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Quantifying the economic benefits and costs of agricultural systems

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Author: Darius Maraulas

Diploma Thesis Supervisor: Dr. Paul Burgess

CRANFIELD UNIVERSITY

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This thesis is submitted in partial fulfilment of the requirements for the degree of MSc

ABSTRACT

Economic growth and an ever rising world population put pressure on food demands and agricultural products. To feed nearly 9 billion people by 2050, a new vision is needed to ensure food supply, environmental sustainability and economic opportunity through agriculture. From national statistics it is possible to derive the gross value added by agricultural systems. For example the annual gross value added by UK agriculture in 2007 was about £5.6 billion. Researchers have also estimated the cost of UK agriculture on non-provisioning ecosystem services. Spencer et al. (2008) estimated that the net environmental cost of UK agriculture was about £1.2 billion in 2007. By adding the two values, we can derive an annual net benefit of UK agriculture to society of about £4.4 billion. The aim of sustainable intensification is to increase this overall value by increasing production values and/or environmental values. The aim of this project is to apply a graphical approach of plotting the value of provisioning services against the value of other ecosystem services to the agricultural and forestry sectors in the UK, and also for different countries within the UK.

Keywords:

Sustainability, Environmental Accounts, Ecosystem Services, Provisioning Services

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CPA	Classification of Products by Activity
FISM	Financial Intermediation Services Indirectly Measured
GV	Gross Value
GVA	Gross Value Added
IMC	Intermediate consumption

1 Introduction

In the context of increasing global population and increasing demands being placed on agricultural land, Foresight (2011) identified "sustainable intensification" as a priority. They described sustainable intensification as the process of "simultaneously raising yields, increasing the efficiency with which inputs are used, and reducing the negative environmental effects of food production". Wood et al. (2000) referred to the "expansion of the agriculture-environment outputs frontier" in order to feed an estimated 9 billion people by 2050 (Figure 1.1). A vision is needed to ensure food supply is enhanced at the same time as environmental sustainability (EU, 2011).

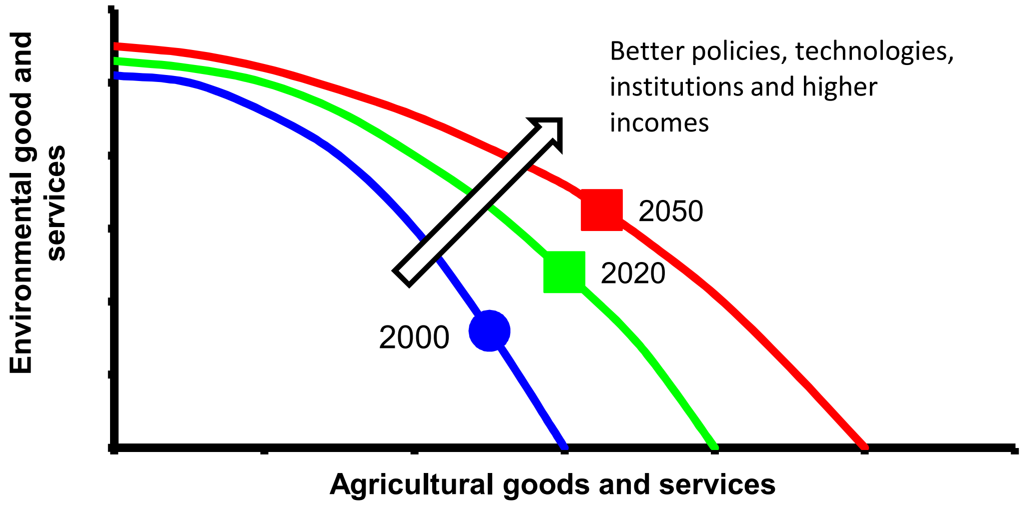

Figure 1.1. Enhancing agroecosystem goods and services (Wood et al., 2000)

The Millennium Ecosystem Assessment (2005), and the UK National Ecosystem Assessment (2011), refer to both agricultural goods and environmental services as "ecosystem services". These are the benefits provided by an ecosystem to people. There are various ways of categorising ecosystem services, but most distinguish between provisioning ecosystem services (such as food and energy) and other "regulating" and "cultural services". In 2013, in a concept diagram within the report "Land as an Environmental Resource", Hart et al. (2013) produced a conceptual diagram highlighting the potential position of conventional and organic agriculture within a food-environment production possibility frontier (Figure 1.2).

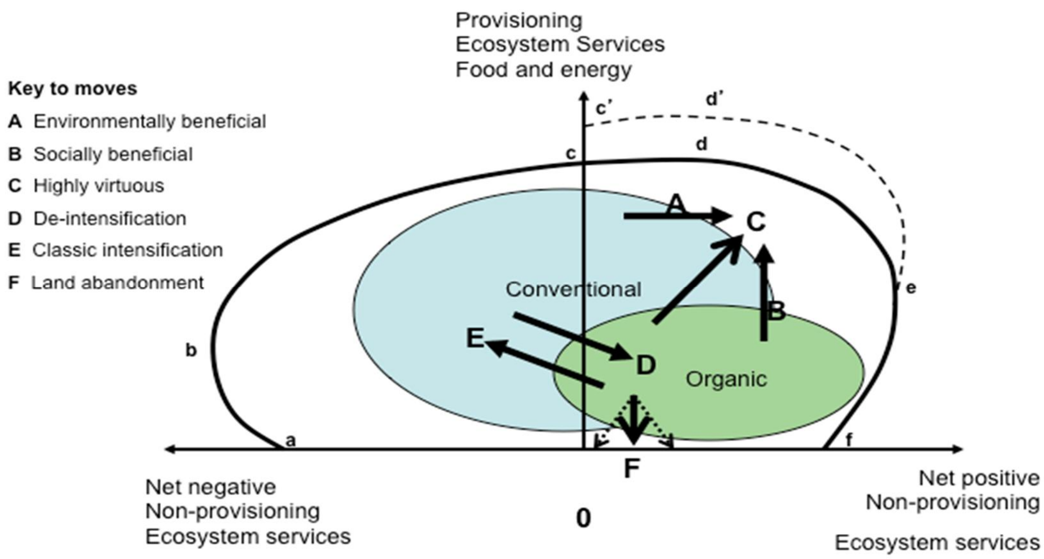

Figure 1.2. The food – environment production possibilities frontier (Hart et al., 2013)

Both Figure 1.1 and Figure 1.2 contain no values. The aim of this thesis is to apply the approach of plotting provisioning services against other ecosystem services to the actual situation in the UK. This paper has three main objectives: to derive best estimates of i) the value of provisioning and other ecosystem services of specific land uses, ii) to apply these data to graphical representations of Figure 1.1 and Figure 1.2, and iii) to critique the potential applicability of the approach. Are such graphs helpful to policy makers who need effective communication tools?

The thesis starts with a literature review of the development of monetised environmental accounting for the agricultural sector, with a focus on the UK. Then explains the framework used to meet the research objectives, and presents the results. It is followed by a discussion of the results and recommendations in terms of the applicability of the framework to identify and address potential improvements within the UK agriculture.

2 Literature review

Agriculture faces many challenges. Population growth and an increased per capita demand for agricultural products requires increased production, while environmental sustainability is affected by issues such as greenhouse gas emissions and land degradation. Increased climate variability can also increase the risk of short-term variability in regional food supply (SSAFS, 2013). Authors such as Chomsky (2011) argue that a drive for short term profits can lead to severe economic threats and possible catastrophe for the global commons. Land managers therefore must seek to combine increased efficiency with improved ecologically sustainability. This process is aided by methods to quantify the true value of agriculture in relation to its environment.

2.1 Environmental accounts

The UK environmental accounts are satellite accounts to the national accounts of the UK, and they help to explain the interactions between the environment and economic activity in the UK. They include natural asset accounts (e.g. oil and gas reserves, forestry, and land), physical flow accounts (e.g. greenhouse gas emissions, air pollutants, energy consumption, and consumption of raw materials) and monetary accounts (e.g. environmental taxes, environmental protection expenditure). This section provides an overview of the concept of environmental accounts, their development, and current applications.

Environmental accounts provide data on the interaction between the environment and the economy: both the effects of the impact of the economy on the environment, and the impact of the environment on the economy. Environmental accounts can be used to inform sustainable development policy (Eurostat, 2008), to model impacts of fiscal or monetary measures, and to evaluate the environmental impacts of different sectors to economy. Environmental accounts are extensions (or satellite accounts) to the main national accounts which facilitate analysis of wider impact of economic change. Stiglitz (2008) describe environmental accounts as ‘vital building blocks’ for indicating sustainability. The phrase “environmental accounting” originates from the early 1990s.

Hueting and Bosch (1990) tried to express the value of sustainable use of the environment and natural resources and costs to achieve it, indicating both positive and negative impacts of agriculture.

2.2 Environmental accounts for agriculture and forestry

Adger and Whitby (1991) suggested modifying sectoral accounts to account for environmental externalities. Using existing studies, their framework attempted to value the positive and negative externalities of UK agriculture and forestry within the national income accounts for the UK. Further research by Adger and Whitby (1993) suggested additional changes to improve the understanding of environmental capital within national accounts, whilst acknowledging that the implementation of such changes was really challenging. A study by Hamilton and Atkinson (1995) used a genuine savings approach introduced by Pearce and Atkinson (1993) to evaluate pollution emissions from European OECD countries. Consistently negative genuine savings rates were taken to indicate unsustainability (Hamilton and Atkinson, 1995).

Pretty et al. (2000) used an accounting framework to describe the environmental costs of UK agriculture. They proposed seven cost categories and did not consider positive externalities. The work highlighted the need for policy reform and suggested further analysis of marginal external costs. Hartridge and Pearce (2001) used a similar environmental framework to look at positive as well as negative impacts of agriculture. Eftec (2004) used the Hartridge and Pearce report as a framework for applying a monetised environmental accounting to the UK agricultural sector. The study provided an accounting framework to describe the impacts of agriculture on the environment, and recognised three main roles of environmental assets. These roles are three main functions of the environment: resource function - environment provides raw materials to produce goods and services; sink function - pollution generated by production is assimilated by the environment; and service function - which provides both survival functions and amenity functions. The Eftec (2004) report provided a base for the Spencer et al. (2008) report. This report highlighted the theoretical inconsistency between accounts and valuation, although it quantified positive and negative impacts on the environment in the UK agricultural sector. Compared to Eftec (2004), it derived a higher cost of ammonia emissions (£48 million in 2004; £525 million in 2007) and included a shadow price for greenhouse gases. This large difference is due to cost attributed to tonne of ammonia emission rather than a change in the quantity of ammonia emitted, which is tending to fall. Steady decline in total estimates of ammonia emission from UK agriculture estimate 27% reduction from 1990-2009, largely due to declining livestock numbers (Defra, 2010).

