12.5**	**1.4**	**13.9**

Table 21.3 Estimated land requirement (in millions of ha) in global Biomes to provide biomass imported to the UK. Land area estimates based on detailed analysis of imported biomass commodity flows, country/region- and crop-specific biomass yields. Not all biomass imports can be assigned to a specific biome. See JNCC (2009) for details of biofuels analysis.

Biomes	Agricultural and forest products area	Biofuels area	Total area
Boreal Forest Taiga	3.3	0	3.3
Temperate Broadleaf and Mixed Forest	3.1	0.2	3.3
Temperate Grasslands	0.6	1.1	1.7
Mediterranean Forest	0.1	0.0	0.1
Tropical/Sub-Tropical Broadleaf Forest	1.7	0.1	1.8
Total	**8.8**	**1.4**	**10.2**

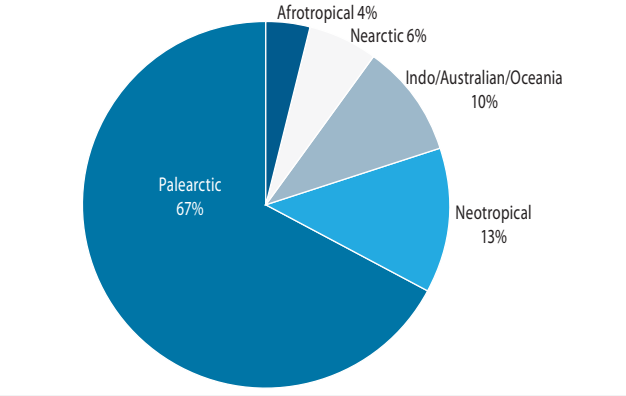


Figure 21.5 Source of UK-imported biomass by Biogeographical Realm (as per Figure 21.1) in 2008.
Source: data from HMRC (2010a).

the land use footprint is almost identical in Temperate Grasslands and Tropical/Sub-tropical Broadleaf Forest. Impacts on Temperate Grassland are due to both food chain and biofuels provision, with soya-based products being the key commodity in both cases.

There are regional and national differences in the global agricultural systems providing biomass to the UK. These differences, due to climatic and economic factors, are reflected in the 'profiles' of their biomass commodity exports. South America (Neotropical Realm) and Sub-Saharan Africa (Afrotropical Realm) have biomass supply profiles skewed towards basic (unprocessed) raw materials. Sub-Saharan Africa is an immature region that has large areas of largely unconverted ecosystems with relatively low agricultural yields which supply basic commodities within national boundaries or to regional neighbours. Provision of basic foodstuffs is the primary concern. Value-added biomass

Box 21.2 The UK's overseas water demand.

Whereas two thirds of the UK's biomass comes from domestic sources, the situation with national water demand is reversed, and only one third of the water we use actually comes from the UK (WWF 2010). The bulk of UK water demand—75% of the total national usage of 102 billion cubic metres per year (Gm^3/yr)—is associated with the production of agricultural commodities (**Figure 1**). Industrial products require 24 Gm^3/yr and household water use is only 3.3 Gm^3/yr. Of the 75 Gm^3/yr agricultural water demand, 46 Gm^3/yr (61%) is an external demand being provided by overseas ecosystems to produce biomass for UK consumption, of which over 70% is from arable crops. In respect of agricultural water use in general, and crop production in particular, overseas water demand significantly exceeds that imposed on domestic supplies.

According to WWF: "*Most of the products that make up the UK's EWF (external water footprint) originate from Brazil, France, Ireland, Ghana and India.*" Brazil, through provision of soybeans, coffee and livestock products, is responsible for 9% of this external water demand, reaffirming the strong link between the UK and South America through import of agricultural commodities.

Combined with the land requirement to produce imported biomass described in this chapter, this water demand represents a quantifiable link between the UK's economy and overseas ecosystems (Hoekstra & Chapgain 2008), and is one basis for monitoring the impacts of UK biomass imports in space and time.

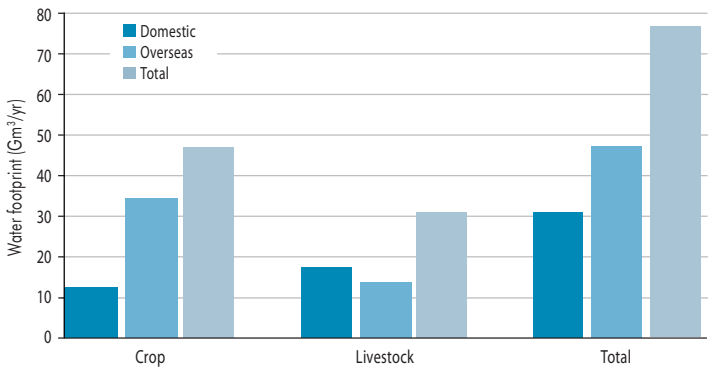


Figure 1 UK water usage (in billion cubic metres per year).
Source: data from WWF (2008).

Box 21.3 The importance of South American biomass within the UK's economy.

The UK imported 6 million tonnes of biomass from Central and South America in 2008, with soya and fruit/vegetables representing almost 70% of these imports (**Figure 1**). Based on crop and country-specific yield data, it is estimated that approximately 2.4 million ha were required to grow these materials.

- Soya products for human and animal feed had a land use requirement of 1.2 million ha in 2008. An additional 500,000 ha requirement also arose from the use of soya-based biodiesel. To put this in context, van Gelder *et al.* (2008) estimate that approximately 12 million ha of South American land were required to supply the whole of the EU with soya products in 2007.
- Brazil and Argentina are the UK's two dominant trade partners in the region, providing at least 4 million tones of biomass from 1.62 million ha of land, principally though their supply of soya-based commodities. This land requirement is equivalent to the agricultural land area within Wales. There is a strong dependency between UK food, agricultural and bioenergy sectors and soya supplies from South America.
- Approximately 60% of biomass sourced from South America can be assigned to specific biomes. Whilst this is only an approximation of the geographical origin of these materials, it demonstrates the importance of two key biomes within the region, specifically Temperate Grasslands, lying exclusively in Argentina, and Tropical Broadleafed Forests, primarily within Brazil but with some small contributions from Ecuador and Colombia.

