9

Cost-benefit analysis using GIS

Introduction

In this chapter we assess the net benefits of converting land out of agriculture and into woodland. This appraisal is made from a number of standpoints. We have considered two types of agricultural production (sheep and milk) each assessed in two ways (farm-gate and social[1] values), and two species of tree (conifer, represented by Sitka spruce, and broadleaf, represented by beech). Furthermore, we have assessed a variety of woodland benefits (recreation, timber and carbon sequestration) allowing us to consider a succession of definitions of what, in economic terms, constitutes a woodland. Finally, we have assessed the net benefits of land conversion using a variety of discount rates.

The results presented here consider various permutations of the factors discussed above. In essence our approach starts with the present agricultural values of a specific farm type (say sheep farming) and subtracts various definitions of woodland benefits (say, timber and carbon storage) assessed at a given discount rate (say 6 per cent). Thus a negative outcome would indicate that woodland benefits outstrip those of agriculture, and vice versa for positive sums. These various net benefit value estimates are obtained by using the GIS to overlay the respective value maps and adding or subtracting values as necessary.

A general caveat to our findings concerns the fact that our study data period is the early 1990s rather than the present day. As discussed at some length in Chapter 8, the intervening years have seen a relative decline in the values of agriculture both generally across the UK and in our study area of Wales. This means that our findings will tend to overestimate the value of farming and hence somewhat underestimate the potential for land use conversion into forestry. However, we are

[1] In this chapter we refer to 'social' rather than 'shadow' values as we are attempting to examine a wider range of internal and external benefits and costs than that considered in the analysis of agriculture alone presented in the previous chapter. We recognise that any definition of 'social' value is open to the criticism that the ensuing set of values is incomplete.

not unduly perturbed by this state of affairs for, in any policy assessment, it is also easy to underestimate the forces of inertia, tradition and risk aversion which can induce lag to a decision which seems economically optimal. In short we are much happier with a situation in which our findings are conservative than we would be if intervening forces had moved against land use conversions.

A further caveat to our calculations concerns the extent to which the marginal benefits of woodland are constant or diminishing. The maps of timber value created in Chapter 6 implicitly assume that the expansion of supply generated by any new planting would have no net impact upon the price of timber. Given that the vast majority of the timber consumed in the UK is imported, and that the price is in effect fixed on the world market, this seems a reasonable assumption. Similarly the maps of carbon sequestration value presented in Chapter 7 assume that the extra carbon stored by any new planting would have a negligible effect upon the unit value of carbon storage. Again, given the relatively minuscule proportion of excess atmospheric carbon which would be removed by such afforestation, this seems a very reasonable assumption. However, we cannot extend this line of reasoning to the recreation value maps created in Chapter 4. Here any substantial increase in the supply of recreational sites is liable to impact upon any excess demand[2] such that the value of any further sites is diminished. In effect, as the number of sites increases so substitute availability rises and the marginal recreational value of woodland falls.

To allow for this we have treated woodland benefits in the following manner. In the first of three stages agricultural values are assessed against timber values alone. Results for the farm-gate perspective include the various forest grants and subsidies available to farmers as well as incurred planting and maintenance costs (as in Chapter 6). This analysis is in effect mimicking the actual decision faced by farmers and provides a useful cross-check between our valuation estimates and the real world. In order to provide social value assessments of the agriculture versus timber trade-off we remove subsidies from both sides of the equation, a procedure which shifts the balance in favour of forestry which has a lower level of subsidisation than does conventional agriculture.

The second step adds carbon values to those derived from timber and reassesses the net benefits of conversion from agriculture.[3] Again values are calculated from both farm-gate and social perspectives.

[2] The impact of substitutes is considered in Bateman *et al*. (1998) and Brainard *et al*. (1999). However, comparison with the work of Willis and Benson (1989), as reviewed in Chapter 3, suggests that for any given individual woodland our estimates are likely to be reasonable and may even be lower-bound values.

[3] Dore *et al*. (2001) also compare agricultural values with timber and timber plus carbon sequestration values in a study of marginal farming regions in northern Saskatchewan, concluding that the latter exceeds the former in about twenty of the thirty years considered (the exception being the 1970s). However, the study is not spatially disaggregated and estimates total annual values only.

Finally, the third stage of analysis adds in recreational values and recalculates conversion net benefits. However, here we have to recognise the diminishing marginal value of recreation as outlined above. Because of this we cannot have confidence in the overall value sum created by such a calculation. Consequently we can only use this stage to identify those areas which would generate the very highest net benefits from conversion. This in itself is a highly useful result given that, in reality, resource limits mean that only a finite, and probably relatively small, amount of funds will be available to support conversion. Using the methodology outlined here enables the identification of prime sites for such conversion.

From the perspective of the farmer, comparison of agriculture with the timber plus carbon value (and with the timber, carbon and recreation value) does not have any immediate resonance with the actual market situation as neither carbon nor recreation values have any market or subsidy 'price'. However, these calculations do indicate the net benefits which farmers could receive if they were compensated for carbon and recreation values in the same manner in which timber values are realised (i.e. via market prices and subsidies).

All three definitions of woodland values (timber only; timber plus carbon; timber, carbon and recreation) have direct relevance when viewed from the standpoint of society which is interested in both the marketed and non-marketed values of woodland.

Results

Results are categorised first by whether we take a farm-gate or social value perspective. Further disaggregation is by the definition of woodland values discussed above and then by the discount rate, woodland species and farm sector under consideration. We begin by holding the discount rate and woodland species constant and examine results by farm sector. We then vary the tree species and finally change discount rate to present a full sensitivity analysis.

Results for the 6 per cent discount rate

In this section we hold the discount rate at 6 per cent throughout. This is a useful initial level to use for the calculation of social values as it is the current (at the time of writing) government rate for socially beneficial projects both now and in our study period. Our analyses of rates of return (Chapter 5) suggests that it is somewhat higher than that commonly used on sheep farms although it may be representative of rates used on some milk farms. We begin our discussion of results by considering potential conversions to conifer woodland.

Conversion from agriculture to conifer woodland

We begin this section by presenting results for conversion from sheep farms to conifer woodland, subsequently turning our attention to the milk farm sector.

Sheep farms

Table 9.1 reports results from one full run of our cost-benefit model holding the discount rate at 6 per cent and analysing the annual per hectare net benefit value of conversion from sheep farming into conifer woodland. Our analysis uses data recorded for (or interpolated to) a 1 km square basis and the entirety of Wales comprises some 20,563 such squares. Each column presents the distribution of values estimated for these squares.

The table is organised into two blocks each comprising four columns. The first block details farm-gate values (columns (1) to (4)) while the second gives social value equivalents (columns (5) to (8)). For both blocks the columns refer to successively wider definitions of woodland benefits. The first columns of each block (columns (1) and (5)) consider only the timber value while the next (columns (2) and (6)) add in carbon sequestration values. Lastly, two columns in each block add in woodland recreation values. Columns (3) and (7) use a lower-bound recreation value (derived from the contingent valuation (CV) cross-study 'meta-analysis' discussed in Chapter 4), while columns (4) and (8) use an upper-bound value (derived from our individual travel cost method (ITCM) analysis, also presented in Chapter 4).[4]

Column (1) of the farm-gate values block of Table 9.1 indicates the net benefit to farmers of converting from sheep farming to woodland under the present regime of grants and subsidies (defining woodland values as purely grants, subsidies and the net benefits of timber production). Remembering that negative sums show situations where these woodland values outstrip the present sheep values, we can see that, in the vast majority of cases (over 90 per cent of cells) the net benefits to farmers of staying in sheep production exceed those of converting into woodland. This difference is relatively marginal with the net benefit of remaining in agriculture being, in almost all cases, less than £100/ha and with almost 10 per cent of cells showing a small net benefit from conversion.[5] Nevertheless, the clear picture is

[4] The CV cross-study meta-analysis and ITCM study derive mean recreation values of £1.82 and £3.59 per party visit respectively. These values are somewhat lower than, although comparable to, those estimated for the study area by Willis and Benson (1989). Site-based values were converted to per hectare equivalents by dividing through by a mean site area of 4,000 hectares (Willis and Benson, 1989; Anna Chylack, Forestry Commission, pers. comm. 1994). The resulting values are within the range quoted by Benson and Willis (1993).