However clarifying conceptual issues, Spencer et al. (2008) highlighted that data limitations meant that there remained a wide gap between theory and data for these accounts. They recommended that should be future updates and they suggested practical ways to reduce inconsistency in valuation approaches. The EU (2011) also highlighted the importance of research and innovation to support "triple performing" land use management that embraces economic, social and environmental objectives.

Willis et al. (2003) suggest that the aggregate total capitalised value of the social and environmental benefits of woodland in GB for year 2002 is £29.2 billion. Thus woodland contributes some £1.02 billion annually in terms of non-market benefits. This value is dominated by recreational and biodiversity values, followed by landscape benefits with carbon sequestration, which contributes to environmental and social benefits of forests. To quantify total value of these environmental benefits, Willis et al. (2003) states that it depend upon individual values (for example the willingness to pay for recreational visits) and the number to which these individual values are applied. However to estimate these values with accuracy is difficult.

2.3 Recent changes in product and land prices

After a period of a long-term decline in food and energy prices, prices for food and energy have increased sharply since 2007 (**Figure 2.1**.) Associated with this increased there has also been a change in UK land values. According to Knight Frank (2013), the price of the land in England has more than tripled since 2002 (Figure 2.2). This has major implications in valuing land use.

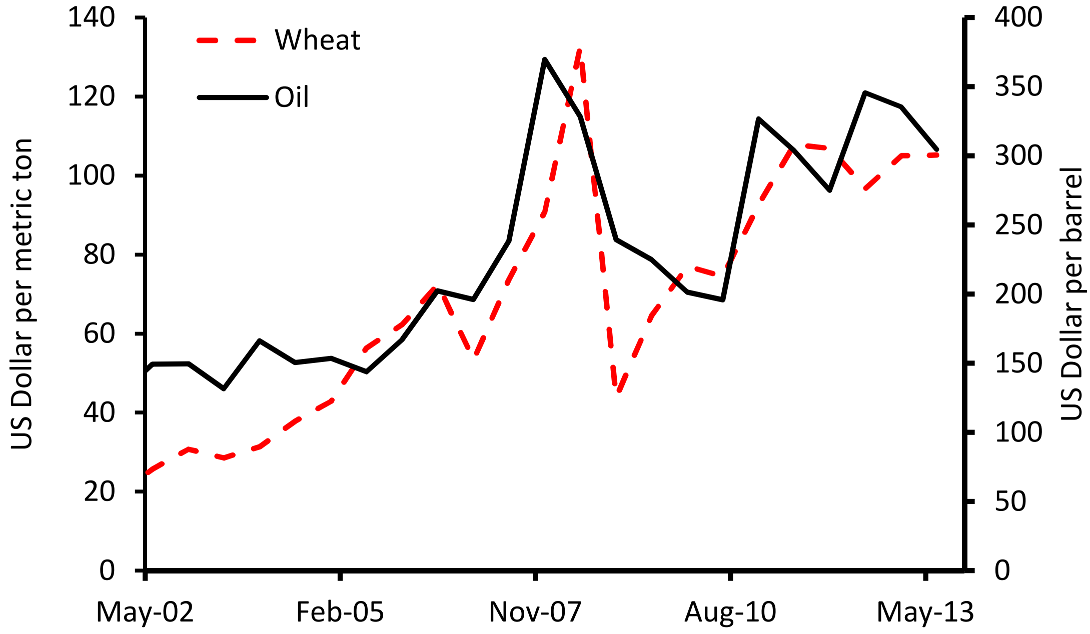

Figure 2.1. Comparing wheat and crude oil prices 2002-2014

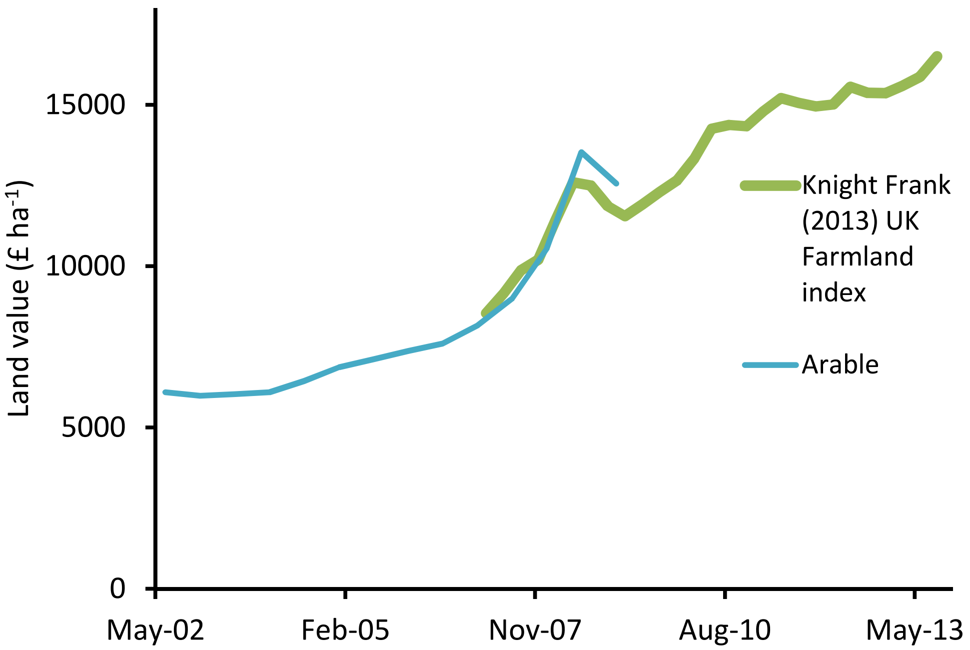

Figure 2.2. Land value in the UK 2002-2013 (Knight Frank, 2013) (Valuation Office Agency, 2009)

Analysis by Savills (2013), tracking values back to 1970, indicates that agricultural land values are more closely aligned to wheat and oil prices than the broader economy. **Figure 2.1** shows that wheat and oil prices almost tripled in a similar way to the increase in land value in Figure 2.2. However Savills (2014) also report that some of the increase in 2008 was due to professional investment, for example investment buyers accounted for 24% of all deals in 2008, up from 16% in 2007, a clear indication that these buyers recognise the relative stability of agricultural land values (Property Wire, 2008).

Between 2002 and 2008, the asset value of land increased by almost 100% over only six years (Table 2.1). During the past decade, land has become a more popular investment asset as the returns from shares and cash savings have been low. Agricultural land can be eligible for inheritance tax relief. On forested land, sales of timber can sometimes be tax-free. Savills (2013) noted that agricultural land values are more closely aligned to wheat and oil prices than the broader economy.

Table 2.1 Gross value added by agriculture (£ ha^{-1} a^{-1}) in the UK and the mean value of mixed land (£ ha^{-1}) calculated with official GVA and land price values with resultant differences.

	2002	2003	2004	2005	2006	2007	2008	2009
Gross value added by agriculture (£ ha^{-1})	289	320	293	289	302	330	447	412
Value of land (£ ha^{-1})	5338	5301	5567	6558	7294	8346	10125	11819
Gross value added as proportion of land value	5.4%	6.0%	5.2%	4.4%	4.1%	3.9%	4.4%	3.4%

Between 2002 and 2009, the gross value added by agriculture, expressed as a proportion of the land value has tended to decline from 6.0% in 2003 to 3.4% in 2009. This could suggest that land prices have some of the characteristics of an economic bubble (a market phenomenon where asset prices levels significantly above the fundamental value of that asset). However it is difficult to define an economic bubble in real time.

3 Methodology

The creation of graphs of the value of provisioning services against the value of other ecosystem services required access to actual values for each component. The application focused on the UK, as data were available for different land uses and different parts of the country. The economic benefits were quantified into two parts matching the two axes used by Wood et al. (2000) and Hart et al. (2013). The study first applied the Hart et al. (2013) environmental production possibilities frontier graphical representation to the UK agricultural environmental accounts described by Spencer et al. (2008). The graphs were presented in both absolute terms and in terms of provisioning and non-provisioning services per hectare where appropriate.

3.1 National accounts for agriculture and forestry

Spencer et al. (2008) attempted to quantify the environment benefits and costs of UK agriculture for each country: England, Scotland, Wales and Northern Ireland. Hence on the basis of these results, it was possible to plot a graph for each individual country. Because the environmental analysis was completed for year 2007, study also used the gross value added value for the same year (Defra, 2012).

The first method of calculating the provisioning services of agriculture and forestry was in terms of the gross value (GV) or revenue indicated in the national accounts. Another method used is Gross value added (GVA), it measures the contribution to the economy of each individual producer, industry or sector in the United Kingdom. It is the difference between the value of outputs and the value of intermediate consumption, so mainly comprises employment costs and profits (Forestry Commission, 2013). It is possible to compare national and subnational values of GVA on a consistent basis. Hence GVA is often used by regional and sub-regional policy and decision makers (ONS, 2010). The use of Gross Value Added can also avoid double accounting occurs where the same goods produced are counted twice. Therefore value of final goods represent value for final use by a consumer and it does not represent next resale or further processing.

In addition to looking at the value of provisioning and non-provisioning services in England, Scotland, Wales and Northern Ireland, the study also looked at UK forestry. Lastly an attempt was made to quantify the benefits of some benefits and costs of specific UK arable systems and UK livestock systems. In each case, the outputs were defined as an absolute output (e.g. £ billion a^{-1}) and as a per hectare output (e.g. £ ha^{-1} a^{-1}). The "per hectare" effects of arable and livestock systems were derived using farm management statistics and the results from life cycle assessments. Figure 3.1 provides a simple graphical representation of forestry and agriculture (arable and livestock) as the key rural land uses in the UK.

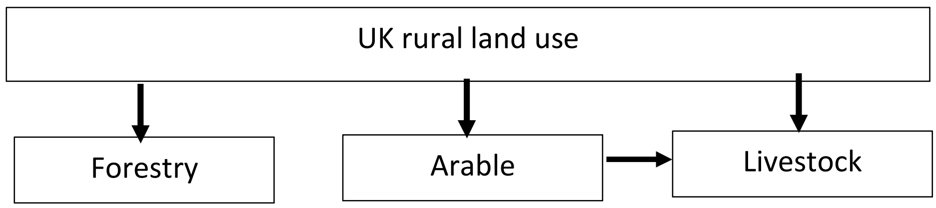

Figure 3.1. Simple diagram of UK land use followed by the study.