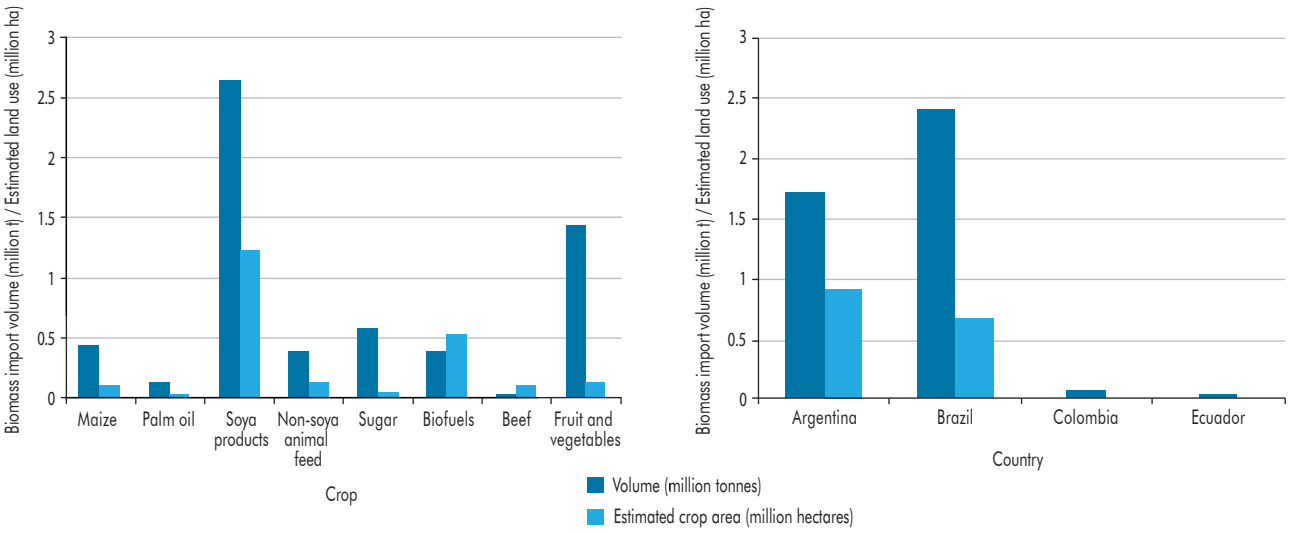


Figure 1 UK biomass import volumes (in millions of tonnes) and estimated land use (in millions of hectares) for South America (Neotropical Realm) in 2008: a) principal biomass imports and land use requirement, and b) total biomass volumes and land use requirement in four key regional countries. Source: ONS for import biomass volumes, HMRC (2010a)

products are a small element in these economies due to the lack of the industrial infrastructure to undertake processing. Long distance exports from such regions are limited.

Some regions, or nation states within regions, are moving away from basic raw materials (including tropical beverages such as tea and coffee) and exporting higher value dairy, meat and horticultural products (FAO 2007). South America shows the beginnings of a transition from being a supplier of basic raw materials to providing more processed biomass materials.

21.5 Trends in UK Consumption of Biomass

Material Flow Analysis provides the basis for tracking the history of biomass use by the UK economy over a 40-year period. Combining data on biomass use with other data provides an insight into the role of biomass in the UK economy and the key drivers underpinning supply and demand.

21.5.1 Background

Over the last 200 years, the UK's economy has moved from a mixture of services, manufacturing and biomass-based activities (farming, forestry and fisheries) to an economy based on the service sector (**Figure 21.6**). The extent to which ecosystem services, such as the use of primary productivity, support a service-based economy are not always obvious, and the shift from an agricultural to a service-based economy can be interpreted as a process that reduces pressures on ecosystems (MA 2005a). This is based on the assumption that services are less demanding on ecosystem products. The decline in agricultural contributions to the economy is only relative, the contributions from the other sectors simply outgrowing biomass-based activities. Reporting of relevant statistics also understates this sector, recording many food-related activities under industrial classifications rather than agriculture.

Biomass remains an undervalued contributor to developed economies, one which is currently being re-evaluated (BTF 2005; Svetlana & Vinterbäck 2009). Furthermore, long-term analysis shows 'Domestic Biomass Consumption' (**Table 21.1**) in the UK to be virtually recession-proof (**Figure 21.7**) and related primarily to population size. This contrasts with mineral and fossil fuel consumption patterns which reflect

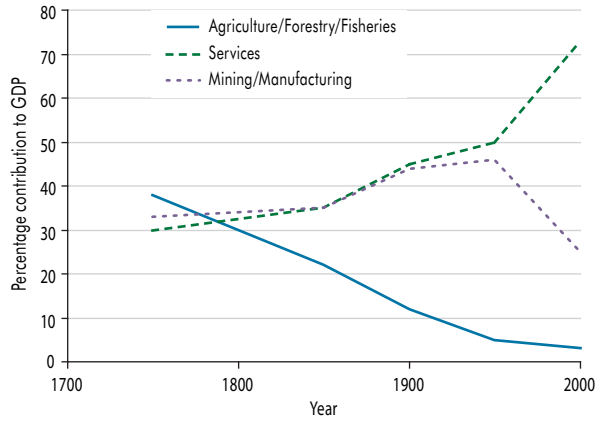


Figure 21.6 Evolution of the UK's economy from 1800+ to 2000. Source: data from MA (2005a).

major recessions that typically reduce mineral consumption (due to contraction in the construction sector) and fuel use. Trend analysis also shows that steady economic growth since 1990 has not been matched by an increase in consumption of domestic natural resources ('Domestic Material Consumption') but over the same period imports have risen. In the words of the Office for National Statistics this suggests that "*t*hat some of the environmental impacts associated with consumption are being transferred abroad" (ONS 2010). The growing import flows, including a steady increase in biomass imports, contrasts with the relatively steady domestic biomass production (**Figure 21.8**) making it clear that the UK is drawing increasingly on the primary production of overseas ecosystems.

21.5.2 Drivers of UK Biomass Demand

Between 1970 and 2002, when consumption peaked, the UK net consumption of biomass, allowing for domestic production, imports and exports, increased by 4.5%. Analysis of primary statistical data on material flows and trade allows demand and supply side drivers for UK biomass consumption to be determined.

21.5.2.1 Population growth

A growing and changing population increases overall consumption and modifies patterns of consumption through changing levels of affluence and degrees of urbanisation (MA 2005a). Increased population size inevitably draws on more, and a greater variety of, ecosystem services. Analysis of UK population growth and Domestic Biomass Consumption shows a strong relationship during the period 1970 to 2002. This relationship is reflected in both an absolute growth in national biomass consumption during this period and an increase in per capita consumption (**Figure 21.9**; **Figure 21.10**). This analysis shows that Domestic Biomass Consumption peaked at 137 million tonnes in 2002, before dropping to 131 million in 2008. Per capita consumption of biomass also increased up to 2002, peaking at 2.31 tonnes (t) per person.