[5] Note that it is at the extremes that the truncation effect discussed in Chapter 8 will apply. These will tend to mask the lowest agricultural values and so conversion could be beneficial in somewhat more than 10 per cent of cases although this effect will be minor (particularly with respect to sheep farms where there is relatively little truncation).

Table 9.1. *Distribution of the net benefits of retaining sheep farming in Wales as opposed to conversion to conifer (Sitka spruce) woodland:*[1] *6% discount rate*

		Farm-gate values				Social values			
Lower limit (£/ha/yr, 1990)	Upper limit (£/ha/yr, 1990)	timber only (1)	timber+ carbon (2)	timber+carbon+ recreation (CVM) (3)	timber+carbon+ recreation (ITCM) (4)	timber only (5)	timber+ carbon (6)	timber+carbon+ recreation (CVM) (7)	timber+carbon+ recreation (ITCM) (8)
−475.00	−450.01								24
−450.00	−425.01								35
−425.00	−400.01								132
−400.00	−375.01								122
−375.00	−350.01				25				274
−350.00	−325.01				99				220
−325.00	−300.01				90			117	610
−300.00	−275.01				133			213	1,004
−275.00	−250.01				232			474	1,472
−250.00	−225.01			9	285			1,687	3,153
−225.00	−200.01			153	737		284	5,121	6,478
−200.00	−175.01			266	1,131		7,136	7,671	4,346
−175.00	−150.01			599	1,582		8,292	3,446	1,639
−150.00	−125.01		5	2,097	3,617	7	3,446	1,081	427
−125.00	−100.01		899	5,852	6,153	771	757	208	111
−100.00	−75.01		8,286	6,612	3,849	10,540	125	40	21
−75.00	−50.01		6,895	3,005	1,459	7,438	27	15	6
−50.00	−25.01	18	2,840	1,074	467	1,486	6	1	
−25.00	−0.01	1,978	809	272	164	296	1		
0.00	24.99	10,811	248	117	46	24			
25.00	49.99	5,929	84	17	5	1			
50.00	74.99	1,287	7	1	1				
75.00	99.99	323	1						
100.00	124.99	188							
125.00	149.99	29							
150.00	174.99								
175.00	199.99								
200.00	224.99								
225.00	249.99								10
250.00	274.99						3	29	92
275.00	299.99						64	146	210
300.00	324.99						236	263	164
325.00	349.99			4	20		177	48	13
350.00	374.99		11	28	87		9	3	
375.00	399.99		57	142	199				
400.00	424.99		228	249	160				
425.00	449.99		181	62	23				
450.00	474.99		12	4					

Notes: [1] Negative sums indicate areas where woodland values exceed agricultural values.
Blank cells indicate that no 1 km cells fall into this category. There are 20,563 1 km cells.

that when we consider farmers' perceptions of income, then, under the levels of woodland grant and subsidy operating during our study period, our analysis predicts very little conversion from sheep farming to woodland in the study area. This was indeed the situation on the ground with sources at both MAFF (Fearn, 1990) and the Forestry Commission (Adrian Whiteman, pers. comm., 1994) suggesting that very few Welsh farms had entered forestry schemes at that time.

Does this result provide validation for our estimates? As indicated, the 6 per cent discount rate used here is somewhat higher than the one we would expect sheep farmers to use in their everyday decision-making, yet it produces a result which is consistent with observed behaviour. There are a number of persuasive reasons explaining this result. These centre around the common observation that decision-makers in almost any field (and notably agriculture) demand a premium from risky or unfamiliar investments. Such diversification brings inherent uncertainty for the farmer regarding the levels of labour, capital, skill and entrepreneurship which will be required, as well as uncertainty regarding the ultimate returns from such an enterprise. This is particularly true of forestry which, for the farmer, is both very different from the well-known patterns of sheep production and involves a time scale which is an order of magnitude different from any of the decisions he/she usually encounters.

Cobb (1993) reviews a number of studies of agricultural risk premiums and reports on his own large-sample survey of UK farmers which revealed that they required very substantial increases in gross margin before they would consider conversion into low input extensification options such as that promoted under the Countryside Stewardship Scheme. Cobb feels that this is primarily due to farmers' preferences for familiar activities or agricultural techniques and to apprehension about the unfamiliar.[6] Our own research (see Chapter 3 and Bateman *et al*., 1996b) found that this is also the case with respect to conversions out of conventional agriculture and into woodland. Here substantial increases in profit rates were required before agreement to convert was forthcoming. As discussed in Chapter 5, Lloyd *et al*. (1995) suggest that one reason for this may be a belief by farmers that conversions to woodland may be irreversible, reducing future opportunities, and may possibly lower land prices. Such perceptions are fostered by the long commitment period of grant schemes and the requirement for replanting as a proviso in the granting of felling orders.

The risk premiums associated with such conversions can be modelled in a number of ways, one of which is to apply a higher discount rate than that normally used for

[6] Another interesting possibility explaining negligible conversion rates is explored by Saarinen (1966). In a study of US farmers who would, on purely financial grounds, have been better off giving up a specific type of farming, Saarinen found a consistent overoptimism about future performance, which persisted over long periods. However, he did identify a subset of innovative farmers who were receptive to the possibility of diversification.

standard investments. That is, in effect, what is being done in the farm-gate values reported in Table 9.1 and we can see that our model produces a result which closely resembles what is observed in the real world (as in column (1)). We return to this theme subsequently (see discussion of Table 9.5 below).

Given that we now have support from the real world for the predictions of our model, the 'timber only' farm-gate values (column (1)) also provide useful indications of the responsiveness of sheep farmers to increases in the level of timber grants and subsidies. Our results suggest that even a modest increase in the real level of such subsidies may produce significant increases in the financial viability of conversion. Given that the higher discount rate used here implicitly takes into account farmers' risk aversion, then we might expect this to translate into actual conversions. Some 10,811 cells (over 50 per cent of all cells) show an excess of sheep values over timber woodland values of less than £25/ha/yr. This suggests that while subsidies are currently too low to be effective, substantial conversions may be induced from modest increases in these subsidies.

While the results shown in Table 9.1 are of interest, the GIS-generated maps from which they are derived are more informative (although less easy to summarise). Plate 3a shows the map which underpins our farm-gate valuation of the conversion from sheep farming to woodland under present subsidy levels (column (1)). As can be seen, the majority of areas produce positive differences between sheep farming and timber, i.e. under present circumstances and if we only consider the market-priced benefits of forestry (timber and subsidies), then farm-gate income is generally higher under sheep than woodland. The map shows that this difference is smallest in mainly lowland, valley-floor areas, indicating that it is in these locations that conversions might be most profitable.