3.2 Individual land use systems

Forestry

Woodland is defined as areas with canopy cover over 20 % or more with minimum area of 0.5 ha and minimum width of 20 m as is specified in The National Forest Inventory for Great Britain (Forestry Commission, 2013). Therefore total woodland -areas less than 0.5ha of open space within woodland - is not included. It was not possible to derive forestry values for Northern Ireland, so the forestry analysis was restricted to Great Britain comprising England, Scotland and Wales. The area of woodland in the Great Britain was estimated to be 2,841,000 ha. This represents 12.3% of the total land area in the Great Britain.

Arable systems: wheat and oilseed rape

Wheat and oilseed rape are two of the principal arable crops in the UK. Spencer et al. (2008) indicate that the main negative environmental externalities associated with crop production include the loss of nitrogen as nitrate (NO_3^-) through leaching, and atmospheric loss as ammonia (NH_3) and nitrous oxide (N_2O). The assessments of price and burdens were based on Gomez (2011), Spencer et al (2008), ENA (2011), and Williams et al. (2006). In order to scale up to an indicative UK-value, the results per hectare results were scaled up according to the total crop area (assuming that 50% of the area was wheat and 50% was oilseed rape).

Livestock – beef, sheep and dairy

Governments use different livestock units per hectare values to monitor the intensity of farming. For this analysis we assumed a weight equivalent of 500 kg per one beef animal, 50 kg per sheep and 7 500 l per cow (1.33 cow per 10.000 l). Despite number of cows in the UK is steadily decreasing, total milk produced has remained relatively stable, because of the average milk yield per cow has steadily increased (DairyCO, 2015). The output, variable costs and gross margins of the livestock systems are described in Appendix B.

Table 3.1 Basic economic indicators of livestock (2007).

	Beef	Sheep	Dairy	Source
Total number	1,600,000	23,000,000	1,800,000	UK agriculture(2013)
Per ha	2.2	11	2	Nix(2008), LU UK (2006)
Total area (ha)	727,272	2,090,909	900,000	

4 Results

The results derived from the spreadsheet are presented firstly in terms of the i) agriculture as a whole ii) forestry in GB, and then iii) arable land (wheat and oilseed) and livestock (beef, sheep and dairy). Each section analyses provisioning and non-provisioning values of both in absolute and per hectare terms.

4.1 Agriculture in the UK

In order to allow the calculation of both absolute and per hectare values, it was necessary to determine the actual area of agricultural land for each area (Table 4.1).

Table 4.1 Agricultural area (thousand ha) (2007) in each country within the UK (Defra, 2012).

	England	Scotland	Wales	N. Ireland	UK
Total agricultural area	9,475	5,254	1,512	1,212	**17,453**

For gross value and the gross value added by UK agriculture in 2007, values were derived from Defra (2012), Scottish Statistics (2009), Statistics for Wales (2009), and DARDNI (2009) (Table 4.2).

Table 4.2 Gross value (2007) (£ million a^{-1}) of all agricultural activities in each country within the UK (Defra, 2012; Scottish Statistics, 2009; Statistics for Wales, 2009; Agriculture of Northern Ireland, 2009)

	England	Scotland	Wales	N. Ireland	UK
Total crop output	4,882	808	51	126	5,867
Total livestock output	5,553	1,087	832	1,044	8,517
Other agricultural activities	1,052	225	105	69	1,451
Gross value	**11,513**	**2,146**	**995**	**1,242**	**15,896**
Intermediate consumption	7,179	1,296	852	892	10,219
Gross value added	**4,334**	**850**	**143**	**350**	**5,677**

Ecosystem values may be both positive and negative. Table 4.3 describes the positive and negative values for each country and each selected indicator as described by Spencer et al. (2008).

Table 4.3 Positive, negative and net (2007) (£ million a^{-1}) environmental benefits of UK agriculture (Spencer et al., 2008).

<table>
<tr><th></th><th>England</th><th>Wales</th><th>Scotland</th><th>N. Ireland</th><th>UK</th></tr>
<tr><td>Positive</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Climate change</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Air (e.g. ammonia)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Water</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Soil</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Waste</td><td colspan="2">34</td><td>1.33</td><td>na</td><td>35</td></tr>
<tr><td>Landscape & habitats</td><td colspan="2">425</td><td>381</td><td>47</td><td>853</td></tr>
<tr><td>Biodiversity</td><td>na</td><td>na</td><td>na</td><td>na</td><td>307</td></tr>
<tr><td>Total</td><td colspan="2">459</td><td>382</td><td>47</td><td>1,195</td></tr>
<tr><td>Negative</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Climate change</td><td>839</td><td>160</td><td>292</td><td>122</td><td>1,413</td></tr>
<tr><td>Air (e.g. ammonia)</td><td>434</td><td>68</td><td>83</td><td>70</td><td>655</td></tr>
<tr><td>Water</td><td colspan="2">250</td><td>31</td><td>14</td><td>597</td></tr>
<tr><td>Soil</td><td>na</td><td>na</td><td>na</td><td>na</td><td>9</td></tr>
<tr><td>Waste</td><td>na</td><td>na</td><td>na</td><td>na</td><td>8</td></tr>
<tr><td>Landscape & habitats</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Biodiversity</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Total</td><td>1,523</td><td>228</td><td>406</td><td>206</td><td>2,683</td></tr>
<tr><td>Net effect (Positive-Negative)</td><td>-1,064</td><td>-228</td><td>-23</td><td>-159</td><td>-1,487</td></tr>
</table>

na = not available.

The combination of the gross value of the provisioning services shown in Table 4.2 and the value of other ecosystem services described in Table 4.3 is shown in Figure 4.2. The figure highlights the high value of provisioning services from agricultural land in England but also the high negative value of ecosystem services. Alternatively the provisioning services can also be expressed in terms of the gross value added shown in Table 4.2. The use of gross value added rather than gross values decreases the relative importance of the provisioning services by 62% in England, 60% in Scotland, by 72% in Northern Ireland, and 85% in Wales.

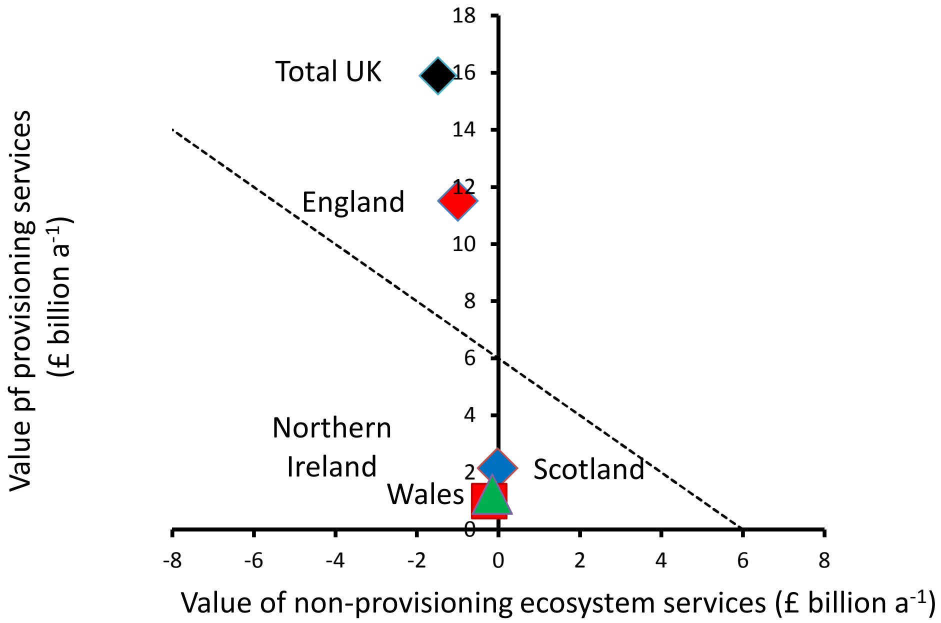

Figure 4.1. Relationship between absolute value (2007) (£ billion a^{-1}) of provisioning (Gross Value) and non-provisioning services for the UK.

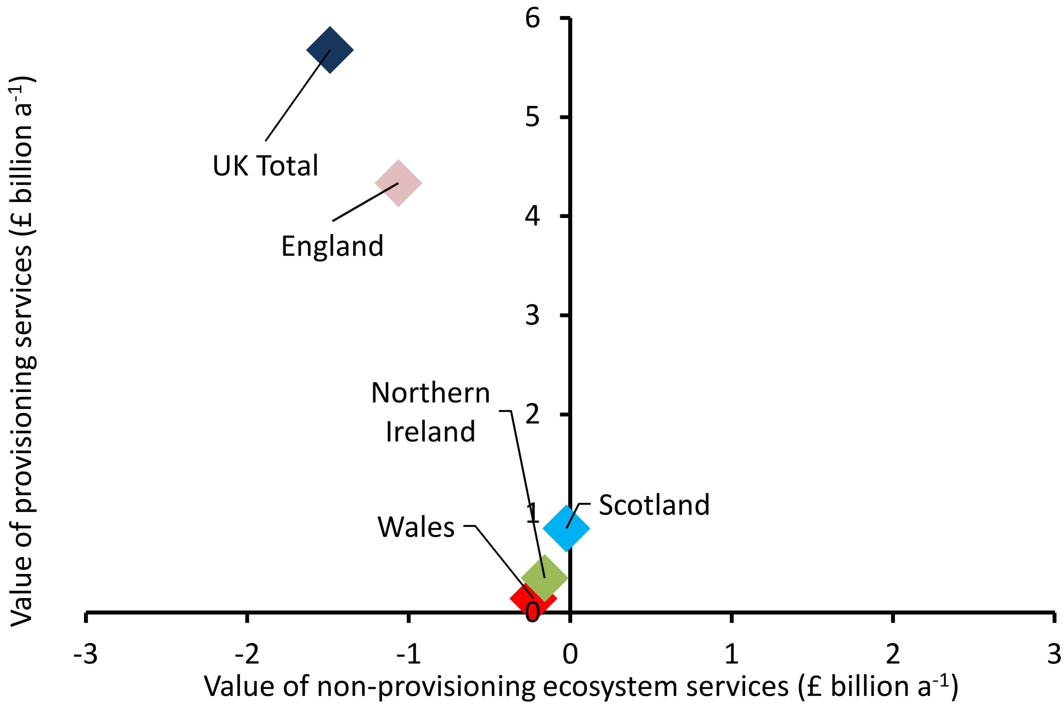

Figure 4.2. Relationship between absolute value (2007) (£ billion a^{-1}) of provisioning (Gross Value Added) and non-provisioning services for the UK.