The change in the population/consumption relationship which occurred early in the 21st Century (and was not related to any economic downturn) appears to represent a fundamental shift in consumption pattern (**Figure 21.9**; **Figure 21.10**). Whilst consumption of food products, including animal feed, has continued to increase during the last decade, there has been a decline in timber imports which probably reflects increased reuse and recycling of available timber as a result of legislation designed to reduce material going to landfill.

21.5.2.2 Food demand

In 2008, the UK's agricultural system contributed approximately 92 million tonnes of biomass into the food chain, supplemented by 35 million tonnes of imported human and animal foods (ONS 2010). Allowing for food exports of 13 million tonnes, the net 'food chain' biomass utilised by the UK population was approximately 114 million tonnes, 87% of the Domestic Biomass Consumption. Biomass consumption in the UK is, therefore, currently driven primarily by food demand.

Annual surveys of the food purchasing and consumption patterns of the UK's population provide detailed statistics on diet (Defra 2008). Actual food consumption is recorded

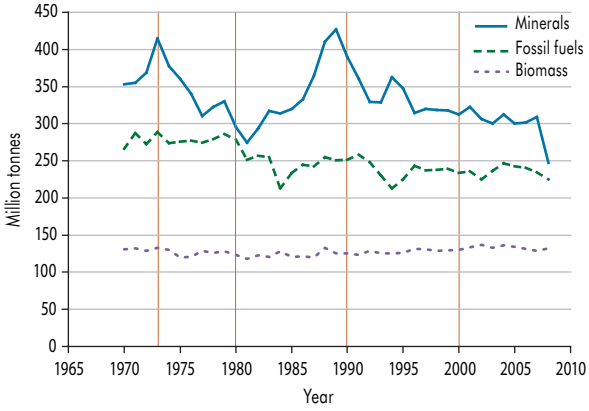


Figure 21.7 Material consumption by the UK's economy from 1970 to 2008. Source: data from ONS (2010b).

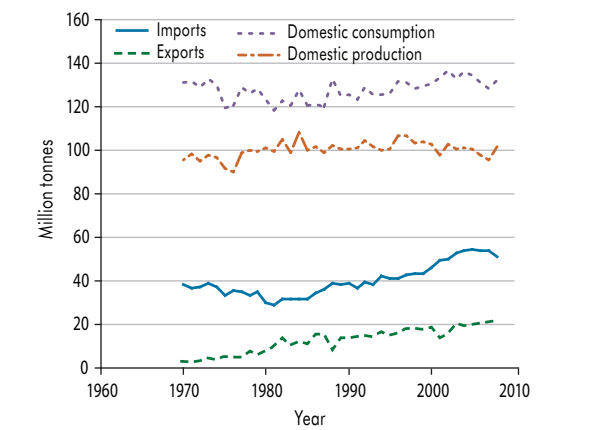


Figure 21.8 UK biomass flows from 1970 to 2008. Source: based on data from ONS (2010b).

as 0.36 t/person/yr, a total national consumption of 22.1 million tonnes. The relationship between food actually consumed and material entering the food chain to support this consumption indicates a ratio of at least 1:5—for every tonne of food consumed there is an underpinning biomass volume of at least 5 tonnes[1].

21.5.2.3 Forest products demand

Food chain biomass dominates the flow and use of biomass in the UK; most of the remainder (including 34% of imported biomass) is classified as forest products such as timber, paper and wood pulp. Current national demand for wood fibre is approximately 12 million t/yr (Confor 2010) representing 0.3 t/capita. Domestic production from UK forest systems has remained relatively constant at 8–9 million t/yr since 2000, but annual imports of timber have declined by over 4 million tonnes from a peak of 10 million t/yr in 2004 (HMRC 2010b).

21.5.2.4 Energy

The UK government has adopted a renewable energy policy which makes provision for substitution of fossil fuels by biomass for the supply of liquid transport fuels, heat energy and electricity. There is also renewed interest in the capacity of the UK's landscape to produce biomass (BTF 2005). Current biomass demand for energy purposes is focused primarily on supplying liquid biofuels as partial replacements for petrol and diesel (Section 21.4.2). In 2008, the bioenergy sector was responsible for only 1.5% of the country's import biomass demand through the use of liquid biofuels (RFA 2010). Demand for biofuels is growing, however (Booth *et al.* 2009; Confor 2010), and the increasing use of biomass for heat and power generation will ensure that this sector has a major impact on future UK biomass demand (Section 21.6).

21.5.3 Biomass Supply

The UK currently utilises approximately 150 million tonnes of biomass per year, of which 130 million tonnes represents actual domestic consumption, and the remaining balance is exported. The balance between domestic supply and imported materials has shifted slowly through time, with UK production (Domestic Biomass Extraction; **Table 21.1**) being relatively constant in the long-term but imports steadily increasing (**Figure 21.8**).

21.5.3.1 Domestic Supply

Since the late 1970s, UK domestic biomass production from agriculture, horticulture and forests has averaged 100 million t/yr, varying between 94–104 million tonnes (**Figure 21.8**). The additional contribution from domestic marine fisheries is less than 1 million t/yr and has been excluded from this analysis. Terrestrial biomass production in the UK comes from three sources: grasslands and agricultural harvests together provide approximately 92 million tonnes of biomass, complimented by 8 million tonnes of timber, primarily from coniferous woodland. A slow decline in domestic biomass output began in 2000, reflecting low profitability in the agricultural sector, but this trend was sharply reversed in 2008 as commodity prices rose, indicating that the UK agricultural system has the capacity to increase output in response to market forces (JNCC 2011).

21.5.3.2 Biomass Imports

The relatively steady domestic biomass supply contrasts with growth in biomass imports from 1980 through to a peak in 2002 (**Figure 21.8**). Post 2002, a different pattern of consumption emerged, reflecting greater reuse of some biomass, particularly timber products (Section 21.5.2.1). Biomass imports stabilised at around 52–54 million tonnes for several years, but data for 2009 indicate a further drop in imports of biomass, down to 47.6 million tonnes. This reduction reflects a continuing decline in imports of forest products and a small (1.2 million tonnes) drop in food chain imports which follows consumer response to price increases in 2008.