The social value equivalent of the above analysis is given in the first column of the second block of Table 9.1 (column (5)). The transfer savings created by a move out of sheep and into the relatively less subsidised production of timber mean that the social net benefits of such conversion are significantly higher than their farm-gate equivalents. This difference is very apparent in Table 9.1 because very nearly 100 per cent of cells record negative values, i.e. even when we only include timber benefits, the social value of woodland generally exceeds that of sheep production. This result is all the more powerful when we recall that the 6 per cent discount rate used here is the same as that used by the UK government for such calculations.

Comparison of columns (1) and (5) is revealing. While a conversion from sheep to woodland is unattractive from the farm-gate perspective, it generates net benefits from society's point of view. The potential clearly exists for a win/win bargain in which society pays some of its subsidy savings back to farmers as compensation for lost income, so that each side benefits. Given that the magnitude of social benefits is similar to that of farm loss, such a compensation scheme would, on these figures, need to be carefully constructed. However, once we widen our definition of woodland benefits the case for compensation becomes much more clear cut.

The second column of each block (columns (2) and (6)) adds in net carbon sequestration values to the benefits of woodland. In the case of the farm-gate values we are in effect modelling the impact of assigning to farmers the net carbon flux value associated with planting trees on their land. In the general case where such planting causes an increase in carbon storage we credit farmers with these values as a hypothetical subsidy. In the more rare case of planting on peat soils, farmers are now debited with a hypothetical charge against the farm account equivalent to the value of carbon liberated.

The impact of this expanded definition of woodland values is highly significant, moving the vast majority of farms (over 95 per cent) to a situation where conversion from sheep farming to woodland creates an increase in farm-gate income (column (2)). However, the large carbon losses associated with planting on peat mean that there are now a small number of farms which would generate strongly negative values from such conversion. This bimodal distribution is echoed in the social value equivalent of this analysis (column (6)). However, here the additional savings of agricultural subsidies substantially improve the net benefits of conversion to woodland.

In effect, then, we only have to expand our definition of the social benefits of woodland to include net subsidy savings, timber production and carbon sequestration to justify very substantial conversion out of Welsh sheep farming and into woodland. This conclusion is further reinforced if we now also consider the recreation benefit values created by making that woodland open-access.[7]

Given our reservations regarding the accuracy of recreational benefit measures, we have used two alternatives here. These are a lower-bound estimate obtained from our cross-study analysis of CV estimates, and an upper-bound measure obtained from our ITCM study. These are used to produce the third and fourth columns of each block. As noted, substitution effects mean that wholesale conversion to woodland would not attain the values shown in these columns. However, the results do indicate that the conversion of just a few select sites (which would not induce major substitution effects) would create woodlands of very high value in some locations. This story is repeated in both blocks, with the social value columns ((7) and (8)) exceeding farm-gate values (columns (3) and (4)) by a significant amount, mainly attributable to subsidy savings.[8]

[7] This statement hinges on the assumption, discussed in Chapter 4, that woodland recreational values are measures of surplus over the values created by general agricultural land use.

[8] Subsidy savings constitute the major difference between columns (1) and (5), a difference which is maintained across subsequent pairs of comparable farm-gate and social values.

Precise location of these prime conversion sites is facilitated by inspection of the net benefit value maps underpinning these columns. Plate 3b illustrates the social net benefit of conversion from sheep to woodland with the latter defined as the sum of timber, carbon storage and recreation values (measured using the lower-bound CV estimate), i.e. column (7). From a policy-making perspective this map illustrates the interpretative advantages of the methodology employed. Optimum sites for conversion are easily identified and (remembering that negative sums indicate areas where woodland values exceed those of agriculture) corresponding estimates of the monetary net benefit of such conversion are given.

While Plate 3b is readily interpretable, its message throws a critical light over past policy decisions. As the map clearly shows, the prime sites for conversion are located in lowland areas (with high timber productivity and carbon storage) and near to centres of high population and accessibility (yielding high recreation values).[9] This is particularly noticeable in South Wales where the urban centres of Cardiff and Swansea, augmented by the infrastructure effect of the M4 motorway, result in very high recreational values in addition to the excellent timber yields and consequent carbon sequestration levels engendered by these lowland areas. Conversely, conversion is least justified in upland areas, most noticeably upon peat soils where our analysis shows that retention within agriculture is clearly preferable. This result seems eminently sensible and accords with the sentiment made popular in the 1980s that policy-makers should 'bring forests down the hill' (MacFarlane, 2000). However, as this slogan implies, actual planting decisions have been almost completely at odds with such logic. The recreational needs of the majority lowland urban populace have not been recognised, and forests have in the main been planted in inaccessible upland areas – quite the reverse of the action suggested by Plate 3b. This policy seems to have been led by a desire to reduce the land purchase costs of planting trees, in ignorance of the economic value of such a strategy.

Milk farms

A second set of comparisons is presented in Table 9.2 which maintains the woodland species as conifer and holds the discount rate at 6 per cent but now examines potential conversions out of milk production. To allow further comparison with previous results, Plate 3c shows the net benefit map for the farm-gate value of converting from milk production to conifer woodland when only timber values and subsidies are considered (i.e. the present-day decision facing milk farmers; column

[9] There is a fascinating comparison here with the prescriptions of von Thunen's (1826) *Isolierte Staat* and subsequent land use analysis. For example Haggett *et al*. (1977: p. 206) note (without the benefit of specific analysis) that although financially non-viable, 'in highly urbanized areas the demand for "recreational" wooded areas may sometimes lead to its persistence in areas of high accessibility'.

Table 9.2. *Distribution of the net benefits of retaining milk farming in Wales as opposed to conversion to conifer (Sitka spruce) woodland:*[1] *6% discount rate*

		Farm-gate values				Social values			
Lower limit (£/ha/yr, 1990)	Upper limit (£/ha/yr, 1990)	timber only (1)	timber+ carbon (2)	timber+carbon+ recreation (CVM) (3)	timber+carbon+ recreation (ITCM) (4)	timber only (5)	timber+ carbon (6)	timber+carbon+ recreation (CVM) (7)	timber+carbon+ recreation (ITCM) (8)
−275.00	−250.01				13				
−250.00	−225.01		3	24	39				
−225.00	−200.01		29	32	75				3
−200.00	−175.01		35	74	82			4	62
−175.00	−150.01		70	77	128		11	55	122
−150.00	−125.01	21	84	145	173		60	107	160
−125.00	−100.01	29	175	197	191		105	191	270
−100.00	−75.01	65	184	210	221	2	211	289	422
−75.00	−50.01	94	227	250	258	37	308	297	568
−50.00	−25.01	168	266	273	260	103	344	422	682
−25.00	−0.01	203	290	209	208	188	423	413	737
0.00	24.99	293	181	182	210	362	322	473	887
25.00	49.99	355	176	164	215	442	299	763	1,180
50.00	74.99	389	136	149	224	543	377	1,174	2,114
75.00	99.99	166	150	150	351	339	1,080	2,324	3,176
100.00	124.99	160	147	251	542	285	1,775	3,849	3,826
125.00	149.99	163	173	351	530	302	4,272	4,658	3,523
150.00	174.99	163	227	443	702	523	5,446	3,522	1,693
175.00	199.99	143	420	765	1,163	1,401	3,331	1,031	388
200.00	224.99	175	743	1,058	1,700	2,245	1,234	316	151
225.00	249.99	215	1,003	1,649	2,162	4,969	351	131	72
250.00	274.99	277	1,239	2,389	2,572	5,138	86	33	28
275.00	299.99	527	2,359	2,978	2,630	2,636	29	20	10
300.00	324.99	847	3,296	2,976	2,475	808	10	4	9
325.00	349.99	1,089	3,113	2,589	1,898	184	7	14	22
350.00	374.99	1,578	2,616	1,676	796	41	19	30	48
375.00	399.99	2,618	1,734	639	252	15	38	54	86
400.00	424.99	3,224	784	240	183		83	95	78
425.00	449.99	3,025	321	149	55		100	79	37
450.00	474.99	2,389	118	28	21		33	9	17
475.00	499.99	1,380	30	28	27		15	24	26
500.00	524.99	559	27	20	20		25	22	16
525.00	549.99	140	20	15	11		14	22	16
550.00	574.99	75	9	13	12		25	19	21
575.00	599.99	29	11	8	15		17	8	4
600.00	624.99	4	12	18	12		2	4	33
625.00	649.99		16	9	9		35	56	26
650.00	674.99		15	21	14		26	10	19
675.00	699.99		10				23	29	31
700.00	724.99			3	3		27	12	
725.00	749.99		3		4				
750.00	774.99		1	9	37				
775.00	799.99		34	34	6				
800.00	824.99		11	4	14				
825.00	849.99		14	24	13				
850.00	874.99		19	23	25				
875.00	899.99		20	17	12				
900.00	924.99		12						