The agricultural results can also be expressed on a per hectare value (Table 4.4). This analysis again highlights the high productivity of agricultural land in England and

Northern Ireland. By contrast the annual gross value added from agricultural land in Wales is low, typically £94 ha^{-1}. The value of non-provisioning ecosystem services was estimated to be greater in Scotland (-£4 ha^{-1} yr^{-1}) than elsewhere in the UK (-£151 to -£112 ha^{-1} yr^{-1}). The lack of a large negative value for Scottish agricultural land is a result of much of the land having low agricultural value and being designated for nature and landscape conservation (The Scottish Government, 2011; Slee et al., 2014). Willis et al. (2003) calculate an estimation of Scotland`s ecosystem services of £20 billion.

Figure 4.4 and Figure 4.3 also shows the combinations where the sum of the two groups of ecosystems services is £200 ha^{-1} and £400 ha^{-1}.

Table 4.4 The value per hectare (2007) (£ ha^{-1} a^{-1}) of provisioning and non-provisioning services for the UK.

	Agricultural service (Gross value)	Agricultural service (Gross valued added)	Non-provisioning ecosystem service
England	1215	457	-112
Scotland	408	162	-4
Wales	658	94	-151
Northern Ireland	1025	289	-131
Total UK	**911**	**325**	**-85**

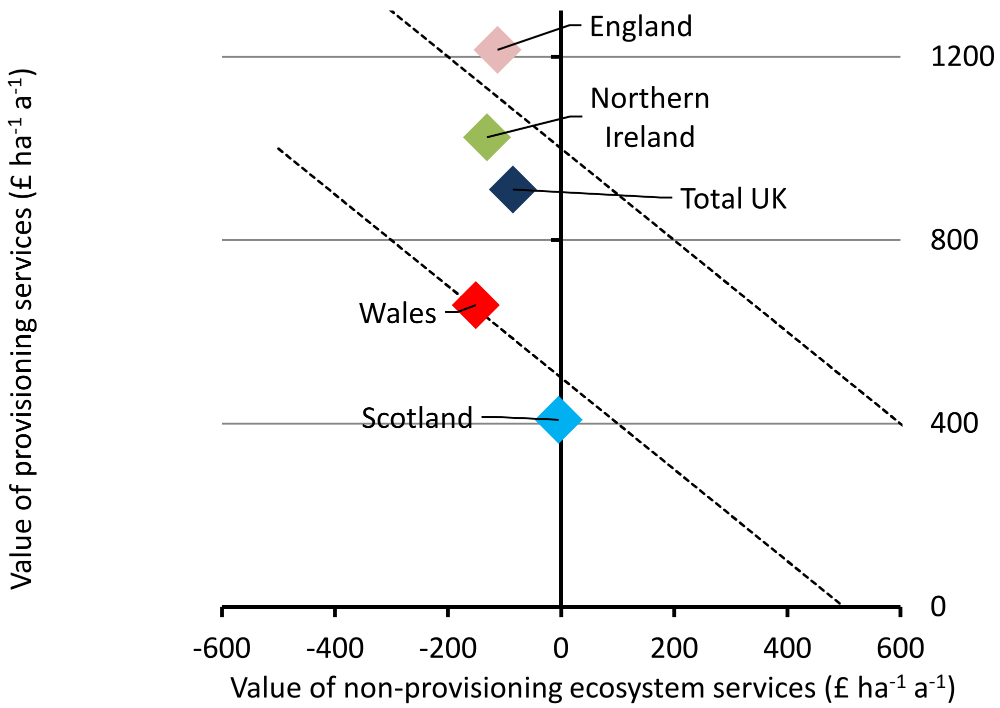

Figure 4.3. Relationship between per hectare value (2007) (£ ha^{-1} a^{-1}) of provisioning (Gross Value) and non-provisioning services in England, Wales, Scotland, and Northern Ireland.

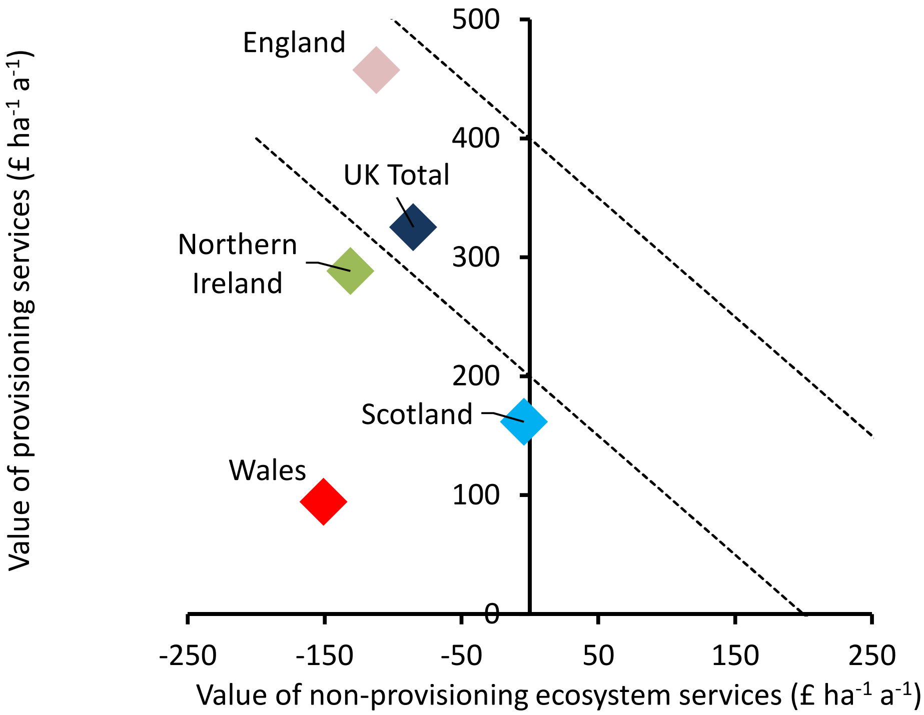

Figure 4.4. Relationship between per hectare value (2007) (£ ha^{-1} a^{-1}) of provisioning (Gross Value Added) and non-provisioning services in England, Wales, Scotland, and Northern Ireland.

4.2 Forestry in Great Britain

There are estimated to be around 3,814 million trees in Great Britain (Forestry Commission, 2013). The majority of these (56%) are in Scotland, with a further 34% in England and the remainder in Wales. According to Forestry Statistics (2013), the gross value added of forestry in 2007 was £384 million. The provisioning services provided by forestry country was computed separately and values are displayed in

Table 4.5. Ecosystem values are displayed in Table 4.6.

Table 4.5 Assumptions regarding the gross value added by forestry (2007) (£ million) in England, Scotland and Wales.

	England	Scotland	Wales	GB
Forest area (000 ha)	1,128	1,341	284	2,841
Ratio	39.7%	47.2%	10.0%	100.0%
GVA for each state (£ million)	**152.5**	**181.3**	**38.4**	**384**

The values of the non-provisioning ecosystem services associated with forestry were derived from UKNEA (2011) and Willis et al. (2003). Values were based on values from year 2003 and 2010. The values for 2007 (Table 4.6) were derived from the interpolation of values from 2003 and 2010 (Table C.2 and C.3 in Appendix C).

Table 4.6 Interpolated annual aggregate value (2007) (£ million) (approximation) of the social and environmental benefits of forestry in Great Britain (UKNEA, 2011; Willis et al., 2003).

	England	Scotland	Wales	GB
Recreation	393.3	27.3	15.4	**436.0**
Landscape	137.5	21.1	8.0	**166.7**
Biodiversity	403.1	21.1	4.4	**428.7**
Carbon sequestration	47.8	45.8	10.2	**103.8**
Air pollution absorption	0.3	0.1	0.0	**0.4**
Total	**982.0**	**115.4**	**38.1**	**1,135.5**

The values in Table 4.6 are estimates and are based on various assumptions. However Read et al. (2009) state that social and environmental benefits of forests in Wales amounted to £34 million in 2009, therefore the values in Table 4.6 seem similar to those reported elsewhere. Using the values from

Table 4.5 and Table 4.6 it is possible to construct a production function for forestry. Figure 4.5 highlights the high ecosystem value in England, which is almost 8 times higher than Scotland.

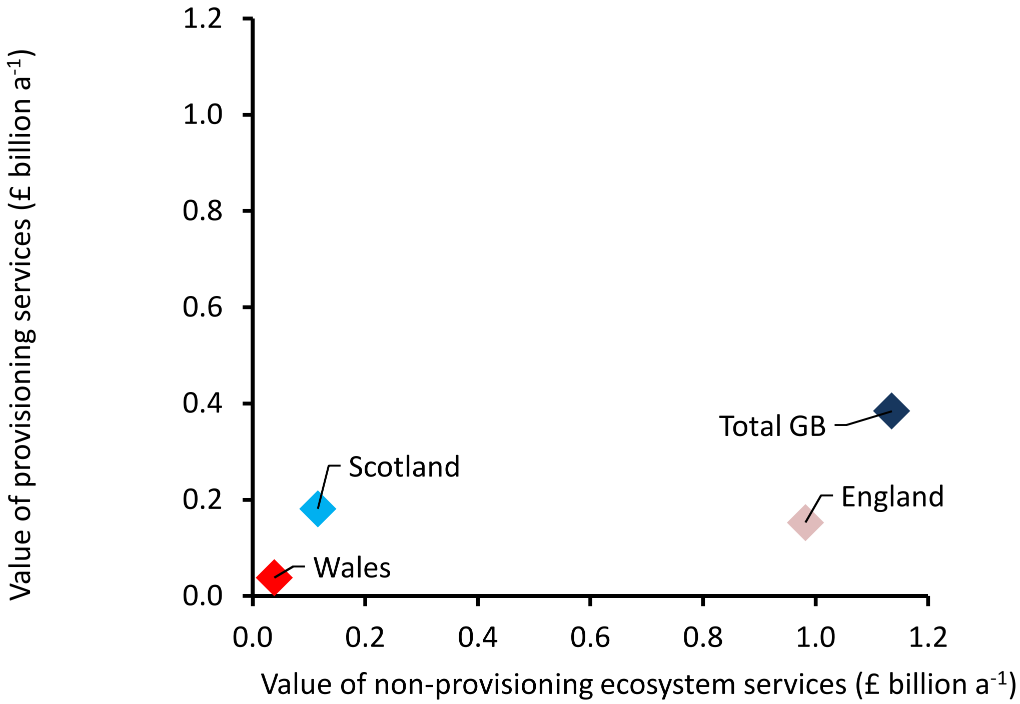

Figure 4.5. Relationship between absolute value (2007) (£ billion a^{-1}) of provisioning (Gross Value Added) and non-provisioning services for forestry services within each country and the total GB.

Table 4.7 Mean annual value per hectare of forest (2007) (£ ha^{-1} a^{-1}) of forest provisioning (Gross Value Added) and non-provisioning services for Great Britain.