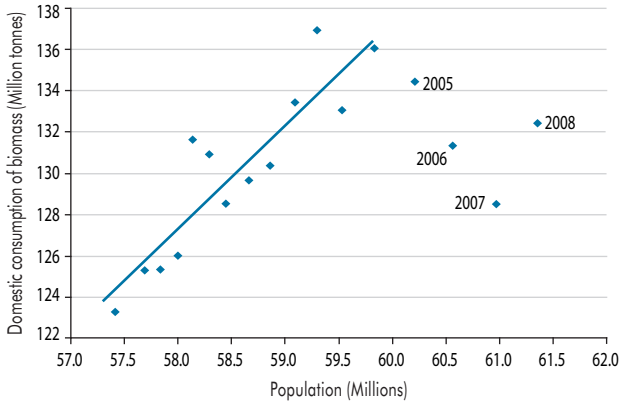


Figure 21.9 Relationship between domestic biomass consumption and UK population size. Source: data from ONS (2010a & b).

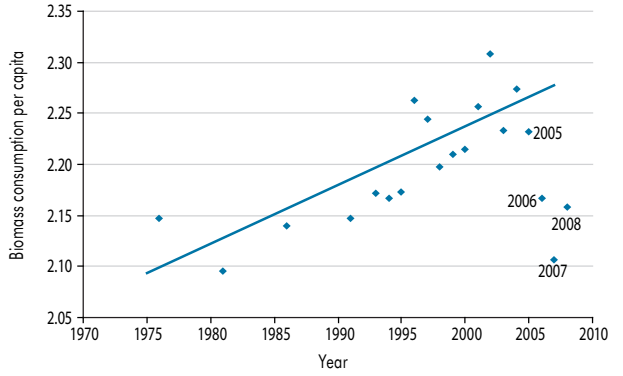


Figure 21.10 Change in biomass consumption per capita from 1975 to 2008. Source: data from ONS (2010a & b).

1 This ratio is based on biomass volumes recorded in government statistics (imported biomass statistics, domestic agricultural production data and food consumption patterns), but does not take into account the significant amount of unused waste biomass associated with domestic and overseas agricultural systems that support the UK food chain. Estimates of these hidden flows suggest that the true ratio is closer to 1:10.

21.6 Future Biomass Demand—Projecting to 2030

An analysis of the historical links between biomass consumption and population size in the UK, combined with an assessment of the future biomass demand likely to result from the new national renewable energy policies, permits assessments to be made of future biomass import demand. The implications of these projections for future UK biomass imports can be described in terms of material flows and overseas land use requirements.

21.6.1 Assumptions

The UK's historical use of biomass has been driven primarily by food consumption, with over 85% of the national biomass demand supporting the food chain. The use of biomass for other purposes, such as construction and bioenergy, has been less important in terms of biomass volumes, but new renewable energy policies will significantly increase the demand for biomass for heat and power generation. Biomass heat and power facilities with significant capacity, and currently under construction or in the planning stage, are principally located on the coast to ensure access to adequate biomass feedstocks. As these facilities come on-line over the next few years, the demand for imported biomass will significantly increase[2] (Confor 2010).

Numerical projections of potential biomass demand up to 2030 are possibly based on population growth forecasts and an assessment of the impact of energy policy. Population growth and the nature of the UK and global policy landscape beyond 2030 are less clear, and forecasts would be more subjective and less valuable in the context of this assessment. Furthermore, the projections presented here suggest that if appropriate biomass demand mitigation measures are implemented in the next decade, imported biomass demand could be stabilised by 2030.

The projection of imported biomass demand up to 2030, and associated overseas land use requirements (**Figure 21.11**; **Figure 21.12**), illustrates population-driven food chain demand augmented by the growing demand for biomass for energy, and is based on the following:

- Up to 2030, there will be a steady population growth, reaching 70.5 million by that date (ONS 2010).
- A *maximum* imported food chain demand up to 2030 has been estimated based on a relatively constant domestic production of approximately 95 million t/yr combined with a 'consumption as usual' model. This implies current patterns of biomass usage continue with a food chain biomass[3] demand of 1.86 t/capita/yr.
- A *minimum* imported food chain demand up to 2030 has been estimated based on a progressive increase in domestic production, achieving a 10% increase by 2030 equivalent to an additional 10 million t/yr. This is coupled with a progressive reduction in food chain waste based on a 50% waste reduction by 2030[4].
- A steady increase in biofuels consumption up to 2020, but a rapid implementation of broader bioenergy policies with an associated abrupt increase in demand for solid biomass (Confor 2010).

21.6.2 Implications: Material Flows

Future biomass demand in the UK, and the associated import requirements, will be determined by two principal factors: food and energy demand. Population growth and new renewable energy policies will increase absolute demand for biomass. This increasing import demand could be mitigated by successful implementation of waste reduction strategies and increased domestic biomass production, both of which would help reduce biomass imports.

The key conclusions in respect of these projections in terms of biomass imports are:

- Unmitigated food consumption will result in a linear increase in food chain biomass import demand in direct proportion to population growth, resulting in an increase from the current 35 million tonnes food chain import to almost 50 million tonnes in 2030 (**Figure 21.11**).
- Food chain biomass import demand can be mitigated by waste reduction (see WRAP 2010) and increased domestic production, potentially reducing total food chain demand by approximately 15 million tonnes by 2030. Such mitigation measures could effectively compensate for the underlying increased food demand arising from population growth.
- In the absence of mitigation, total imported biomass demand will rise rapidly in the next decade due to steady population increase and an abrupt increase in the use of biomass for energy production (**Figure 21.11**).

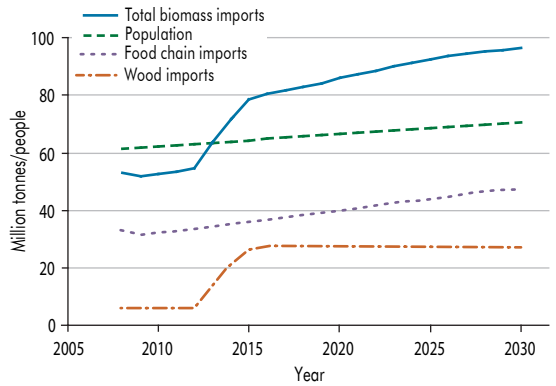


Figure 21.11 Possible UK biomass imports to 2030 based on current food consumption patterns and bioenergy policies. Source: Confor (2010) and ONS (2010a).

2 Two facilities planned for Tyneside and Teesside, and due to be commissioned in 2013, will use 4 million tonnes of imported woodchips a year. These facilities alone will increase the UK's imported biomass demand by almost 8%.
3 All forms of biomass supporting the human food chain, including direct input for human consumption and animal feed.
4 This total biomass saving is based on the 5:1 ratio of food consumption to underpinning biomass.