Notes: [1] Negative sums indicate areas where woodland values exceed agricultural values.
Blank cells indicate that no 1 km cells fall into this category. There are 20,563 1 km cells.

(1) of Table 9.2), while Plate 3d indicates the social value of conversion when the broad definition of woodland (timber, carbon storage and recreation, with the latter again measured using our CV cross-study value) is used (column (7)).

The overall pattern of values shown in Table 9.2 is similar to that for sheep farms, with expansion of the definition of woodland benefits increasing the value of the latter. However, the pattern of farm-gate values illustrated in Plate 3c (where woodland benefits are defined as arising just from timber and subsidies) is different to its sheep farm equivalent (Plate 3a). Here we find that the optimal locations for conversion to woodland (shown as negative sums) are clustered in upland rather than lowland areas. This difference in itself is of interest and shows that in contrast to the sheep sector, where it was the superiority of woodland in the lowland areas which was the driving force behind the net benefit of conversions, here it is the fall-off in milk farm values as we approach the most upland areas which allows woodland to become viable – but only at the extremes of topography. This difference is repeated in our social value analysis of the wider definition of woodland values (Plate 3d) where, with the exception of peat soil regions, it is again the upland areas which show more promise of net conversion benefits (in contrast to the sheep farm equivalent illustrated in Plate 3b).

The sheep and milk farm analyses differ not only in their relative pattern but also in the absolute level of conversion values. Even when all possible woodland values are considered, milk values almost always substantially exceed those generated by woodlands. Given that we know there are very few milk farms in the extreme upland areas of Wales this differential is probably even stronger than Table 9.2 indicates. Furthermore, as the discount rate used here is not out of line with (and may even be below) that likely to be used by milk farmers in everyday decision-making, any increase in the discount rate due to risk aversion would only reinforce the result. The social value assessment given here uses the government discount rate and so results are valid as they stand.

In summary, conversions out of milk production and into woodland are generally not justified by this study. We now extend our analysis to consider changes in the species of tree used in conversions.

Conversion from agriculture to broadleaf woodland

Sheep farms

Table 9.3 presents results for conversions from sheep farming to broadleaf woodland, maintaining the discount rate at 6 per cent. It is useful to contrast these results with the sheep to conifer conversion summarised in Table 9.1. In the latter, if we consider only timber values, conversion generally (but not always) fails to generate net benefits when viewed from the farm gate, but almost always creates social gains. However, the case for conversion is less clear in Table 9.3 where the slow growth rates associated with broadleaves mean that delayed timber benefits are heavily discounted; indeed, it is discounting which principally drives the differences between Tables 9.1 and 9.3. Accepting such a discount rate means that in less than half of the cells is conversion from sheep farming to broadleaved woodland justified upon social grounds and in no case do farm-gate values support conversion.

Broadening the definition of woodland benefits to include carbon sequestration does improve the farm-gate case for conversion, although in almost all cases the value of sheep farming marginally outperforms that of woodland. However, social values now generally support conversion except on areas of peat soil.

We now turn to consider recreation values. With respect to conversions to conifers we have up to this point focused attention upon the lower-bound CV measures. However, while evidence of a link between tree species and recreation values is somewhat anecdotal (see Hanley and Ruffell, 1991, 1992), we feel that the use of upper-bound measures has at least some justification with respect to broadleaf woodlands. The use of such measures does significantly improve the apparent viability of land use conversions, with virtually all cells producing net social benefits and most generating farm-gate gains from conversion. However, because we expect strongly declining marginal recreation values for additional woodlands in any given area (i.e. once a given locality has a recreational woodland then the marginal value of an additional woodland is relatively low) then we cannot take the values given in columns (4) and (8) of Table 9.3 at face value. This being so, it is of more interest to use this analysis to identify optimal locations for conversion rather than to look at total values. Plate 3e illustrates the farm-gate value of conversion using our wider definition of woodland benefits (and the upper-bound ITCM value of recreation), i.e. the net benefit map underpinning column (4), while Plate 3f illustrates the social value equivalent of this analysis, i.e. column (8).

It is clear from both Plate 3d and Plate 3f that, when our wider woodland benefits definition is applied, the net benefits of conversion from sheep rearing are highest in areas of high population accessibility (enhancing recreation values) and decrease as we move to more remote locations. The only areas where conversion is never justified are on peat soils where large-scale carbon liberation occurs. This echoes, in particular, the results shown in Plate 3b.

Analysis of the social values illustrated in Plate 3f indicates that the South Wales valleys are an area of particular interest. In the highly populated valleys and around the cities of Cardiff and Swansea there is a clear and very substantial net social benefit from conversion out of sheep farming and into multipurpose broadleaf woodland. This falls rapidly as we move away from such areas and into the sparsely populated upland areas which run down through the centre of Wales or the more inaccessible Pembroke and Lleyn peninsulas which characterise the west coast of

Table 9.3. *Distribution of the net benefits of retaining sheep farming in Wales as opposed to conversion to broadleaf (beech) woodland:*[1] *6% discount rate*

		Farm-gate values				Social values			
Lower limit (£/ha/yr, 1990)	Upper limit (£/ha/yr, 1990)	timber only (1)	timber+ carbon (2)	timber+carbon+ recreation (CVM) (3)	timber+carbon+ recreation (ITCM) (4)	timber only (5)	timber+ carbon (6)	timber+carbon+ recreation (CVM) (7)	timber+carbon+ recreation (ITCM) (8)
−350.00	−325.01								25
−325.00	−300.01								54
−300.00	−275.01								151
−275.00	−250.01								174
−250.00	−225.01				25				312
−225.00	−200.01				114			14	431
−200.00	−175.01				126			177	923
−175.00	−150.01				193			434	1,159
−150.00	−125.01				294			1,259	3,345
−125.00	−100.01			25	465		236	5,089	7,128
−100.00	−75.01			223	993		5,775	8,588	5,160
−75.00	−50.01			469	1,411		10,289	3,891	925
−50.00	−25.01			1,517	3,916	3,166	3,074	401	190
−25.00	−0.01		427	5,676	7,000	6,669	464	140	94
0.00	24.99		6,345	8,991	4,538	8,822	232	81	3
25.00	49.99	1	10,816	2,500	608	1,392	4		
50.00	74.99	3,400	1,703	294	172	317			
75.00	99.99	8,894	295	211	125	197			
100.00	124.99	6,810	269	74	17				
125.00	149.99	872	101	91	77				
150.00	174.99	173	118	3					
175.00	199.99	214							
200.00	224.99	159							
225.00	249.99	40							
250.00	274.99								
275.00	299.99								
300.00	324.99								34
325.00	349.99							165	380
350.00	374.99						418	305	65
375.00	399.99						57	19	10
400.00	424.99				51		14		
425.00	449.99		3	174	343				
450.00	474.99		393	282	88				
475.00	499.99		86	33	7				
500.00	524.99		7						

Notes: [1] Negative sums indicate areas where woodland values exceed agricultural values.
Blank cells indicate that no 1 km cells fall into this category. There are 20,563 1 km cells.

the country. The map also amply illustrates the ready interpretability of results generated by the methodology developed in this research.