	Provisioning services of forestry	Non-provisioning services of forestry
England	228.3	870.6
Scotland	64.5	86.1
Wales	140.8	134.1
Total GB	**135.2**	**399.7**

The values per hectare described in Table 4.7 are plotted in Figure 4.6. The upper and lower boundaries in Figure 4.6 represent price boundaries of £200 ha^{-1} and £400 ha^{-1} respectively. The reason for the high ecosystem value of England forestry is explained by different type of forests and is described in the discussion.

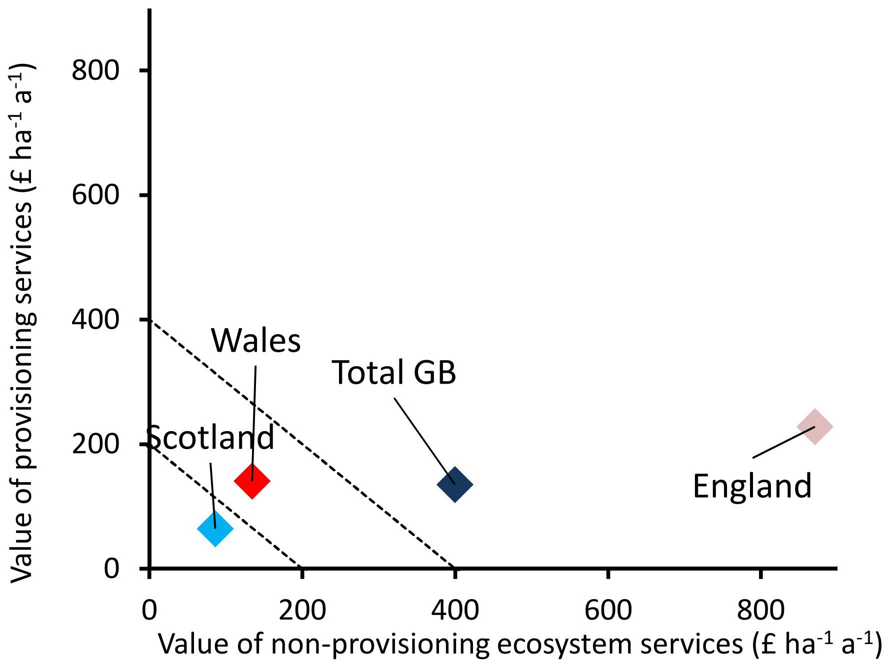

Figure 4.6. Value per hectare (2007) (£ ha^{-1} a^{-1}) of provisioning (GVA) and non-provisioning services for forestry services in Scotland, Wales, and England, and for Great Britain as a whole.

4.3 Individual agricultural enterprises

The dominant agricultural enterprises in the UK are arable production, and livestock production (including beef, sheep and dairy production). The national UK accounts differentiate between the gross value added from arable production and that from, livestock (Table 4.8). The gross value added by arable production in 2007 was £1,195 million, compared to £2,286 million for the livestock sector. This compares with a total gross value added for the whole agricultural sector of £5,667 million (Table 4.2), perhaps because the value below ignores the costs associated with pigs and poultry.. Non-provisioning values were derived based on Spencer et al. (2008). Arable land and livestock were assumed to have negative environmental externalities of £697 million and £2,076 million respectively. This compares to a total value of -£1,487 million in Table 4.2.

Table 4.8 Gross value, gross value added, intermediate consumption and non-provision values - arable and livestock sectors in the UK in 2007.

	Arable area	Livestock area	Total
Area (000 ha)	6,215	11,238	17,453
Gross value (million £)	1,980	4,265	6,244
Intermediate consumption (million £)	785	1,979	2,764
Gross value added (million £)	1,195	2,286	3,480
Non-provisioning values from (million £)	-697	-2,076	-2,486

Table 4.9 Gross value, Gross Value Added, intermediate consumption and non-provision values per hectare (£ ha^{-1} a^{-1}) for the arable and livestock sectors in the UK in 2007.

	Arable area	Livestock area
Area (000 ha)	6,215	11,238
Gross value	319	380
Intermediate consumption	126	176
Gross value added	192	203
Non-provisioning values	-112	-185

It should be noted that there are difficulties with dividing the value of livestock production by the area of livestock. However the initial values suggest that the per hectare output of livestock and arable land is similar, and that there is tendency for the livestock production to have greater negative environmental externalities per hectare.

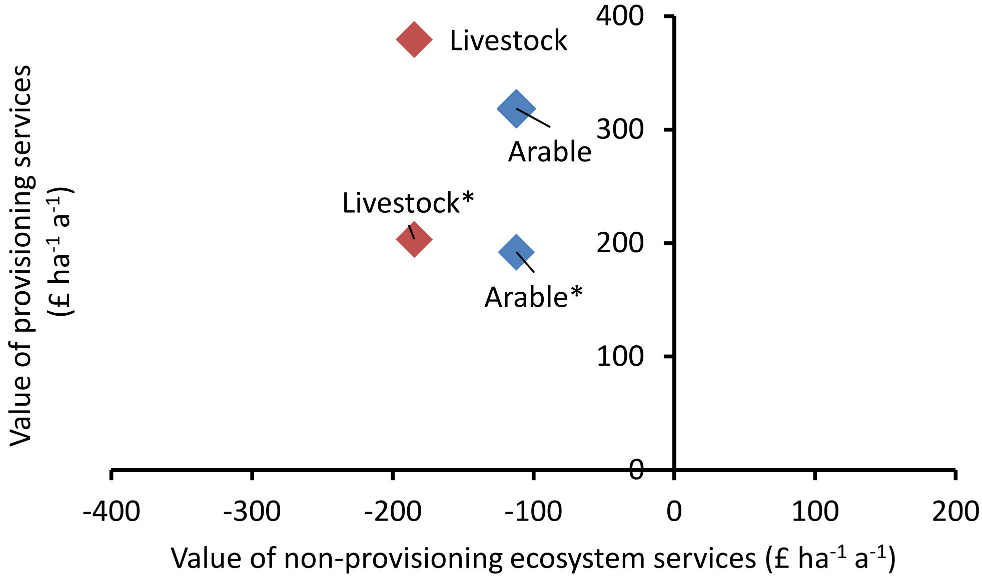

Figure 4.7. Relationship between the gross value per hectare and the gross value added per hectare (with asterisks) in 2007 of provisioning and non-provisioning services for arable and livestock services for the total agriculture area of the UK.

Arable – wheat and oilseed

Wheat and oilseed rape are two of the principal arable crops in the UK. In order to scale up to a UK-value, the per hectare results were then scaled up according to the total crop area. The environmental costs associated with each system are described in Appendix A.

Table 4.10 Value per hectare of revenue and costs of wheat and oilseed rape for 2007 with references, the total area of each crop, and a UK estimate of the value of each crop.

	Wheat	Oilseed	Source
Output (£ ha^{-1})	**846**	**633**	Nix (2008)
Variable costs(£ ha^{-1})	329	269	Nix (2008)
Gross margin (£ ha^{-1})	**517**	**365**	Nix (2008)
Mean yield (t ha^{-1})	7.55	3.25	Nix (2008)
Total area(ha)	1,830,000	681,000	UK Agriculture (2012)
Output (£ million)	1,548.1	431.5	
Variable costs (£ million)	602.0	183.1	
Gross margin (£ million)	946.1	248.5	

Table 4.11 Some values of the negative impact of nitrogen emissions and leaching per hectare (£ ha^{-1}) by wheat and oilseed rape production in the UK.

	Wheat	Oilseed
NO_3-N	28	33
NH_3-N	14	19
N_2O	189	257
Total burden (£ ha^{-1})	231	309

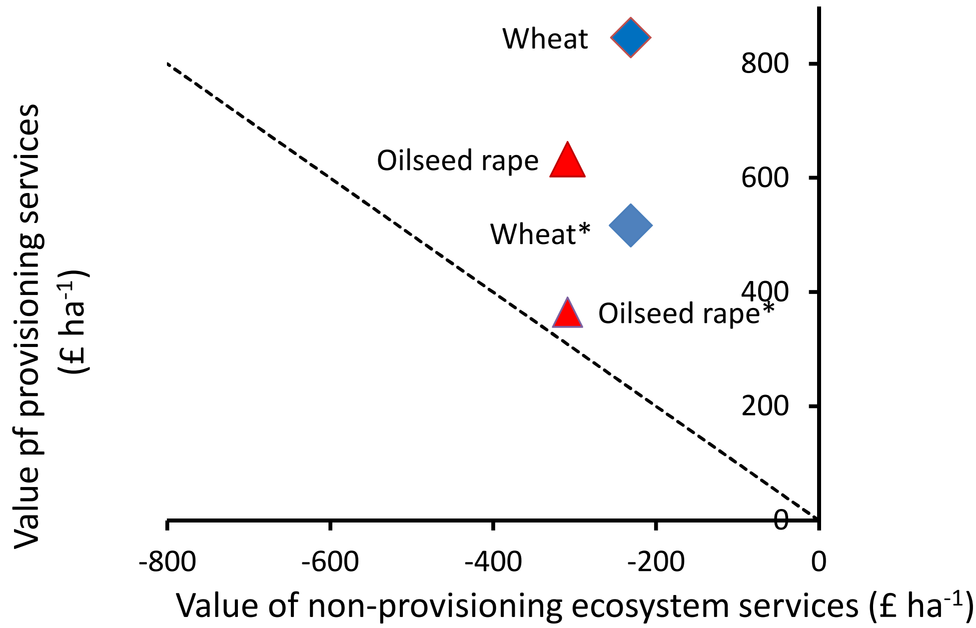

Figure 4.8. Gross value added and gross value (with asterisk) of the provisioning services of wheat and oilseed rape production in the UK compared to the value of non-provisioning services in 2007.

Livestock – Beef, Sheep and Dairy

The results for the dairy, beef and sheep sectors are described in Table 4.12 and Table 4.13. Additional data is provided in Appendix B.

Table 4.12 Total output (2007) (£ million) from selected livestock (Nix, 2008).

	Beef	Sheep	Dairy	Total
Output	446	1,065	2,754	4,265
Variable costs	259	692	1,028	1,979
Gross margin per forage hectare	187	373	1,726	2,286

Methane is considered as one largest environmental cost of livestock production and it is important to include it in any assessment of the environmental costs. Selected components which determine final costs are in Table 4.13. Combining values from Table 4.12 and Table 4.13 are presented in Figure 4.9 as per hectare values. These values are represented in Table 4.14.

Table 4.13 Total negative costs (2007) (£ million) for selected livestock.

	Beef	Sheep	Dairy	Total
NO_3-	100	276	144	520
NH_3	175	224	176	576
N_2O	139	164	269	571
CH_4	43	12	323	379
CO_2	6	10	13	30
Total	464	687	925	2,076

Table 4.14 Value per hectare (2007) (£ ha^{-1} a^{-1}) of provisioning and non-provisioning services for beef, sheep and dairy.