21.6.3 Implications: Overseas Land Use Impacts

Potential land requirements to supply future biomass imports are estimated on the basis of an average yield value for UK biomass imports in 2008[5].

The impacts of a growing future demand for imported biomass, in terms of overseas land use requirement, are likely to be as follows:

- If biomass import demand is unmitigated by increased domestic production and reduced waste, the overseas land use requirement could double from the current 14 million ha to 28 million ha by 2030. However, if appropriately mitigated, this land use requirement could be limited to approximately 20 million[6].
- Additional national biofuels demand (mostly imported) will create a land use requirement of at least 5 million ha by 2020 if current consumption patterns persist, most of which will be in South America (Argentina) through the supply of soya-based biodiesel. There may be an increase in imports from Sub-Saharan Africa and associated growth in footprint in that region. Sugarcane ethanol and palm oil diesel have higher energy yields per unit of land area, so the overseas land requirement could be mitigated by switching to greater use of these fuels[7].
- If current food consumption patterns continue, and domestic production remains unchanged, the import demand will grow significantly, creating an additional overseas land demand of approximately 5 million ha to support UK food consumption.
- Modified food consumption patterns, particularly a reduction in waste throughout the whole food chain, could mitigate the increased demand from a growing population, and the overseas land use impact could be held close to the existing level of 10 million ha.
- The UK's demand for biomass for energy alone (driven by government policy to generate power and heat from biomass) will potentially create an additional 7 million ha global pressure on overseas ecosystems by 2020.

These simplified projections illustrate the potential effects, in terms of biomass demand and overseas land use, which could arise from continued population growth and the implementation of new bioenergy policies in the UK. Given current domestic policies and global trends, it is highly likely that a combination of factors, including increased agricultural yields in the UK and overseas and food waste reduction, will exert a downward pressure on food import demand. Bioenergy policies will exert a contrary pressure, increasing demand. The elementary projections presented here illustrate that significant opportunities exist to reduce biomass imports and the associated overseas impacts that come with population growth. They also illustrate the policy drivers that will increase import demands and their associated impacts.

21.6.4 Projections of Overseas Biomass Demand in the Context of the UK NEA

The UK NEA recognises the role of direct and indirect drivers on ecosystem function. The implications of changing circumstances within UK society, and the changing roles of these drivers for national ecosystems, are examined through a set of UK NEA scenarios for the year 2060. As with the UK domestic landscape, the causal links between the evolution of UK society and the associated impacts on overseas ecosystems are complex. This chapter simplifies the analysis by reference to the key overseas ecosystem service upon which the UK's economy is dependent (the supply of biomass), the use of which is driven by food consumption and, increasingly, energy-related demand. At both strategic or details levels, the biomass material flow streams are easy to quantify and can be used to identify key direct drivers putting pressure on ecosystems.

As with the main UK NEA scenarios (Chapter 25), an understanding of current states and past trends has been used to develop simple plausible projections of biomass import demand and the associated overseas land use requirement (**Figure 21.11**; **Figure 21.12**). The land use projections show high and low case scenarios up to 2030. The higher case assumes no change in current consumption patterns or policies on bioenergy. It also assumes global sources can supply demand. The lower case assumes that import demand can be moderated through a combination of increased domestic biomass production and a reduction in biomass waste arising in the food chain. Given the numerical nature of these biomass and land use demand projections they have not been extended beyond 2030 because the population projections and policy developments that underpin them become increasingly uncertain beyond that date.

Each of the UK NEA scenarios has implications for the future balance to be struck between reliance on domestic

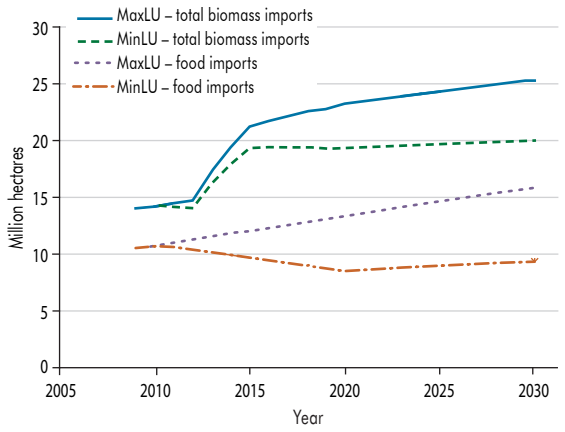


Figure 21.12 Projected overseas land use requirement to supply the UK with imported biomass under high and low import scenarios. MaxLU = maximum land use; MinLU = minimum land use.

5 Calculated as 3.7 t/ha average biomass yield across all biomass import categories based on a detailed analysis of UK biomass imports and country-specific yields.
6 Resulting in a balance between the use of UK and overseas land area to support the UK economy: 20 million ha at home and 20 million ha overseas.
7 Data available in late 2010 on the use of biofuels in the UK suggests that this is already happening with increased national use of bioethanol as a fossil fuel substitute.

biomass production and imports. The six UK NEA scenarios describe the end state of each storyline rather than a timeline for each. The biomass import projections in this section do not extend beyond 2030. However, it can be argued that, given current rates of change in biomass use and consumption patterns, policy initiatives adopted to manage biomass imports over the next two decades will effectively determine domestic and global landscapes in later years.

The high case biomass impact trajectory presented here could result from either of the '*Green and Pleasant Land*' or '*World Market*' UK NEA scenarios. The former involves a preservationist attitude to the UK's own landscape, meeting increased demand for food and energy biomass primarily from overseas sources. The *World Market* scenario, although not seeking to protect the UK's landscape to the same extent, allows free markets to determine the source of the UK's biomass with little regard for environmental issues. Import demand grows considerably under this scenario.

The low case impact trajectory could reflect a conscious decision by the UK to be more self-reliant, or be imposed by a need to fall back on our own resources through lack of access to world markets for political or technical reasons. The former, free choice, situation is embodied in the '*Local Stewardship*' UK NEA scenario, where self-sufficiency is a key concept and both exports and imports are minimised. The '*National Security*' scenario describes a situation where global food supplies may be limited through climate change or other factors such as the breakdown of free trade with food exporters limiting outward flows or supplying preferred clients through unilateral agreements that exclude the UK. Under this scenario biomass imports are limited by supply.

