Economic perspectives

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Exploring the value of Scotland's environment

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Introduction

Protection of the environment can be regarded as representing a substantial cost to business. However, it is typically considered from the point of view of effect on company profitability, rather than its relative importance to human kind. This paper estimates the value of Scotland's natural environment by applying the methodology developed by Costanza ***et al*** (1997a and b) for estimation of the value of the earth's ecosystem services. Ecosystem services provide the vital functions to support life on Earth, such as flows of materials and energy. Since the study's publication, further research has sought to apply this global methodology to a regional and national level (for example Loomis ***et al***, 2000, Farber and Griner, 2000 and Stevens et al, 2000). The value derived for Scotland provides a useful context for understanding the scale and importance of Scotland's natural habitats and it helps to reinforce the message that the environment is central to human welfare (Williams et al, 2003).

The valuation of ecosystem services in monetary terms provokes theoretical, practical and philosophical arguments. This paper does not seek to revisit in depth these debates; rather the valuation should be taken as a starting point for setting the importance of Scotland's ecosystems in an interesting perspective. A recent edition of the journal Ecological Economics (Costanza and Farber, 2002) was devoted to considering some of these issues and providing many avenues for further exploration.

Methods

The environmental valuation model

The environmental valuation framework adopted for Scotland is that developed by the Costanza ***et al*** global valuation study. The authors generated a single value per unit area for each of 17 ecosystem services (Table 1) using published studies that measured individuals' willingness-to-pay for the ecosystem services.

The values were then applied to the earth's natural habitats, or biomes[1] (see Table 2 for the biomes used in the global study) to generate a value per hectare annually for each biome. Finally, the values were multiplied by the surface area of each biome to yield a global estimate for

each biome, plus an aggregate global estimate. For the Scotland study this methodology was applied, initially without modification, by multiplying the ecosystem service values derived by Costanza *et al* by the spatial areas of Scotland's marine and terrestrial habitats. Costanza *et al* estimated values in 1994 US Dollars. To arrive at a current value of Scotland's environment, the original USD 1994 values were converted to 2001 Pounds Sterling.

Scotland's natural habitats

Scottish Natural Heritage (SNH) supplied information on the areas of 31 habitat types that were then consolidated to establish the extent of terrestrial biomes for Scotland (Mackey et al, 1999).

Determination of the appropriate areas of marine biomes for Scotland was undertaken using areas based upon official Government GIS coastal and maritime areas (SEGIS, 2002) covering estuaries, coastal waters, and the area of the European continental shelf. The Scottish Environment Protection Agency (SEPA) (S. Mathieson, personal communication 2002) provided the estuarine areas used in the study, based on earlier research (Buck, 1993a and 1993b). Table 2 provides a breakdown in km^2 of Scotland's biomes. The coastal waters around Scotland were derived by reference to the 'baseline' as defined in the United Nations Law of the Sea Convention (United Nations, 1982). Scotland's baseline is drawn to encompass the Outer Hebrides, Orkney and Shetland, and the smaller islands off Scotland's west coast. The baseline forms the boundary between Scotland's 'internal' waters and the offshore marine zone. The principal offshore marine boundary used in this research is the 12 nautical mile line, which forms the extent of Scotland's territorial waters. All of these territorial waters lie on the European continental shelf; and for the purpose of this valuation, all of Scotland's offshore waters were defined up to the 12 nautical mile limit as a continental shelf biome, with the exception of estuaries.

Results and discussion

The value of Scotland's ecosystem services

On the basis of the methodology described above, the annual value of the ecosystem services generated by Scotland's marine and terrestrial biomes is estimated to be £17.027 billion. To put this into context, in 1999, the Scottish Gross Domestic Product (GDP) was estimated to be £64.050 billion (Scottish Executive, 2002). The value of ecosystem services is roughly one quarter of this total. Ecosystem services are valued at more than eight times the value of exports of whisky from Scotland in 2000 which was estimated to be £2.156 billion and only a little less than the total value of all manufactured exports from Scotland in 2000 which was estimated to be £21.055 billion (SCDI, 2001). Ecosystem services are of course not directly comparable to GDP or to export values, but these values do demonstrate the order of magnitude of ecosystem services relative to production and consumption of goods and services in the economy.