	Beef	Sheep	Dairy
Agricultural service (Gross value)	614	509	3,060
Agricultural service (Gross valued added)	257	178	1,918
Ecosystem service	-638	-329	-1,029

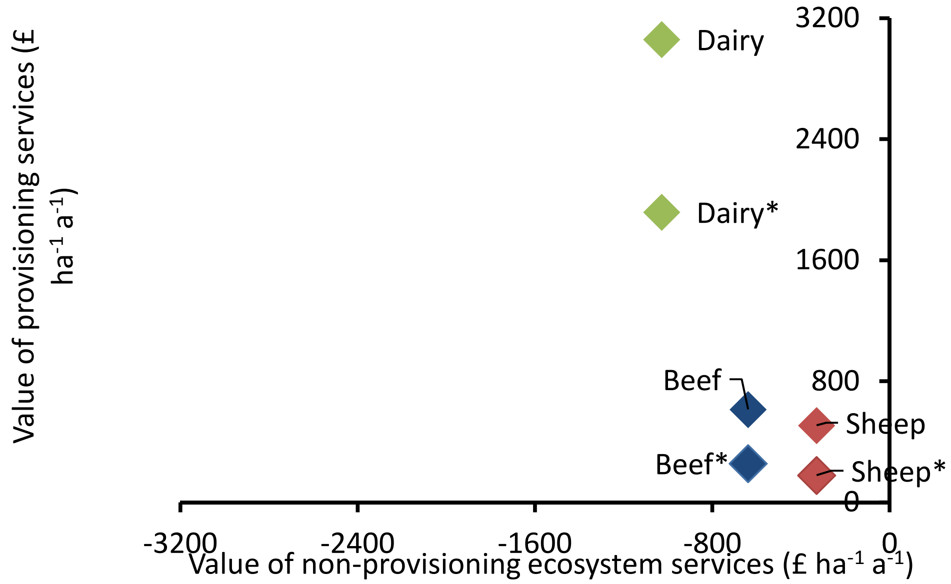

Figure 4.9. Gross value and gross value added (with asterisk) of the provisioning services of beef, sheep and dairy production in the UK compared to the value of non-provisioning services in 2007.

5 Discussion

This discussion section considers the results against the aims and objectives and places the work in context, and describes the limitations.

5.1 Gross value versus gross value added

The approach used both the gross value and the gross value added by agricultural activities to describe the value of the provisioning services. There is a question as to whether Gross Value or Gross Value Added is the appropriate value to use. Gross Value is probably a more comparable measure with the assessment of valuation of non-provisioning services and hence it is used. It can be argued that many environment-related production activities do not involve the intermediate consumption of environment related goods and services (Bartelmus, 1998). However because of the lack of clarity, this paper uses both gross value and gross value added to present calculated values where appropriate.

The differences between using a gross value or a gross value added measure can be seen in the per hectare value of agricultural services across England, Scotland, Wales and Northern Ireland (Table 5.1). The high level of intermediate consumption in Wales, means that its proportional contribution to the gross value of agriculture in the UK is double that of the gross value added.

Table 5.1 Gross value and gross value added (2007) (£ million a^{-1}) of agricultural activities in each country within the UK (Defra, 2012) (Scottish Statistics, 2009) (Statistics for Wales, 2009) (DARDNI, 2009)

	England	Scotland	Wales	N. Ireland	UK
Gross Value	11,513	2,146	995	1,242	**15,896**
	72%	14%	6%	8%	
Intermediate consumption	7,179	1,296	852	892	**10,219**
Gross value added	4,334	850	143	350	**5,677**
	76%	15%	3%	6%	

5.2 Value of woodland

Total ecosystem value of woodland is dominated by recreational and biodiversity values, followed by landscape and carbon sequestration. Willis et al. (2003) states that there is some uncertainty in valuing total benefits of forestry, and this uncertainty is particularly high in terms of the recreation, landscape and biodiversity values. For example, the landscape value in Willis et al. (2003) is derived from marginal values depending upon the habitat characteristics of different woodland. Willis et al. (2003) describe values for biodiversity as ''ball-park'' estimates. On the other hand carbon sequestrated by woodland is quite accurate (Willis et al., 2003).

The UKNEA (2011) reports that the value of the social and environmental benefits of forests in Great Britain in 2010 was £1,261 million. Munday et al. (1999) states that the gross output of the Wales forestry industry is estimated at £403 million, although this included wood products, pulp, paper and paper products. Edwards et al. (2008) suggest that the harvesting, planting and farm woodland aspects of forestry in Scotland amounted to a gross value added of about £134 million.

According to Willis et al. (2003), the amount of carbon sequestration by forestry in England was greater in England (£43.1 million) than in Scotland (£41.4 million), despite Scotland having a larger woodland area (1.048 million ha against 0.367 million ha). This difference could be caused by the higher carbon content of broadleaves (which are more prevalent in England) compared to conifer plantations, and higher average growth rates (Forestry Commission, 2014).

The non-provisioning ecosystem services of English woodlands (£871 ha^{-1}) were estimated to be eight times higher than in Wales and Scotland (£86-134 ha^{-1}) (Table 4.7). One reason is that the non-provisioning services of broadleaf woodlands (prevalent in England) may be higher than coniferous woodland (Table 5.2, Table 5.3, Figure 5.1).

Table 5.2 Number (2007) (million trees) of trees in GB (Forestry Commission, 2013)

	England	Scotland	Wales	GB
Broadleaves (woods over 2 ha)	588	188	92	**857**
Conifers (woods over 2 ha)	523	1,892	252	**2,667**
Small woods and other	179	73	38	**290**
All trees	1,279	2,154	382	**3,814**
Proportion of broadleaf trees	46%	9%	24%	

Table 5.3 Area of woodland by forest type (thousand ha^{-1}) (Forestry Commission, 2013)

	England	Scotland	Wales	UK
Broadleaves	761	297	128	1,207
Conifers	366	1,045	157	1,634
Total	1,127	1,342	285	2,841
Proportion of broadleaf woodland	67%	22%	45%	

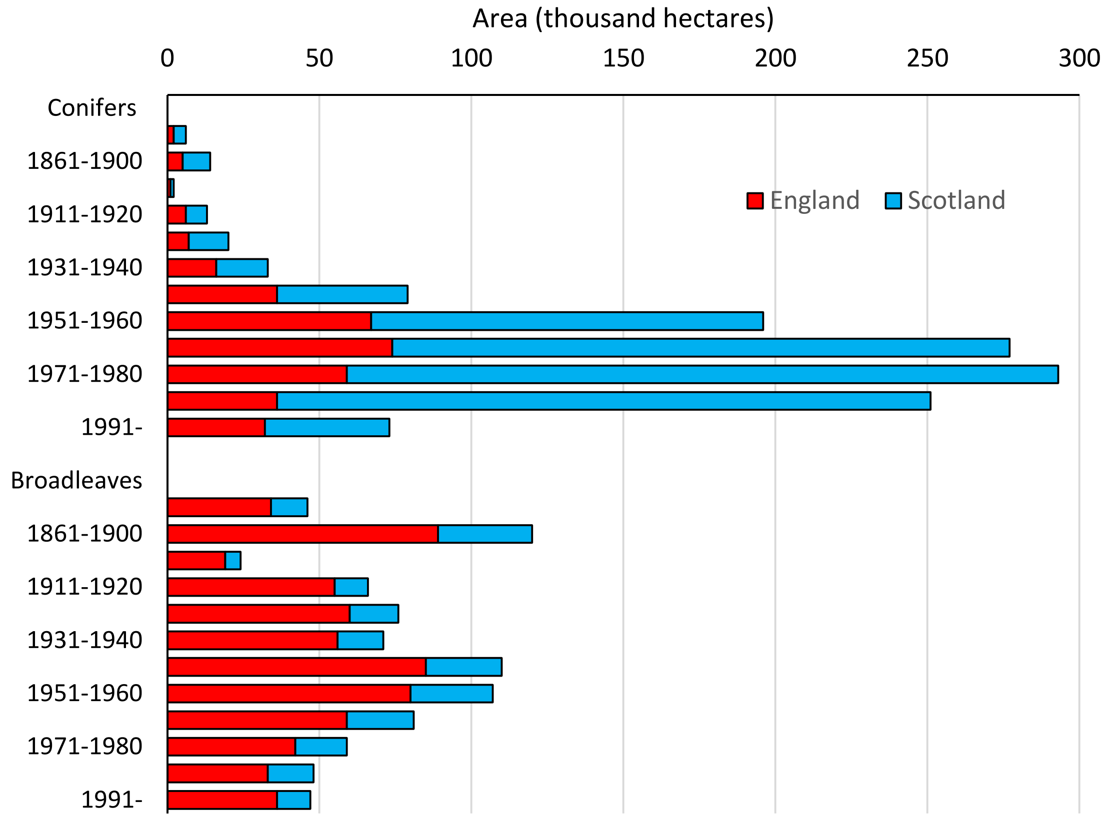

Figure 5.1. Comparison of area of woodland in GB between broadleaves and conifers according to planting year (Forestry Commission, 2013)

UKNEA (2011) suggest that conversion of broadleaf areas to conifer plantations after 1945 reduced the proportion of broadleaved woodland habitat. Several studies state that conifers have lower ecosystem values than broadleaves. Avery (1989) criticised such conifer-planting and Humphrey & Nixon (1999) noted that loss of valued habitat is connected to conifer-planting.

5.3 Arable and livestock

It is possible to represent the mean value of the provisioning and non-provisioning services of the dominant agricultural enterprises (arable and livestock) in terms of gross value per hectare (Figure 5.3) and gross value added per hectare (Table 4.8). The value of the negative environment values associated with arable and forestry systems were £697 million and £2,076 million respectively (Table 4.8)..