Underpinning all of the UK NEA scenarios, and the simple projections of this chapter, is the key question of population growth within the UK over the coming decades. The six UK NEA scenarios are built around population storyline attributes involving a UK population that varies from 65 million (slightly more than today) to 75 million by 2030. The direct link between biomass consumption through the food chain and population size makes this driver critical.

21.7 UK Dependence on Overseas Ecosystems: a Monitoring, Evaluation and Policy Framework

Policy on sustainable consumption and production in the UK, as outlined in Securing the Future (HMSO 2005), identifies the need for reliable indicators of the impact of the UK economy on other countries, including the measurement of resource use. This strategy advocates the use of indicators that are:

- comparable with those used internationally and other national accounts;
- capable of reporting on national, EU and global trends;
- and capable of measuring the overseas impact of UK material consumption.

The strategy stresses that domestic policies to monitor and modify material consumption should be complemented by following through on our international commitments to spread good practice and maintain political pressure for change. The use of a biomass material flow framework provides the basis for reporting on UK, EU and global trends in biomass use, measurement of impacts on overseas ecosystems, and the formulation of domestic and international policy initiatives.

21.7.1 Biomass Material Flow Analysis as a Framework for Measuring and Reporting on National, EU and Global Trends

The biomass flow framework allows the UK's use of specific biomass commodities from individual eco-political regions (countries, biomes) to be quantified and monitored in time and space. Monitoring can focus on strategic analysis of major commodity groups or focus on individual commodities, total global flows or individual regions. Biomass flow analysis can highlight key commodities coming out of individual eco-political regions and link directly to socioeconomic drivers within the UK's economy such as population growth, food consumption patterns and bioenergy policies.

Key variables for measuring and reporting on biomass consumption by the UK's economy are summarised in **Table 21.1** and **Figure 21.13**. The important characteristics of these indicators are that they:

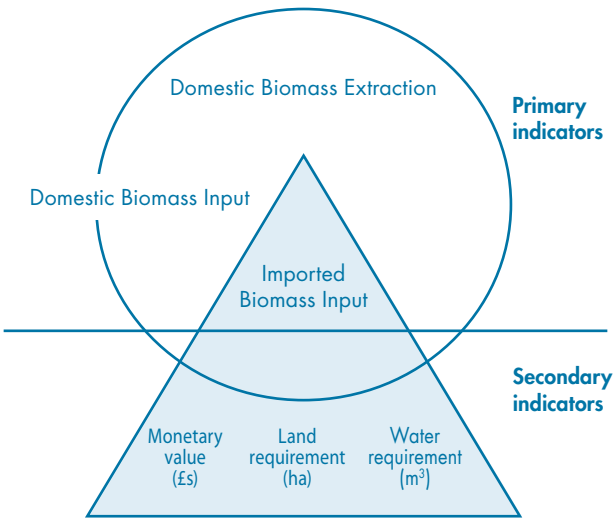


Figure 21.13 Total biomass available to the UK economy 'Domestic Biomass Input') comprises domestic extraction plus imports. These material flows are directly recorded (as mass) and provide a set of Primary Indicators of UK biomass supply. Secondary Indicators, derived from mass flow data, can be generated including the monetary value of biomass flows and the land or water required for biomass production.

- are based on published data that have been gathered consistently over long time periods;
- are easily understood by policy makers;
- are themselves statistical data and can be related to other economic and demographic statistics, notably GDP and population statistics;
- provide information about the changes in biomass imports in time and space.

The UK is one of many countries placing demands on overseas ecosystems. The MFA approach, based on freely available data gathered according to international standards, allows international biomass flows to be quantified, and the demand created by the UK's consumption to be placed in context. For example, the UK's import of South American soya products in 2008 is recorded as approximately 3 million tonnes (almost 6% of all biomass imports) with an estimated land use impact of 1.7 million ha. This is in the context of a total EU soya-based land use impact in the region of 12 million ha (Profundo 2010).

Monitoring the flow of biomass out of specific ecosystems and into the UK and other economies provides a direct measure of our dependencies (**Figure 21.14**) on these systems and the means to report on national, EU and global trends. The data available data makes clear which countries and which ecosystems we are dependent upon.

21.7.2 Biomass Material Flow Analysis as a Framework for Measuring the Overseas Impact of UK Material Consumption

Primary indicators of biomass use can be combined with other information to derive a measure of the overseas impacts of this aspect of our material consumption. In the case of agricultural and managed forest systems, the pressure we are applying to overseas ecosystems can be measured in terms of water demand and land required to produce the biomass that is imported into the UK. For 'harvested' commodities, such as fish and hardwoods, this analysis is not applicable, and the ecosystem pressures can only be expressed in terms of volume (mass) of biomass being extracted from individual eco-political areas.

Quantitative analysis of the land and water required to sustain imported biomass supply provides the context for identification and assessment of specific environmental pressures which our economy may be causing overseas (**Figure 21.14**). Knowledge of the specific characteristics of biomass streams ('crop type') permits specific associated environmental pressures to be identified.

In general terms these pressures are:

- *agricultural/forestry frontier expansion or agricultural intensification* to meet increasing demand for biomass; land use requirement estimates indicate where such pressures may be increased through UK biomass imports.