Costanza *et al* use estimates from a number of published studies to derive global average values in the original study, necessitating a range of estimates for each ecosystem service. The range consisted of high and low values from various point estimate studies, and the averaged value. An

Table 1: Ecosystem services and their functions from Costanza et al (1997a)

Ecosystem Service	*Ecosystem Function*
Gas regulation	Regulation of atmospheric chemical composition
Climate regulation	Regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels
Disturbance regulation	Capacitance, damping and integrity of ecosystem response to environmental fluctuations
Water regulation	Regulation of hydrological flows Water
supply	Storage and retention of water Erosion
control and sediment retention	Retention of soil within an ecosystem
Soil formation	Soil formation processes
Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients
Waste treatment	Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds
Pollination	Movement of floral gametes
Biological control	Trophic-dynamic regulations of populations
Refugia	Habitat for resident and transient populations
Food production	That portion of gross primary production extractable as food
Raw materials	That portion of gross primary production extractable as raw materials
Genetic resources	Sources of unique biological materials and products
Recreation	Providing opportunities for recreational activities
Culture	Providing opportunities for non-commercial uses

analysis of this type on the aggregate value of Scotland's environment indicates a range from £10.050-£24.016 billion, using the per hectare values from the original global valuation study. The average of this range has been taken to be the value of Scotland's environment, following the same principle applied by Costanza *et al*. More than half of the possible values for ecosystem services are unassigned in the global study because sufficient research to derive credible estimates had not been undertaken. This paper is based on values from the original global study and therefore, it too has also left over half of the possible values unassigned. This does not imply that these functions have no value; simply that it was not possible to estimate the magnitude of these values.

Table 2: Area of Costanza biomes in Scotland (1988) and at the global level (1994): km²

Costanza Biomes		*Scotland 1988 Areas*
	Km²	*%*
Marine Biomes	89 694	53.3
Open Ocean	-	-
Continental Shelf	88 597	52.6
Coastal Estuaries	1 097	0.6
Terrestrial Biomes	78 790	46.8
Tidal Marsh	43	-
Swamps & Floodplains	143	0.1
Lakes & Rivers	1 526	0.9
Temperate & Boreal Forests	11 541	6.9
Grass & Rangelands	41 773	24.8
Cropland	19 933	11.8
Ice & Rock	1 961	1.2
Urban & Developed	1 914	1.1
Others	44	
Total Non-Tropical Biomes	168 484	100.0
Tropical & Other Global Biomes	-	-
All Costanza Biomes	168 481	100.0

While Scotland has a proportionately larger area of terrestrial biomes than found at the global level, approximately 84 percent of the value of its annual ecosystem services is generated by its continental shelf waters and estuaries. In comparison, these marine biomes generate only 22 percent of the total global value. There are a number of reasons that account for this discrepancy. Firstly, only 9 of the 16 global biomes are found in Scotland, placing a proportionately higher value per biome. Secondly, continental shelf is by far the largest biome by hectare in Scotland, and although the per-hectare value of continental shelf is mid-ranged in comparison with the other biome values, its sheer area gives this biome the highest gross value. Thirdly, estuaries, which are especially productive biomes, were assigned the highest value globally. And finally, nutrient cycling, which makes up 89 and 92 percent of the total value of continental shelf and estuarine biomes respectively, is an unassigned value in all of the terrestrial biomes applicable to Scotland. Thus the lack of published studies in this area greatly underestimates the potential value of Scotland's terrestrial biomes, lending to the higher value placed on marine biomes (Table 3). Grassland and rangelands, which are the source of significant ecosystem service benefits for Scotland, have relatively low ecosystem service values per hectare. Grasslands store approximately 34% of the global stock of CO_2 (WRI, 2002) yet the global valuation study assigns just $7 per hectare for the gas regulation function of this biome. It is likely that this value represents a substantial under-estimate.

Of the terrestrial biomes, Scotland's lochs and rivers contribute just over 6.5 percent of annual ecosystem services values. When added to the marine valuation, over 90 percent of Scotland's gross ecosystem service value is derived from water habitats.

Scotland's forests and woodlands (which are a gradually expanding though still small habitat) and its agricultural cropland together account for less than 3 percent of the calculated total annual value. This can possibly be attributed to missing values such as water regulation and erosion control being unavailable. This is one of a number of areas where the value of ecosystem services for Scotland will probably be underestimated in the global study, from which this value for Scotland was derived.

The contribution of individual ecosystem services

The model estimates the value to society of providing seventeen ecosystem services. These estimates are presented in Table 4 below. The most striking feature of the results is that over three quarters of the annual generation of ecosystem services in Scotland can be attributed to nutrient cycling. Other important ecosystem services in Scotland include food production, much of which translates directly into market benefits, others such as water regulation, waste treatment, and the cultural value of habitat types provide both market and non-market benefits.