Milk farms

We now briefly consider the viability of transfers from milk farming to broadleaf woodland. Results for this analysis are presented in Table 9.4. As before, while the pattern of results obtained for milk farms is similar to that for sheep farms, the absolute values are very different, with insignificant levels of conversion being justified under either the farm-gate or social value analysis. Given this, we do not discuss these findings further here.

Conversions between milk and sheep farming

In the above analyses we have calculated both farm-gate and social net benefit sums for conversion from sheep farming to woodland and from milk farming to woodland. However, these results also allow us to consider the net benefits of potential conversions between the two farming types (assuming a hypothetical lifting of the market entry restrictions currently imposed by milk quotas) and to ask whether this is more likely than a move into woodland. For simplicity in the following discussion we will refer to the net benefits of conversion to conifer woodland although the analysis could also be repeated for broadleaves, producing roughly similar results.

Considering those farm-gate values which farmers might actually have received during our study period (i.e. ignoring non-timber woodland benefits), then we have shown that in lowland areas sheep farming generally, but only marginally, outperforms woodland, with some conversions being viable where poorer soils predominate (for example, the north-west of Wales as illustrated in Plate 3a). However, the farm-gate value of dairying (Plate 3c) always and very substantially outperforms that of woodland in such lowland areas and consequently exceeds the value of sheep farming by a similar extent. Moving to consider upland areas, the farm-gate value of sheep farming always exceeds that of woodland, this excess being in places over £100/ha. The picture for milk to woodland conversions in upland areas is more mixed. While in areas of less extreme elevation milk values still exceed those of woodland by over £200/ha, in the highest areas the situation changes rapidly as dairy values fall rapidly, and the net benefits of retaining milk production drop below £100/ha. Thus, in the most mountainous areas, conversion to woodland becomes profitable. Therefore, we can see that our model predicts that the farm-gate value of sheep farming exceeds that of both woodland and milk production in these upland areas. Such a prediction is borne out by actual farming practice in these regions (see Chapter 8).

Turning to consider social values, it is perhaps most valid to define woodland value using the full range of benefits considered in this study. Using this measure we can see that woodland substantially outperforms sheep farming (Plate 3b) but is itself consistently outperformed by dairying (Plate 3d) in lowland areas. Therefore, in a scenario of full agricultural liberalisation and with farmers being paid for positive externalities we would expect no conversions from dairying but complete conversion from sheep farming, primarily into milk (if all policy restrictions had been lifted) with woodland as a possible second choice.[10] However, such a result ignores the impacts upon milk price of such a supply expansion and given the very strong likelihood of entry restrictions remaining upon the milk market we believe that this does not invalidate analysis of the social benefits of potential conversions from sheep farming to woodland in lowland areas.

In the uplands the social value of woodland exceeds that of sheep farming in all but peat soil regions, with net benefits of conversion generally in the range of £100 to £200 per hectare. For dairy farming the picture is again less clear with about the same area converting as not. In the former, the net benefits of conversion generally range up to about £100/ha with only a few areas exceeding this. Consequently, assuming no entry barriers or requirement for risk premiums, we would expect all sheep farms to convert, with approximately the same number turning to woodland as to milk farming. Given the improbable nature of such assumptions we do not foresee movement from sheep to milk production, so this implies that all conversion would be towards woodland. The one exception throughout is the peat soil regions, where afforestation is never justified on social grounds.

Results for the 6 per cent discount rate: summary

Looking back across the full range of analyses conducted using the 6 per cent discount rate we can see that an economic case can be made for conversion from sheep farming, particularly in lowland areas with high population accessibility, but that under the subsidy schemes available in our study period such conversion was not financially attractive to the farmer. (The intervening years have changed little here, with subsidies still not being available for most of the non-market benefits of woodland.) Considering the choice of species, conifer woodlands generally seem to be a more viable option for conversion than broadleaves. However, in the following chapter we discuss omissions from this analysis (e.g. acidification impacts and biodiversity effects) which are generally favourable to broadleaf trees and militate against certain coniferous species. Given this, it is interesting to note that our analysis of broadleaf values indicates that, using the wider definition of benefits, conversions from sheep farming usually generate net benefits.

[10] As noted in Chapters 1 and 5, this is only a partial CBA; we were not able to consider all possible opportunity costs – a characteristic failing of many practical CBA applications.

Table 9.4. *Distribution of the net benefits of retaining milk farming in Wales as opposed to conversion to broadleaf (beech) woodland:*[1] *6% discount rate*

		Farm-gate values				Social values			
Lower limit (£/ha/yr, 1990)	Upper limit (£/ha/yr, 1990)	timber only (1)	timber+ carbon (2)	timber+carbon+ recreation (CVM) (3)	timber+carbon+ recreation (ITCM) (4)	timber only (5)	timber+ carbon (6)	timber+carbon+ recreation (CVM) (7)	timber+carbon+ recreation (ITCM) (8)
−225.00	−200.01				16				
−200.00	−175.01		3	17	20				
−175.00	−150.01		17	15	26				
−150.00	−125.01		14	35	100				25
−125.00	−100.01	11	49	100	118			21	74
−100.00	−75.01	20	81	156	188		31	44	148
−75.00	−50.01	19	187	146	186		61	181	203
−50.00	−25.01	79	136	270	295	11	192	288	371
−25.00	−0.01	174	283	335	326	27	309	440	520
0.00	24.99	158	455	253	179	118	608	415	358
25.00	49.99	293	146	175	117	304	268	224	419
50.00	74.99	489	151	78	129	518	191	254	452
75.00	99.99	346	103	160	149	648	247	255	649
100.00	124.99	154	130	148	178	216	233	418	769
125.00	149.99	100	153	133	203	233	250	628	923
150.00	174.99	148	142	138	249	255	376	889	1,675
175.00	199.99	140	125	156	364	230	838	1,987	2,995
200.00	224.99	150	140	289	404	340	1,638	3,120	3,558
225.00	249.99	157	203	296	458	465	2,934	4,164	3,341
250.00	274.99	128	237	385	601	1,283	4,699	3,956	2,465
275.00	299.99	183	329	702	1,274	1,910	4,236	2,349	959
300.00	324.99	255	758	1,079	1,402	3,843	2,386	342	152
325.00	349.99	239	964	1,350	2,026	4,449	473	96	17
350.00	374.99	446	1,172	2,142	2,353	3,908	103	3	1
375.00	399.99	931	1,947	2,492	2,472	1,471	1	4	25
400.00	424.99	1,011	2,671	2,800	2,238	297	18	33	49
425.00	449.99	1,483	2,903	2,583	2,250	37	32	96	119
450.00	474.99	2,286	2,708	2,157	1,234		131	128	83
475.00	499.99	2,740	2,213	1,257	583		95	18	6
500.00	524.99	2,564	1,231	344	121		7	21	18
525.00	549.99	2,568	424	144	104		17	3	13
550.00	574.99	1,807	216	35	9		11	22	34
575.00	599.99	1,003	80	4	7		25	26	7
600.00	624.99	328	8	11	13		38	24	21
625.00	649.99	116	9	14	24		1		
650.00	674.99	36	21	20	9		2	4	31
675.00	699.99	1	16	8	24		24	41	19
700.00	724.99		24	22			24	5	8
725.00	749.99						25	38	56
750.00	774.99						38	26	
775.00	799.99		2	2	4		1		
800.00	824.99		2	24	28				
825.00	849.99		25	18	18				
850.00	874.99		21	6					
875.00	899.99				10				
900.00	924.99		25	25	28				
925.00	949.99		13	25	26				
950.00	974.99		25	14					
975.00	999.99		1						

Notes: [1] Negative sums indicate areas where woodland values exceed agricultural values.
Blank cells indicate that no 1 km cells fall into this category. There are 20, 563 1 km cells.