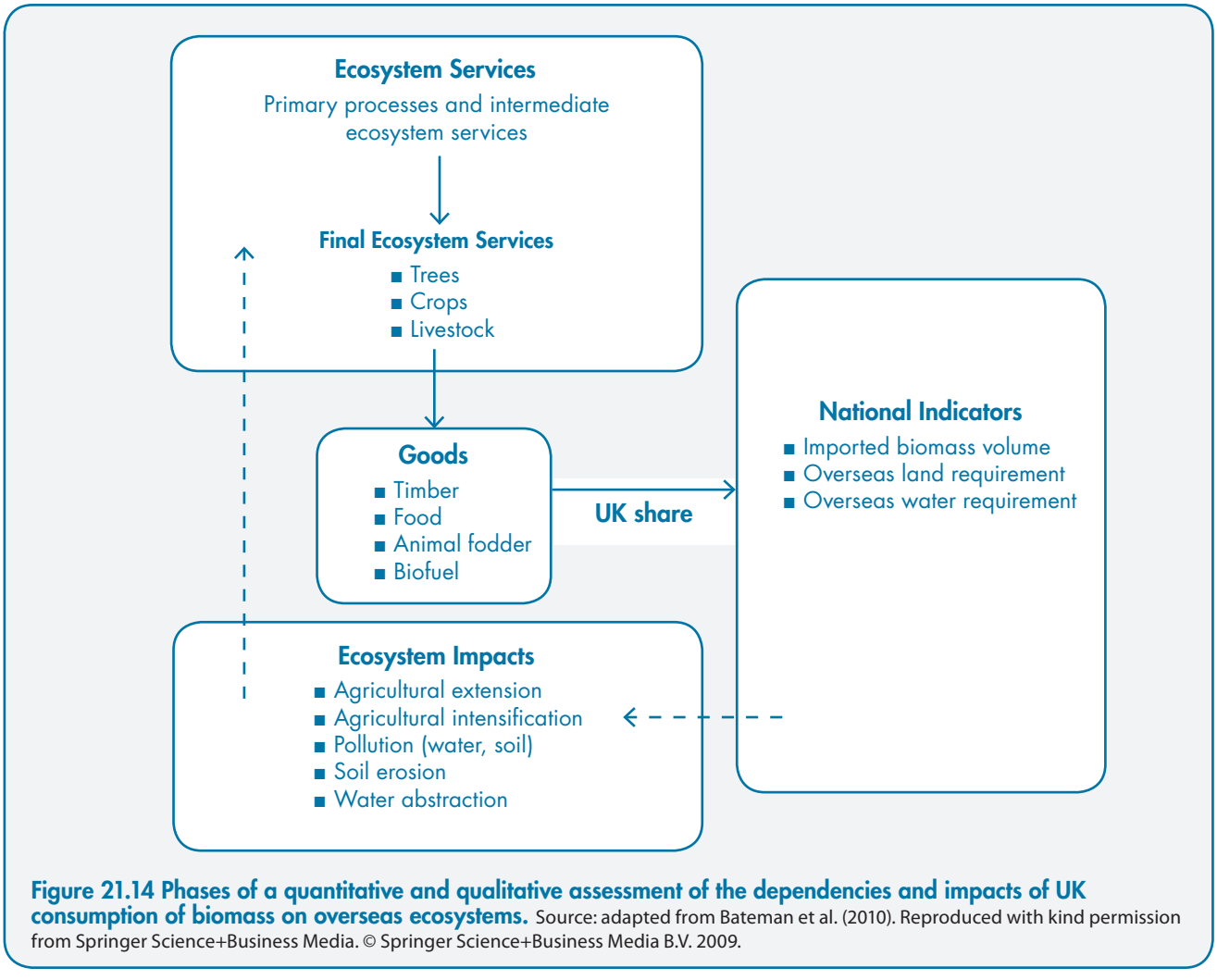


Figure 21.14 Phases of a quantitative and qualitative assessment of the dependencies and impacts of UK consumption of biomass on overseas ecosystems. Source: adapted from Bateman et al. (2010). Reproduced with kind permission from Springer Science+Business Media. © Springer Science+Business Media B.V. 2009.

- *water abstraction*—UK overseas water use due to biomass production can be quantified for agricultural commodities and related to existing, or predicted, water stress in source ecosystems with the potential to impact on wetlands, river systems, etc.
- *pollution*—arising from use of agrichemicals and potentially affecting soil and water.
- *soil degradation*—through erosion or impairment of function (pollution, reduction in organic matter, soil biodiversity, etc.).
- *use of invasive alien species*—crop species for food, bioenergy or wood fibre potentially displacing indigenous populations.

The biomass analysis framework discussed here allows the UK (or any other economic unit) to undertake two important actions. Firstly, to identify and quantify its overseas biomass dependencies, including the spatial determination of where material is being sourced from. Secondly, to determine the nature of potential ecosystem impacts that may arise from use of imported biomass imports. The framework allows us to determine what we are importing, where it comes from and how impacts may be occur. By integrating material flow data with other socioeconomic information, we can also understand why the demand is occurring.

The biomass framework provides the basis for a three-stage process for sustainability analysis of UK use of overseas ecosystems, specifically:

- Primary analysis of biomass material flows into the UK to monitor use and trends;
- Secondary analysis to derive a measure of overseas ecosystem pressures in terms of land and water use;
- Tertiary sustainability analysis focusing on key global pressure points, key commodities and the direct impacts recognised through the framework to assess the resilience of the ecosystems supplying the UK with biomass.

21.7.3 Biomass Material Flow Analysis as a Framework for Policy Implementation

Through its ability to enable monitoring of biomass flows through the economy, and focus sustainability analysis in critical areas, this framework provides a basis for developing forward looking policies. These policies should be designed to minimise our overseas impacts and maximise biomass security, whilst ensuring the long-term sustainable use of the ecosystems upon which the country depends. This can include current dependencies and those which MFA projections suggest may develop in the future.

The analysis presented here suggests that there are a small number of current pressure points where detailed sustainability analysis of particular commodity production should be carried out. Approximately 60% of the overseas land requirement to supply imported biomass falls within the UK's EU partners and the adjacent European countries. As a member of the EU, the UK participates in policy development to protect the European landscape and, therefore, is already engaged in mitigating the impacts of its biomass imports from these areas. It can be argued that the impact occurring in North America (less than 10% of the total) is either effectively managed or beyond the influence of UK policies. This leaves the three tropical regions (South America, Sub-Saharan Africa and Oceania) which provide almost 30% of the UK's overseas land requirement and where significant changes are occurring to natural environments; it is here that the UK should actively engage in mitigating its impacts. In terms of biomes outside the EU, Argentinean Temperate Grasslands and Brazilian and Asian Tropical Broadleafed Forests are the key ecological units supplying food and biofuels to the UK (**Table 21.2**; **Table 21.3**) and merit immediate attention.

Looking forward, potential increases in imports of palm oil from Ecuador and Colombia into the UK will affect tropical forests in these areas. Additional pressure is likely to be exerted on Brazil and Argentina through increased food, animal feed and biofuels imports, including biodiesel from soya and ethanol from sugarcane. Increased biomass for bioenergy use is expected to be met from Baltic and South American forest sources. As a global supplier of biomass, Sub-Saharan Africa remains a giant-in-waiting. As well as helping to monitor impacts on existing global pressure points, biomass flow analysis, including the routine use of indicators, can also act as an early warning system, showing where new pressure points are emerging.

Geographical identification of key areas now providing biomass to the UK's economy, or likely to supply it in the future, provides the basis for targeted international policies designed to protect the long-term functioning of the ecosystems vital to the UK's national interest. Technical assistance, financial aid and political dialogue are all options to achieve this objective. These could be executed through bilateral actions between the UK and its key overseas suppliers and dialogues with other significant global consumers for traded biomass. Increasing domestic biomass production through appropriate policies can also be used to moderate overseas demand.