Modifications to the global valuation methodology

In the global valuation study, the point estimates from approximately 100 studies were employed to derive the global average value of ecosystem services. The values related to studies in different countries and were averaged to arrive at the global estimate. For example, in deriving a value for recreation in swamp ecosystems, the results of three studies were employed: two from the United States (Thibideau and Ostro, 1981) and one from Malaysia (Gupta and Foster, 1975). In this case and others, a combination of values from developed and developing countries was used. Costanza *et al* acknowledge that this methodology introduces error because inter-country comparisons of

valuation are affected by a variety of factors, not least income differences (Costanza ***et al***, 1997b). Residents of higher income countries might be expected to be willing to pay more for an environmental benefit or to protect a particular ecosystem service than residents of lower income countries, simply because of differences in ability to pay. This type of bias is difficult to overcome when deriving average global value of ecosystem services. For this research it was not possible to use specific data for Scotland as the number of studies undertaken remain relatively small, and where they do exist they are rarely framed in a way which allows a per hectare valuation to be derived.

Several methods of modification are possible, including the addition of more recent studies to those employed in the original study, and the elimination of studies not appropriate for the region of study. This research utilises only the studies cited in Costanza ***et al's*** work but makes slight modifications by eliminating less relevant point estimates where possible. Values from studies with the most similar socio-economic conditions to Scotland were employed. If a Scottish study was used to help derive the global value, then it alone was taken as the value for this study. A UK study was favoured next, followed by a study (or average of studies) from higher income countries. Additionally, the value for CO_2 regulation was modified to reflect a more recent value of £70 per tonne of carbon derived in the UK (Pearce, 2001). Where there was no specific component study of relevance the original value remained unchanged. A total of 6 modifications were made, resulting in changes in value to 8 ecosystem services (Table 5).

The net effect of incorporating these modifications into the Scotland case study is to increase the monetary value of total ecosystem services generated in Scotland from £17.027 billion to £17.258 billion, an increase of only 1.3 percent.

Issues for further development

The estimates of the environmental value of ecosystem services generated by Scotland's habitats should be regarded as an initial exploration of a complex and evolving area of ecological economics. This approach has generated annual values that are conservative and broadly defensible in relation to both to their probable order-of-magnitude and to the relative contribution of different types of biome and ecosystem service. This research has, however, identified some future research priorities in relation to the value of Scotland's environment. There are three specific research issues of interest and importance: the absence of ecosystems services research on a number of biomes and on other habitats not yet considered; the influence upon ecosystem service valuations of measurements made at different spatial scales; and the issues related to the reliability and validity of environmental valuation.

Table 3: Ecosystem service values per biome type (GBP 2001)

Spaces marked with 'n' indicate services that do not occur or are known to be negligible. Spaces marked with '+' indicate lack of available information

Biome (Value in £)					Tidal						
			Forrest	Grass	Marsh/	Swamps/	Lakes/				
Ecosystem Service	*Estuaries*	*Shelf*	*Boreal*	*Rangeland*	*Mangr.*	*Floodpl*	*Rivers*	*Ice Rock*	*Cropland*	*Urban*	*Total*
Gas regulation	+	+	+	24,969,721	+	3,235,951	+	+	+	n	28,205,671
Climate regulation	+	+	86,725,356	+	+	+	+	+	+	n	86,725,356
Disturbance regulation	53,114,080	+	+	+	6,752,587	88,408,614	+	+	+	n	148,275,281
Water regulation	n	n	+	10,701,309	+	366,334	709,532,667	+	+	n	720,600,310
Water supply	n	n	+	+	+	92,804,622	275,864,216	+	+	n	368,668,838
Erosion control	n	n	+	103,445,986	+	+	+	+	+	n	103,445,986
Soil formation	n	n	9,855,154	3,567,103	+	+	+	+	+	n	13,422,257
Nutrient cycling	1,976,555,714	10,826,264,363	+	+	+	+	+	+	+	n	12,802,820,077
Waste treatment	+	+	85,739,840	310,337,957	24,586,906	20,258,272	86,655,505	+	+	n	527,578,480
Pollination	n	n	+	89,177,574	+	+	+	+	23,829,816	n	113,007,389
Biological control	7,306,699	295,055,423	3,942,062	82,043,368	+	+	+	+	40,851,112	n	429,198,664
Habitat/refugia	12,271,507	+	+	+	620,548	5,360,688	+	+	n	n	18,252,743
Food production	48,805,001	514,455,609	49,275,770	238,995,898	1,711,096	573,923	5,342,670	+	91,915,003	n	951,074,971
Raw materials	2,341,891	15,131,047	24,637,885	+	594,844	598,346	+	+	+	n	43,304,013
Genetic resources	+	+	+	+	+	+	+	+	+	n	+
Recreation	35,690,414	+	35,478,555	7,134,206	2,416,097	5,995,667	29,971,077	+	n	+	116,686,015
Culture	2,716,593	529,586,656	1,971,031	+	+	21,503,808	+	+	+	+	555,778,088
Total	2,138,801,899	12,180,493,099	297,625,653	870,373,120	36,682,077	239,106,225	1,107,366,135	+	156,595,930	+	17,027,044,138