Table 9.5. *Distribution of the net benefits of retaining sheep farming in Wales as opposed to conversion to conifer (Sitka spruce) woodland:*[1] *3% discount rate*

		Farm-gate values				Social values			
Lower limit (£/ha/yr, 1990)	Upper limit (£/ha/yr, 1990)	timber only (1)	timber+ carbon (2)	timber+carbon+ recreation (CVM) (3)	timber+carbon+ recreation (ITCM) (4)	timber only (5)	timber+ carbon (6)	timber+carbon+ recreation (CVM) (7)	timber+carbon+ recreation (ITCM) (8)
−575.00	−550.01								29
−550.00	−525.01								128
−525.00	−500.01								73
−500.00	−475.01				9				199
−475.00	−450.01				37				217
−450.00	−425.01				125			61	378
−425.00	−400.01				116			155	803
−400.00	−375.01				169			321	1,170
−375.00	−350.01				234			992	1,823
−350.00	−325.01			93	478		37	2,725	4,216
−325.00	−300.01			200	912		2,963	5,814	5,056
−300.00	−275.01			359	1,233		6,962	4,959	2,954
−275.00	−250.01			1,263	2,170	3	5,092	2,653	1,612
−250.00	−225.01		246	3,435	4,326	839	2,865	1,475	934
−225.00	−200.01		3,998	5,464	4,565	7,486	1,518	601	288
−200.00	−175.01		6,549	5,304	2,721	6,505	412	217	126
−175.00	−150.01	18	4,452	2,455	1,532	3,570	156	58	37
−150.00	−125.01	2,024	2,568	1,487	907	1,689	36	21	21
−125.00	−100.01	7,549	1,499	676	361	352	17	15	8
−100.00	−75.01	5,610	554	238	113	82	13	6	2
−75.00	−50.01	3,032	141	60	36	20	2	1	
−50.00	−25.01	1,671	34	18	20	14	1		16
−25.00	−0.01	526	16	15	8	3	14	18	10
0.00	24.99	98	14	6	1		7	26	70
25.00	49.99	17	2	1	4		51	109	143
50.00	74.99	15	1	10	13		169	199	194
75.00	99.99	3	16	8	10		207	122	51
100.00	124.99		5	29	74		36	13	5
125.00	149.99		53	106	146		5	2	
150.00	174.99		167	196	181				
175.00	199.99		194	124	56				
200.00	224.99		48	13	6				
225.00	249.99		6	3					
250.00	274.99								
275.00	299.99								
300.00	324.99								

Notes: [1] Negative sums indicate areas where woodland values exceed agricultural values. Blank cells indicate that no 1 km cells fall into this category. There are 20,563 1 km cells.

Our analysis of milk farms suggests that, in general, there is not a strong economic case for conversions from this sector to either conifer or broadleaf woodland. One further interesting difference here is the result that if any such conversions were justified these would be in upland (but non-peat) areas. This seems mainly attributable to a rapid fall-off in milk values as we reach the upland extremes of the Welsh environment. However, we again remind ourselves of the relative scarcity of milk farms in such environments.

Having analysed the effects of changing tree species we now consider the effect of changing discount rates. Given our discussions in Chapter 5 and above, any increase in rates seems unrealistic (and will almost inevitably rule out any possibility of conversion), so a reduction seems more interesting.

Results for the 3 per cent discount rate

A 3 per cent discount rate is worth considering for two reasons: first, it more closely approximates what we believe to be the rate used by sheep farmers for everyday decision-making; secondly, it is closer to the social discount rates recently proposed by many commentators and currently being considered by H. M. Treasury. The 3 per cent rate thus has applicability to the sheep farm-gate results and to both the sheep and milk farm social value analyses.

Conversion from agriculture to conifer woodland

Sheep farms

Table 9.5 reports results from the analysis of conversions from sheep to conifer using a 3 per cent discount rate. Considering column (1) we can see that lowering the discount rate to 3 per cent makes conversion from sheep into woodland beneficial for almost all farmers even when we only consider timber values and the availability of grants and subsidies during our study period; Plate 3g presents the corresponding map of values. Given that this scenario represents the available returns to farmers, why does such a rate of conversion not occur? The answer, as before, is most likely to be related to a risk premium. A farmer's risk premium can either be modelled as a higher required discount rate (as discussed earlier in this chapter) or, at existing discount rates, as a requirement that unfamiliar goods, such as those provided by forests, provide a substantially higher income than does conventional production (our discussion of Table 9.2 is relevant here). As before, net savings on subsidies mean that social values of conversion under this scenario (column (5)) are substantially above farm-gate values; indeed, using this analysis, all Welsh sheep farms should be converted to woodland. Given that we are here ignoring all non-timber benefits, this is a powerful result.

For both farm-gate and social value analyses the addition of carbon sequestration values again produces a bimodal distribution, with the majority of cells now more strongly benefiting from conversion to woodland (columns (2) and (5)). The further addition of recreation values reinforces this result.

Milk farms

Table 9.6 repeats the above analysis but now considers conversion from milk farms. Given the discussion presented in Chapter 5, the 3 per cent discount rate is not especially relevant to farm-gate analyses of milk farm conversions. However, that same chapter shows that such a rate is, arguably, relevant to social values (although it is currently being considered by the UK government for such purposes). Examining the social values block we can see that it is only when carbon sequestration values are included that significant conversions are justified. Here about 18 per cent of cells generate net social benefits from conversion, a proportion which rises substantially when lower-bound (most appropriate for conifers) CV-based recreation values are added, although substitution effects mean that this has to be a significant overstatement of conversion viability. Examination of the maps underpinning these results confirmed that it is high population, high accessibility, lowland areas which generate the largest net benefits from conversion.

Conversion from agriculture to broadleaf woodland

Sheep farms

As before we now hold the discount rate constant (at 3 per cent) and consider the impact of conversions to our representative broadleaf tree species, beech. Table 9.7 shows results for sheep farms. Considering first the farm-gate values, the contrast between our 3 per cent discount rate analyses of conversions from sheep to conifers as opposed to broadleaves is very marked. Whereas present timber values and related grants were sufficient to generate net farm-gate benefits from conversion in the former instance (Table 9.5, column (1)), for the latter such conversion fails to pass the cost-benefit test (Table 9.7, column (1)). Given that grants for broadleaf trees exceed those for conifers, this result seems to be due to the longer rotations, and hence delay to felling benefits, typical of broadleaves.

Addition of carbon sequestration benefits makes conversion of just over 10 per cent of cells apparently profitable from a farm-gate perspective (column (2) of Table 9.7). However, the likelihood of farmers requiring a risk premium means that in reality we would not expect conversions to occur until recreation benefits are also paid. Even if, as argued previously, higher rate recreation values can be justified for broadleaf woodlands, then such a premium means that relatively high increases in subsidies would be required to generate attractive levels of farm-gate income.