These 'supply side' policies to influence the means of biomass production can be complemented by domestic 'demand side' policies which influence UK consumption. Biomass flow analysis suggests that more effective national use of biomass, particularly through reducing waste within the food chain, can significantly affect biomass demand, including imports[8]. Domestic ecological footprinting of the UK's material consumption shows that whilst "the food supply chain is complex, food footprints can be reduced and success will have a major impact" (Dawkins *et al.* 2008). The ecological footprint of food consumption in the UK has been reviewed by Frey and Barnett (2007) and in a global context by the MA (MA 2005b). New analysis for this chapter of the UK NEA demonstrates the potential benefits of reducing food waste, in particular the reduction in import demand and attendant reduction in overseas ecosystem impacts. In addition to reducing biomass demand throughout the food chain and the

8 Food waste reduction implies that food which would have been wasted would not be purchased, reducing total demand.

land required to produce this biomass, significant reductions in energy use and greenhouse gas emissions would result.

Monitoring material flows of biomass out of a particular ecological unit (at Realm, Biome or Ecosystem scale) says nothing, in itself, about the capacity of a system to continue to supply these materials into the future. This will depend upon the resilience of the systems concerned, and their ability to withstand the stresses imposed and to continue to provide the services we need from them. We need to identify which of the systems that we are dependent on are resilient, and which are not. Judgements also need to be made in the context of safe minimum standards where conventional economic decisions prevail (i.e to continue to exploit) until a threshold value/tipping point is identified (Turner 2007). Beyond this point, the onus shifts to a presumption of protection. We need to know which ecosystems we depend upon are close to their tipping points and why.

This chapter focuses on the UK as the consuming entity but MFA can also be undertaken at the regional level (WWF 2006), highlighting regional differences in per capita consumption of food and fuel. The dependence of individual regional economies, or individual citizens, on overseas biomass production can be estimated and used for regional sustainability analysis and policy development. For example, based on per capita consumption of imported biomass, Scotland currently depends upon approximately 4.5 million tonnes of imported biomass per year, or 1.2 million ha of overseas land. Material flow analysis can follow policy initiatives down to the appropriate regional level at which actions may be most effective.

The value of biomass to the UK and global economy is currently being re-evaluated (BTF 2005; Booth *et al.* 2009; Openshaw. 2010). The recognition that biomass for energy production is relevant to developed economies and is not just a third world resource is leading to ambitious renewable energy strategies in the developed world (Svetlana & Vinterbäck 2009). These strategies will dramatically increase demand for biomass use in the production of transport fuels, heat and electricity. Global demand for food is increasing, reflecting population growth and increased global incomes. Continued national population growth will inevitably increase demand for human food and animal feed within the UK. As a result of the food and bioenergy drivers, biomass will take a more prominent role in the UK's economy in the future. The UK's obvious dependence on the primary productivity of overseas ecosystems makes it imperative that we take steps to ensure the long-term productivity of these systems. Routine monitoring and analysis of imports flows, and the formulation of policies to ensure long-term productivity, are, therefore, in the national interest.

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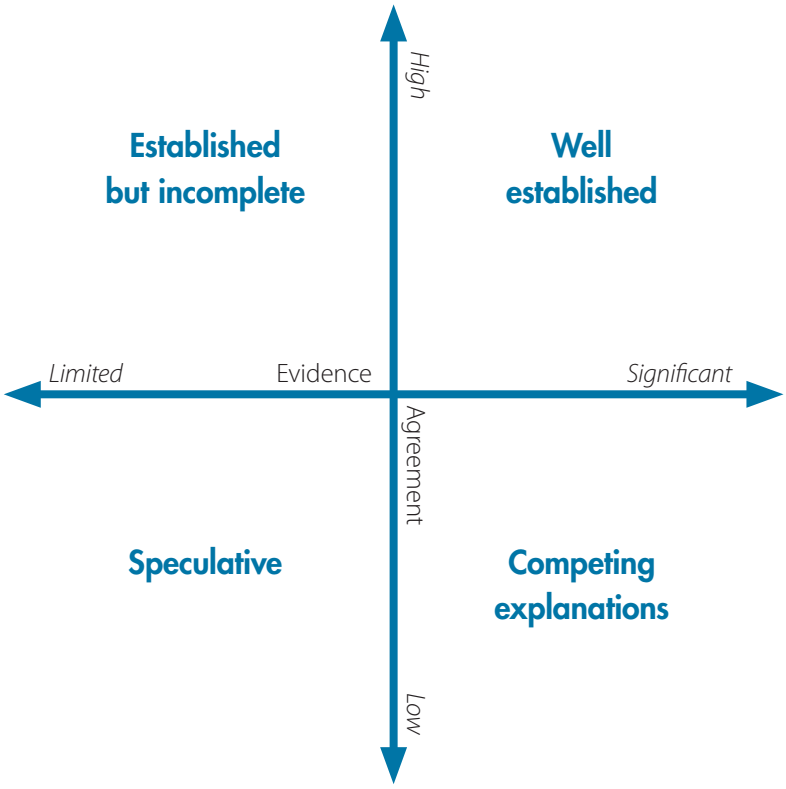
Appendix 21.1 Approach Used to Assign Certainty Terms to Chapter Key Findings

This chapter began with a set of Key Findings. Adopting the approach and terminology used by the Intergovernmental Panel on Climate Change (IPCC) and the Millennium Assessment (MA), these Key Findings also include an indication of the level of scientific certainty. The 'uncertainty approach' of the UK NEA consists of a set of qualitative uncertainty terms derived from a 4-box model and complemented, where possible, with a likelihood scale (see below). Estimates of certainty are derived from the collective judgement of authors, observational evidence, modelling results and/or theory examined for this assessment.

Throughout the Key Findings presented at the start of this chapter, superscript numbers and letters indicate the estimated level of certainty for a particular key finding:

1. *Well established:* high agreement based on significant evidence
2. *Established but incomplete evidence:* high agreement based on limited evidence
3. *Competing explanations:* low agreement, albeit with significant evidence
4. *Speculative:* low agreement based on limited evidence



a. *Virtually certain:* >99% probability of occurrence
b. *Very likely:* >90% probability
c. *Likely:* >66% probability
d. *About as likely as not:* >33–66% probability
e. *Unlikely:* <33% probability
f. *Very unlikely:* <10% probability
g. *Exceptionally unlikely:* <1% probability

Certainty terms 1 to 4 constitute the 4-box model, while *a* to *g* constitute the likelihood scale.