Table 4: Annual value of ecosystem services generated by Scotland's environment: percentage distribution

Ecosystem Service	*Annual Value* £	*Percentage Contribution* %
Gas Regulation	28,205,671	0.17
Climate Regulation	86,725,356	0.51
Disturbance Regulation	148,275,280	0.87
Water Regulation	720,600,310	4.23
Water Supply	368,668,838	2.17
Erosion Control	103,445,986	0.61
Soil Formation	13,422,257	0.08
Nutrient Cycling	12,802,820,076	75.19
Waste Treatment	527,578,480	3.10
Pollination	113,007,389	0.66
Biological Control	429,198,664	2.52
Habitat/Refuge	18,252,743	0.11
Food Production	951,074,970	5.59
Raw Materials	43,304,013	0.25
Genetic Resources	-	0.00
Recreation	116,686,015	0.69
Culture	555,778,088	3.26
All Ecosystem Services	17,027,044,138	100.00

The authors recognise the significant conceptual, theoretical and practical challenges in seeking to identify a monetary value of the environment at either global or local scale.

Monetary-based valuations of the natural and man-made environment does face criticism from those who fail to understand how a monetary value can be placed on little understood natural processes and assets that are not traded in recognised markets. Whatever the views of individuals on environmental valuation, important national and international policy decisions are increasingly incorporating estimates of monetary values for non-market goods and services, and an absence of a value can mistakenly be taken to imply that a zero value is appropriate.

Conclusions

The research reported in this paper suggests that the 2001 annual value of Scotland's environment and ecosystem services derived through the use of the global valuation methodology may be of the order of £17.027 billion. It is probable that this is a significant underestimate because of the conservative research approach adopted. Modification of some basic valuations within the original framework to reflect better the nature of the Scottish environment results in a marginal rise in this value to £17.258 billion The global valuation methodology used in this research is one approach to placing the value of a national environment in a broad economic context. The purpose of the research reported here is principally as a means of raising public awareness of Scotland's living environment, and of contributing to the growing policy debate about national economic, environmental and social sustainability.

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Table 5: Modifications to the basic Costanza type valuation of scotland's ecosystem services value

Ecosystem Service	*Original Value* $/ha	*Biome Valuation Modified Value* $/ha	*Study Used*
Boreal Forest			
Recreation	36	57	Scotland Point Estimate (Hanley, 1989)
Culture	2	4	Pont estimate from US (Pope and Jones, 1990)
Grass Rangeland			
Gas Regulation	20.4	110.8	UK Point estimate (Pearce, 2001)
Soil Formation	20.4	110.8	UK Point estimate (Pearce, 2001)
Tidal Marsh/ Mangrove			
Disturbance Regulation	1 839	7 337	UK Point estimate (Pearce, 2001)
Swamps/Floodplains			
Water Supply	7 600	15 095	US Point estimate US (Gupta and Foster, 1975)
Habitat/Refugia	439	28	Scotland Point estimate (Gren and Soderqvist, 1994)
Recreation	491	575	Average US studies (Thibideau and Ostro, 1981 and Gupta and Foster, 1975)

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Endnote

1. Biomes are defined as "the world's major communities, classified according to the predominant vegetation and characterized by adaptations of organisms to that particular environment"

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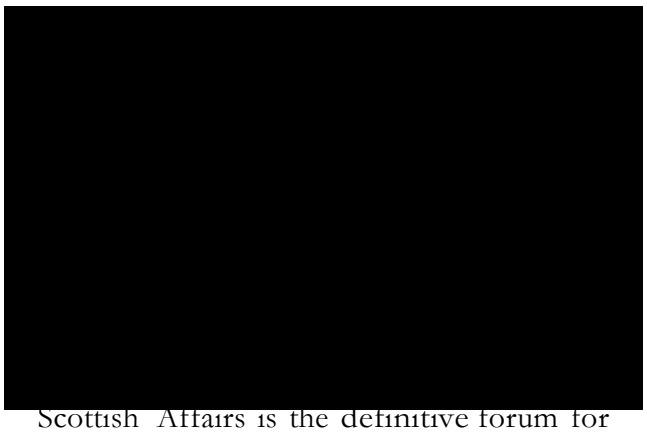

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