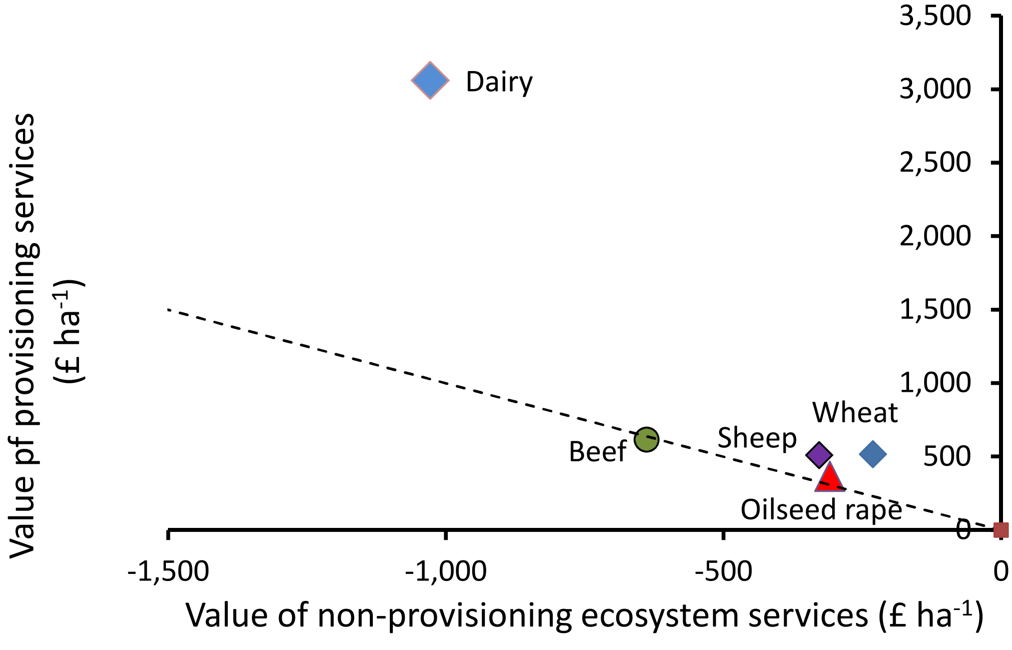

Figure 5.2. Per hectare value (2007) (£ ha^{-1} a^{-1}) of provisioning (Gross value) and selected non-provisioning services for arable and livestock combined.

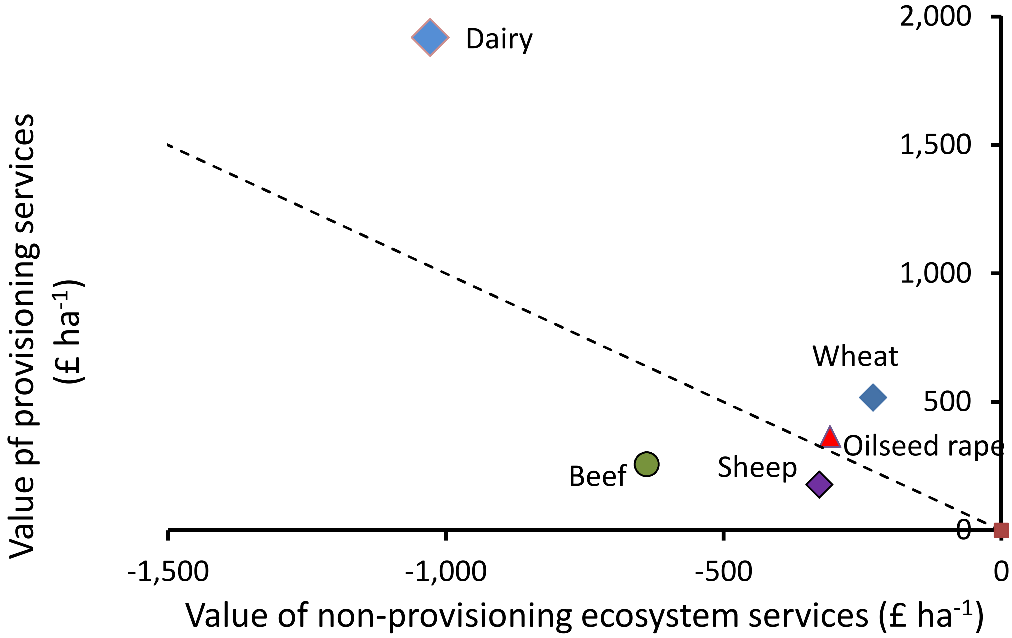

Figure 5.3. Per hectare value (2007) (£ ha^{-1} a^{-1}) of provisioning (Gross Value Added) and non-provisioning services for arable and livestock combined.

5.4 Agricultural area, forestry area, and arable and livestock compared

Table 5.4 summarises the gross values of the provisioning and non-provisioning services derived used in the study and these are also presented graphically in Figure 5.4. The figures and the table show the higher provisioning services of agriculture and the higher non-provisioning services in forestry. The output of the dairy sector per hectare is particularly high.

Table 5.4 Comparison of the values (2007) (£ ha^{-1} a^{-1}) represented with absolute of provisioning (gross value) and non-provisioning services

System	Country	Provisioning services	Other ecosystem services
Agriculture	England	1,215	-112
	Scotland	408	-4
	Wales	658	-151
	N. Ireland	1,025	-85
	UK	**911**	**-85**
Forestry	England	228	871
	Scotland	64	86
	Wales	141	134
	Great Britain	**135**	**400**
Arable in the UK	Wheat	846	-231
	Oilseed	634	-309
Livestock in the UK	Beef*	614	-638
	Sheep*	509	-328
	Dairy*	3,060	-1,028

*Values per forage hectare

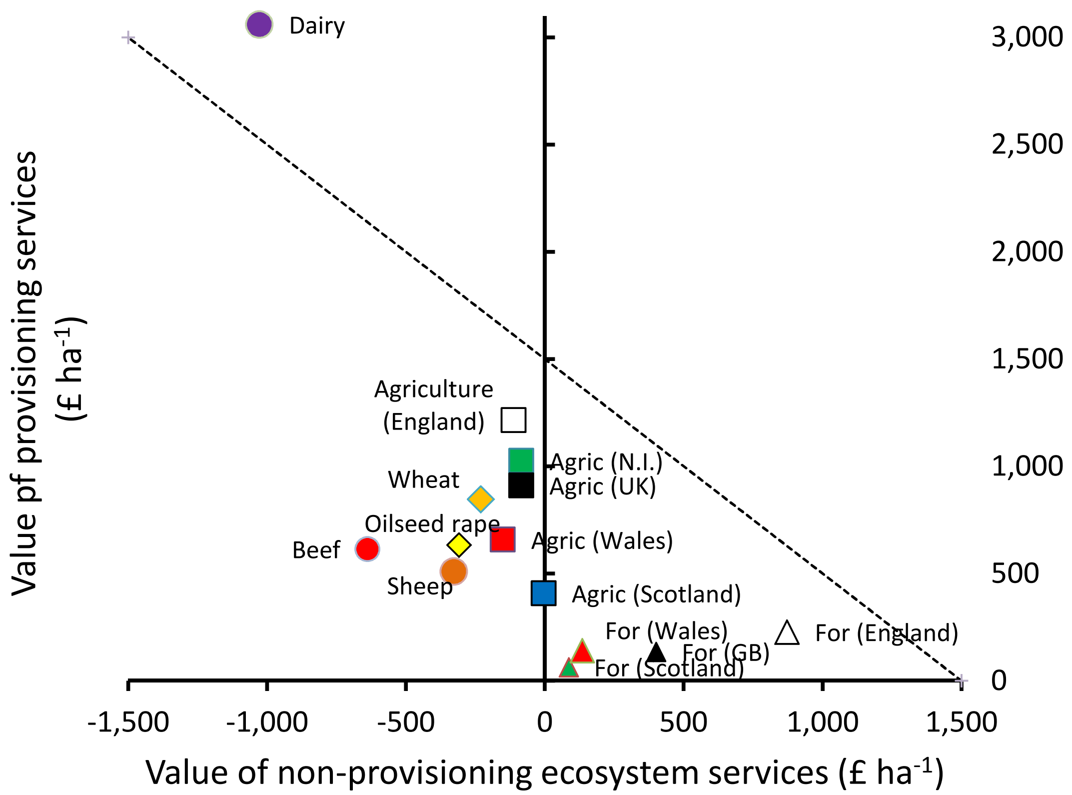

Figure 5.4. Comparison of all per hectare values (£ ha^{-1} a^{-1}) (2007) represented with provisioning and non-provisioning services.

5.5 Graphical representation

Proper representation of data can help readers to understand key issues. Graphical representation is particular helpful to allow readers to compare values. Selected graphical representation in this paper is based on Hart et al. (2013). If correctly used, graphical representation can help educators and policy makers who need effective communication tools.

5.6 Issues, limitations and assumptions

This section discusses some of the key limitations and assumptions in the study.

Data consistency and geographical scale

The gross added value estimates are from official sources. It is assumed that within the different parts of the United Kingdom, the methods for calculating the gross value added is consistent. It would be more difficult to extend the analysis to other countries.

Emission levels

There are substantial variations in the assumed emission levels from agricultural production. For example Webb et al (2000) measured nitrous oxide emissions from wheat equivalent to 1 kg N2O per hectare. By contrast, using a life cycle assessment approach, Williams et al (2010) estimate that the production of 7.7 t ha^{-1} of wheat results in emissions of 12 kg N_2O ha^{-1}. Assuming a value of £52 per tonne of CO_2equivalent and that N_2O has a warming potential of 310 times, these values represent between £16 ha^{-1} and £189 ha^{-1}.

Environmental valuation

The environmental impacts of agriculture vary with the form of production. For example Williams et al. (2006) reports that the NO_3-N losses from inorganic production (147 kg per tonne of meat) are less than for organic production (427 kg per tonne of meat). Williams et al. (2006) also states that organic production of beef can increase land use by 80%. The nitrate losses with non-organic sheep production (282 kg per tonne of meat) are also less than for organic production (700 kg NO_3-N) per tonne of meat). The rate of nitrogen and greenhouse gas emissions for livestock also vary substantially between reports (Table 5.5). There are also large variations in the valuation of environmental costs from the same source. For example the value of NH_3 ranges from is £87 t^{-1} to £1,840 t^{-1}, N_2O ranges from £25 t^{-1} to £15,810 t^{-1} and methane ranges from £25 t^{-1} to £263 t^{-1} (Table 5.5; Table 5.6).

Table 5.5 Unit rates for estimating the price (£ t^{-1}) of different nitrogen and greenhouse gas emissions (Cranfield University, 2011).

	Eyre et al. (1997)	Holland et al. (1999)	Spencer et al (2008)	DECC (2010)
NO_3-			**837**	
NH_3		87-270	**1,840**	
N_2O	7,530			**15,810**
CH_4	263			**1,071**
CO_2	63		25	**51**

Actual prices used are presented in **bold.** DECC (2010) estimated a central non-traded cost of £51 per tonne of CO_2equivalent. In Table 2.14 IPCC (2007) report that methane has a global warming effect (over 100 years) 21 times greater than CO_2, and that nitrous oxide has an effect 310 times greater. The same values are reported by Cranfield University (2011).