Table 9.6. *Distribution of the net benefits of retaining milk farming in Wales as opposed to conversion to conifer (Sitka spruce) woodland:*[1] *3% discount rate*

		Farm-gate values				Social values			
Lower limit (£/ha/yr, 1990)	Upper limit (£/ha/yr, 1990)	timber only (1)	timber+ carbon (2)	timber+carbon+ recreation (CVM) (3)	timber+carbon+ recreation (ITCM) (4)	timber only (5)	timber+ carbon (6)	timber+carbon+ recreation (CVM) (7)	timber+carbon+ recreation (ITCM) (8)
−375.00	−350.01				4				
−350.00	−325.01		2	10	38				
−325.00	−300.01		14	37	52				5
−300.00	−275.01		36	50	68		2	12	33
−275.00	−250.01	2	55	68	95		15	23	117
−250.00	−225.01	17	70	91	144		27	83	118
−225.00	−200.01	34	96	176	180		83	134	236
−200.00	−175.01	63	193	192	178	10	142	218	452
−175.00	−150.01	78	185	188	197	36	243	285	464
−150.00	−125.01	132	204	206	230	90	285	286	722
−125.00	−100.01	209	226	258	296	165	325	475	890
−100.00	−75.01	234	278	252	253	311	395	614	1,085
−75.00	−50.01	303	219	182	255	357	398	1,003	1,393
−50.00	−25.01	324	180	179	274	451	513	1,592	2,423
−25.00	−0.01	309	164	175	427	450	1,330	2,975	3,503
0.00	24.99	191	154	260	527	358	2,934	4,134	3,924
25.00	49.99	180	198	408	608	481	4,981	4,419	2,846
50.00	74.99	165	252	498	853	1,129	4,462	2,250	1,029
75.00	99.99	159	502	937	1,388	2,023	2,350	905	426
100.00	124.99	191	881	1,261	1,862	4,699	932	385	271
125.00	149.99	245	1,031	1,835	2,445	5,083	447	241	182
150.00	174.99	416	1,677	2,803	2,572	3,050	246	165	136
175.00	199.99	788	2,922	3,104	2,851	1,167	139	109	78
200.00	224.99	1,030	3,386	3,071	2,253	435	85	45	31
225.00	249.99	1,276	3,123	2,098	1,389	189	29	28	27
250.00	274.99	2,548	2,164	1,218	471	57	26	18	21
275.00	299.99	3,220	1,156	450	243	15	19	23	15
300.00	324.99	3,316	616	198	126	7	19	14	19
325.00	349.99	2,440	246	107	72		24	29	23
350.00	374.99	1,501	104	58	40		16	10	16
375.00	399.99	746	51	29	24		19	22	28
400.00	424.99	254	32	34	31		26	26	19
425.00	449.99	125	29	15	4		22	25	22
450.00	474.99	31	6	4	2		20	15	9
475.00	499.99	22			4		9		
500.00	524.99	13	3	10	22				
525.00	549.99	1	34	45	35				
550.00	574.99		23	6					
575.00	599.99		2	10	13				
600.00	624.99		15	20	25				
625.00	649.99		22	11	12				
650.00	674.99		12	9					
675.00	699.99								

Notes: [1] Negative sums indicate areas where woodland values exceed agricultural values.
Blank cells indicate that no 1 km cells fall into this category. There are 20,563 1 km cells.

Table 9.7. *Distribution of the net benefits of retaining sheep farming in Wales as opposed to conversion to broadleaf (beech) woodland:*[1] *3% discount rate*

		Farm-gate values				Social values			
Lower limit (£/ha/yr, 1990)	Upper limit (£/ha/yr, 1990)	timber only (1)	timber+ carbon (2)	timber+carbon+ recreation (CVM) (3)	timber+carbon+ recreation (ITCM) (4)	timber only (5)	timber+ carbon (6)	timber+carbon+ recreation (CVM) (7)	timber+carbon+ recreation (ITCM) (8)
−400.00	−375.01								
−375.00	−350.01								25
−350.00	−325.01								14
−325.00	−300.01								178
−300.00	−275.01								102
−275.00	−250.01				25				308
−250.00	−225.01				61			1	364
−225.00	−200.01				158			102	709
−200.00	−175.01				141			334	1,047
−175.00	−150.01				260			740	1,962
−150.00	−125.01			19	397		24	2,826	5,691
−125.00	−100.01			165	795		2,492	7,718	7,189
−100.00	−75.01			350	1,222		9,828	7,432	2,089
−75.00	−50.01			897	2,181	362	6,691	619	287
−50.00	−25.01		42	3,284	6,196	6,512	740	205	92
−25.00	−0.01		2,967	8,853	6,668	10,498	231	97	17
0.00	24.99		11,859	5,629	1,533	2,565	68		
25.00	49.99	567	4,288	462	182	405			
50.00	74.99	7,413	398	175	156	220			
75.00	99.99	10,549	259	140	11	1			
100.00	124.99	1,336	92	81	88				
125.00	149.99	231	169	19					68
150.00	174.99	257					12	194	331
175.00	199.99	135					395	279	90
200.00	224.99	75					82	16	
225.00	249.99			1	71				
250.00	274.99		16	198	319				
275.00	299.99		378	270	97				
300.00	324.99		95	20	2				

Notes: [1] Negative sums indicate areas where woodland values exceed agricultural values.
Blank cells indicate that no 1 km cells fall into this category. There are 20,563 1 km cells.

Table 9.8. *Distribution of the net benefits of retaining milk farming in Wales as opposed to conversion to broadleaf (beech) woodland:*[1] *3% discount rate*

		Farm-gate values				Social values			
Lower limit (£/ha/yr, 1990)	Upper limit (£/ha/yr, 1990)	timber only (1)	timber+ carbon (2)	timber+carbon+ recreation (CVM) (3)	timber+carbon+ recreation (ITCM) (4)	timber only (5)	timber+ carbon (6)	timber+carbon+ recreation (CVM) (7)	timber+carbon+ recreation (ITCM) (8)
−300.00	−275.01								
−275.00	−250.01								
−250.00	−225.01				8				
−225.00	−200.01			11	15				
−200.00	−175.01		11	18	21				
−175.00	−150.01		20	18	61				9
−150.00	−125.01	3	22	63	114			11	44
−125.00	−100.01	20	69	113	136		14	27	106
−100.00	−75.01	11	124	147	179		32	106	158
−75.00	−50.01	55	156	192	217	3	111	203	278
−50.00	−25.01	91	214	266	306	28	235	344	413
−25.00	−0.01	204	273	379	266	64	371	433	460
0.00	24.99	174	395	175	174	216	528	359	471
25.00	49.99	345	143	155	130	362	238	231	436
50.00	74.99	543	118	92	159	710	255	258	488
75.00	99.99	202	121	191	144	357	228	343	809
100.00	124.99	151	159	128	205	213	230	552	822
125.00	149.99	113	146	126	201	253	309	754	1,375
150.00	174.99	153	129	150	349	248	566	1,457	2,428
175.00	199.99	145	148	259	412	292	1,396	2,619	3,388
200.00	224.99	142	205	320	532	401	2,128	4,117	3,564
225.00	249.99	145	236	360	561	926	4,374	4,160	3,295
250.00	274.99	161	325	643	959	1,649	4,986	3,258	1,436
275.00	299.99	209	687	981	1,506	3,204	3,272	954	322
300.00	324.99	270	962	1,262	1,789	4,722	916	130	44
325.00	349.99	355	1,014	1,843	2,212	4,259	156	56	28
350.00	374.99	796	1,601	2,392	2,546	2,189	29	8	20
375.00	399.99	949	2,495	2,847	2,267	377	13	20	27
400.00	424.99	1,214	2,947	2,521	2,360	89	26	25	9
425.00	449.99	2,031	2,786	2,455	1,520	1	25	24	19
450.00	474.99	2,686	2,310	1,576	817		11		3
475.00	499.99	2,836	1,680	543	150		2	4	40
500.00	524.99	2,710	614	117	95		27	43	7
525.00	549.99	2,055	209	91	35		21	3	10
550.00	574.99	1,155	117	13	3		20	52	54
575.00	599.99	399	12	2	1		44	12	
600.00	624.99	175	3	3	3				
625.00	649.99	62	2	24	36				
650.00	674.99	3	26	18	10				
675.00	699.99		20	5	0				
700.00	724.99		0	1	11				
725.00	749.99		20	30	27				
750.00	774.99		18	33	26				
775.00	799.99		26						