Table 5.6 Assumed costs of nitrate leaching losses and ammonia and greenhouse gas emissions to the atmosphere

	£ per kg	£ per tonne	Source
NO_3-	0.837	837	Jacobs (2008)
NH_3	1.840	1,840	Jacobs (2008)
N_2O	15.810	15,810	DECC (2010)
CH_4	1.071	1,071	DECC (2010)
CO_2	0.051	51	DECC(2010)

There are also different methods to valuing environmental services. For example the values of marginal changes in woodland biodiversity should be regarded as "ball-park" estimates (Willis et al., 2003). The biodiversity values for woodland are gross values and not a value net of the alternative land-use (Willis et al., 2003). Therefore reducing inconsistency in valuation approaches would be beneficial, despite this difficulty.

Temporal change

This study is based on values from 2007 alone. The brevity of this time scale raises some concerns. Future values may vary significantly and therefore evaluation of such values may be difficult. Also change in profitability of the systems may change from 2007. We may anticipate that profitability of cereal systems has increased since 2007. The study was restricted to 2007 due to availability of environmental valuation data. However the implication is difficult to observe because study is complex and these changes would affect more factors, especially in the matter of environmental service.

6 Conclusions

This paper has three main objectives: to derive best estimates of i) the value of provisioning and other ecosystem services of specific land uses, ii) to apply these data to graphical representations of Figure 1.1 and Figure 1.2, and iii) to critique the potential applicability of the approach. Are such graphs helpful to policy makers who need effective communication tools?

Glendining et al. (2009) report that sustainable agriculture has to consider both economic benefits and environmental costs. Burgess and Morris (2009) noted that much of the recent technological advances in agriculture have been used to address environmental issues as much as increased production.

One means proposed for improving the supply of non-provisioning ecosystem services is to move to more extensive production. However this can decrease food production (Seufert et al., 2012), potentially requiring additional land to be brought into production. The past decade has seen the development of frameworks and models to ascertain the balance between intensifying land use and releasing land for other uses relative to maintaining extensive land use over the current area (Hodgson et al. 2010; Del Prado et al. 2011). These tools provide a means for farmers and land use planners to identify the relative benefit or cost of, for example, organic systems relative to other forms of production. In this paper, I have attempted to show the relative effects of different agricultural sectors, and the agricultural sector of different countries.

Economic growth and an ever rising world population put pressure on food demands and agricultural products. To feed nearly 9 billion people by 2050, a new vision is needed to ensure food supply, environmental sustainability and economic opportunity through agriculture. This analysis provides a pilot study to represent the effect of land use changes on both production and non-provisioning ecosystem services. A time series of such measures could help indicate how agriculture is developing over time, leading to a clearer decision making.

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Appendix A: Environmental costs of arable production

Main burdens of production of each crop commodity is difficult to determine, therefore some assumptions have been made. The assessment of price is based on Gomez (2011) and Jacobs (2008). Study selected burdens used in several studies (Jacobs, 2008), (ENA, 2011) and (Gomez, 2011). Therefore these main burdens are determined as following: nitrate, ammonia, nitrous oxide and nitrogen. However primary energy is only a minor contributor to global warming as in arable agriculture the main contributor is the N_2O-N emissions which are 80% of the cause because they are 400 times more potent than CO_2 (Williams et al. 2006).

To determine loss of these burdens, I used the study by Williams et al. (2006) which determines kg losses for selected burdens per tonne. These values were then multiplied by crop yield to get the total loses per ha in kg. Crop yield is based on Nix (2008) and values are following: 7.55 t/ha for wheat, 3.25 t/ha for oilseed rape. These estimates result in a N_2O emission of about 12 kg ha^{-1} from wheat, although other authors (Webb et al 2000) report values of 1 kg ha^{-1}. Such a difference has a major impact on the assumed environmental cost of nitrous oxide emissions from wheat and oilseed rape production.

Table A.1 Selected ecosystem burdens by Williams et al. (2006) and values per hectare derived from average yields.

	Wheat (kg t^{-1})	Oilseed (kg t^{-1})	Wheat (kg ha^{-1})	Oilseed (kg ha^{-1})
NO_3-N	4.4	12.2	33.2	39.7
NH_3-N	1.4	3.0	10.6	9.7
N_2O-N	1.0	3.2	7.6	10.4
N_2O			11.9	16.3

It should be noted that the above values are for N_2O-N. The actual amount of N_2O released would be higher by 44/28.

Different sources (Spencer et al, 2008; ENA, 2011, and Gomez, 2011) estimate different prices for total damage cost from main burdens. For example the damage costs of NH_3

were revised upwards from £178 t^{-1} in the 2004 framework to £1840 t^{-1} (2006 prices) in the 2007 Framework (Spencer et al. 2008).

The assumed values used in the analyses are described in Table 5.5. The ecosystem burdens for the wheat and oilseed rape crops were calculated as the product of the burden per tonne of crop and the yield. The total cost of the negative nitrogen effects (Table A.2) per crop was calculated as the total cost per hectare of selected crop multiplied by the total hectares of selected crop. The negative environmental costs associated with arable production are summarised in Table A.3.

Table A.2 Selected crops and theirs negative ecosystem impacts (£ per hectare) according to average yield due to N losses.

	Wheat	Oilseed
NO_3-N	28	33
NH_3-N	14	19
N_2O	189	257
Total burden	**231**	**309**

Table A.3 Selected crops and theirs total negative ecosystem impacts (£ million) due to N losses.

	Wheat	Oilseed
Area (million ha)	1.830	0.681
NO_3-N (£ million)	51.2	22.4
NH_3-N (£ million)	25.6	12.9
N_2O	345.9	175.0
Total burden	**422.7**	**210.3**

Appendix B: Gross margins and assumed environmental costs of livestock production

Basic production indicators (Table B.1, B.2, and B.3) needed for analysis are based on Nix (2008).

Table B.1 Dairy production indicators

	(£ cow^{-1})	(£ ha^{-1})	(£ million)
Output	1,530	3060	2,754
Variable costs	571	1142	1,028
Gross margin per forage hectare	959	1918	1,726

Table B.2 Beef production indicators.

	(£ $animal^{-1}$)	(£ ha^{-1})	(£ million)
Output	279	613	446
Variable costs	162	356	259
Gross margin per forage hectare	117	257	187

Table B.3 Sheep production indicators.

	(£ $animal^{-1}$)	(£ ha^{-1})	(£ million)
Output	46.3	509.3	1,064.9
Variable costs	30.1	331.1	692.3
Gross margin per forage hectare	16.2	178.2	372.6

Environmental costs of livestock production

The impacts of livestock on environmental services were estimated using different sources. There are specific existing meanings of livestock units. The original meaning was the metabolisable energy requirement of an average yielding dairy cow and this was a way of estimating the productivity of grassland. There is also another way of using livestock units in which the definition is simply 500 kg live weight. Therefore following values were used for Table B.6: Beef 500 kg, Sheep 50 kg and 1.33 cow to produce 10,000 l of milk (7500 l/year a cow). A comprehensive summary by Cranfield University (2011) provides dataset on the impact of livestock systems presented in table B.4. Values shows variety of valuations of main burdens developed through time. Calculations in Table B.6 use shaded rates from Table B.5.

Table B.4 Main burdens (kg) of production (t or 10000l) for each separate livestock (Williams et al., 2006) (UK Annual National Inventory report: 1990-2012, 2014)

	Beef(t)	Sheep(t)	Dairy(10000l)
NO_3-	149	287	72
NH_3	119	106	40
N_2O	11	9	7
CH_4	51	10	126
CO_2	158	175	106
Total	488	587	351

Table B.5 Unit rates for estimating the price (£ t^{-1}) of impacts of livestock based on different reports.

	Eyre et al. (1997)	Holland et al. (1999)	Spencer et al (2008)	DECC (2010)
NO_3-			**837**	
NH_3		87-270	**1,840**	
N_2O	7,530		25	**15,810**
CH_4	263		25	**1,071**
CO_2	63		25	**51**

The values assumed are presented in **bold**

Table B.6 Per hectare values of negative impact of each separate selected livestock (£ per hectare). Price of burdens is based on (Spencer et al, 2008) (DECC, 2010)

	Beef	Sheep	Dairy
NO_3-	137	132	160
NH_3	241	107	196
N_2O	191	78	299
CH_4	59	6	359
CO_2	9	5	14
Total	637	328	1,028

Table B.7 Total burden (thousand tonnes) of production for each separate livestock (Williams et al., 2006).

	Beef	Sheep	Dairy
NO_3-	119,200	330,050	172,368
NH_3	95,200	121,900	95,760
N_2O	8,800	10,350	16,997
CH_4	40,400	11,500	301,644
CO_2	126,400	201,250	253,764
Total	390,000	675,050	840,533

Combining prices in table B.4 and total burdens in table B.6 total price is calculated in table B.7.

Table B.9 Total price (£ million) of production for each livestock sector.

	Beef	Sheep	Dairy	Total
NO_3-	100	276	144	520
NH_3	175	224	176	576
N_2O	139	163	268	571
CH_4	43	12	323	379
CO_2	6	10	13	30
Total	464	687	925	2,076

Major ecosystem costs were associated with impacts on NO_3-, NH_3 and N_2O. In comparison Chatterton et al. (2014) states that impact on livestock Dairy& beef is £1,219 million and calculation provided in table B.6 shows slightly bigger result as beef and dairy is £1.389 million.

Appendix C: Gross margins and assumed environmental costs of forestry production

In order to calculate per hectare values, forestry area in Table C.1 was used as a base.

Table C.1 Forestry area (2007) (thousand ha) in each country within the GB (Forestry Commission, 2013).

England	Scotland	Wales	GB
1,128,000	1,341,000	284 ,000	2,841,000

Environmental benefits of forestry in GB for year 2007 are based on Willis et al. (2003) (Table C.2) and UKNEA (2011) (Table C.3).

Table C.2 Annual aggregate value (2003) (£ millions) of the social and environmental benefits of forestry in GB (Willis et al. 2003).

	England	Scotland	Wales	GB
Recreation	354.2	24.6	13.8	**392.7**
Landscape	123.9	19.1	7.3	**150.2**
Biodiversity	363.0	19.0	4.0	**386.0**
Carbon sequestration	43.1	41.4	9.2	**93.7**
Air pollution absorption	0.3	0.1	0.0	**0.4**
Total	884.6	104.1	34.3	**1022.9**

Table C.3 Annual aggregate value (2010) (£ million) of the social and environmental benefits of forestry in GB (UK National Ecosystem Assessment, 2011).

	England	Scotland	Wales	GB
Recreation	436.6	30.3	17.1	**484.0**
Landscape	152.6	23.5	8.9	**185.0**
Biodiversity	447.6	23.4	4.9	**476.0**
Carbon sequestration	52.9	50.8	11.3	**115.0**
Air pollution absorption	0.4	0.1	0.1	**0.5**
Total	1090.2	128.1	42.3	**1260.5**