Notes: [1] Negative sums indicate areas where woodland values exceed agricultural values.
Blank cells indicate that no 1 km cells fall into this category. There are 20,563 1 km cells.

Turning to consider social values, and remembering that sustainability criteria may justify use of the 3 per cent rate here, we can see that even if we only consider timber benefits a large majority (84 per cent) of cells would pass a cost-benefit test of conversion. Addition of carbon benefits indicates that almost the only cells that would not pass such a test are those located on peat soils. Further addition of recreation benefits merely reinforces this result.

Milk farms

Table 9.8 summarises results for a conversion from milk production to broadleaf woodland under a 3 per cent discount rate. Consideration of the farm-gate values detailed here has to be tempered by the knowledge that a 3 per cent rate is lower than that we would expect milk farmers to use for everyday decision-making (and that a risk-weighted rate would be even higher than this). Even so, Table 9.8 indicates that the long delays associated with broadleaves mean that farm-gate values do not justify anything but the most minor conversions even when all benefits are paid. The situation with social values is very similar, with little conversion out of milk being justified.

Other discount rates

Given the above discussions and comparisons with observed rates of conversion, it seems likely that farmers are attaching significant risk premiums to any decision to convert to woodland, an observation made elsewhere regarding other non-standard production (Cobb, 1993). This can be modelled either as a required surplus of net benefits or as an inflated discount rate. Given this, consideration of further reductions in discount rate does not appear to be justified.[11]

CBA summary and the present situation

CBA summary

Inspecting the analyses presented in this chapter we feel that the link between our value estimates calculated at a 6 per cent discount rate, the wider case for using such a rate and the rates of conversion observed in reality is compelling. Furthermore, the fact that this is also the UK government's current discount rate for socially beneficial projects makes the analyses reported in Tables 9.1 to 9.4 of particular interest.

Considering results for a 6 per cent discount rate and taking conifer woodlands first, we found (Table 9.1) that for sheep farmers the level of grants and subsidies

[11] Analyses of lower discount rate scenarios were undertaken. These merely extended the trends observed when we moved from a 6 per cent to a 3 per cent discount rate.

paid during our study period was insufficient to justify conversion, a situation which seems unlikely to have changed up to the present day. However, increasing these transfers in line with the wider definition of external woodland benefits would substantially shift the balance of farm-gate values in favour of conversion. Furthermore, our analysis suggests that relatively modest increases in woodland subsidy could result in significant rates of uptake among Welsh sheep farmers. Interestingly, our analysis of social values shows that these are already strongly in favour of conversion and that the increase in subsidies outlined above could generate very substantial net social benefits. However, turning to consider milk farms, Table 9.2 suggests that neither farm-gate nor social values justify substantial transfers out of this sector and into conifer woodlands.

When we consider potential conversions to broadleaf woodlands, Table 9.3 shows that, relative to conifers (Table 9.1), the longer rotation periods mean that the 6 per cent discount rate militates heavily against conversion from sheep farming, although this is still generally justified if all the non-market benefits of woodland are appraised or we shift from farm-gate to social value assessments. However, Table 9.4 shows that with a 6 per cent discount rate conversions from milk farming to broadleaf woodland are not generally justified.

Shifting to a 3 per cent discount rate considerably increases the benefits of woodland and so strengthens the case for conversion from sheep farming. However, while such a rate may theoretically be justified for the calculation of social net benefits, it is not in line with present government policy and does not seem to reflect sheep farmers' attitudes towards this type of conversion. Furthermore, this switch does not fundamentally alter the position with regard to farm-gate values on milk farms although some positive net social benefits may be derived from conversion if a wide definition of woodland benefits is employed. Such a low discount rate may not be valid for assessment of farm-gate values on milk farms.

Clearly, if conversions are to occur, then both farm-gate and social valuations indicate that these will be most readily derived from the sheep farm sector. In reality, decision-makers are likely to be faced with only limited resources to effect such conversions. In such situations our methodology is particularly suited to the identification of optimal sites for conversion onto which subsidies can be targeted. Plate 3f provides a useful illustration of this capacity, showing how we can target sites according to the net social benefits created by conversion.

Our results also reveal an interesting dichotomy between economic analysis and policy practice. We have shown that highly populated, readily accessible, lowland areas provide the optimal location for conversions out of agriculture and into woodland. Such sites combine high rates of tree growth with high recreational demand. However, it is only in recent years, with the advent of the Community Woodland Scheme and similar schemes, that policy has begun to recognise the strength of this argument.[12] The legacy of virtually all preceding policies has been a concentration of woodlands in upland areas, inaccessible to the majority of the population. Figure 9.1 illustrates the present locations of Forestry Commission conifer woodlands in Wales (superimposed upon an elevation map). Comparison with our maps of optimal conversion areas reveals the disparity between those areas and the actual locations of the current woodland stock. The overall message of our analysis is clear: extended economic analysis of both the internal and external net benefits of conversion shows considerable justification for bringing forestry down the hill.

The present situation

Finally, we can consider the extent to which the findings presented in this chapter need to be modified by events which have occurred since our 1990 study period. First, let us consider the timber, carbon-fixing and recreation values which dominate our analysis of woodland.

The analysis of timber values presented in Chapter 5 considered a variety of studies examining possible trends within real timber prices. Arguments can be put forward in favour of both increases and decreases in real prices. However, the weight of long-term analysis currently suggests that neither viewpoint can be adequately established and that an assumption of constant real prices is less prone to error than either of the alternatives. Such a view is reinforced by recent government policy papers describing an expanding and vibrant forest estate and industry. This target can only be achieved, in the absence of new planting by the Forestry Commission, by maintaining the real value of woodland grants and subsidies, which form a substantial portion of the discounted income received by forest-owners. Similarly, as noted in Chapter 7, the increasingly pessimistic predictions of the IPCC and other experts regarding the apparent acceleration in climate change suggests that carbon sequestration values will be at least non-declining and arguably may increase in real terms over time. Such assumptions seem well founded given the recent US exit from the Kyoto Climate Change Convention on reductions in greenhouse gas emissions.

Considering the real value of open-access woodland recreation, in our conclusions to Chapter 3 we presented results suggesting that such values were non-declining and may even be rising slowly over time. Models of economic development suggest that such results are to be expected as economic growth leads to increasing demand for leisure activities. Although studies of changing work patterns can challenge the assumption that growth necessarily leads to increased voluntary

[12] Interestingly it may well be a non-governmental organisation, the Woodland Trust, which plays a significant role in future forest development, funded in part by a grant of over £6 million from the Millennium Fund (Smith, 1996).

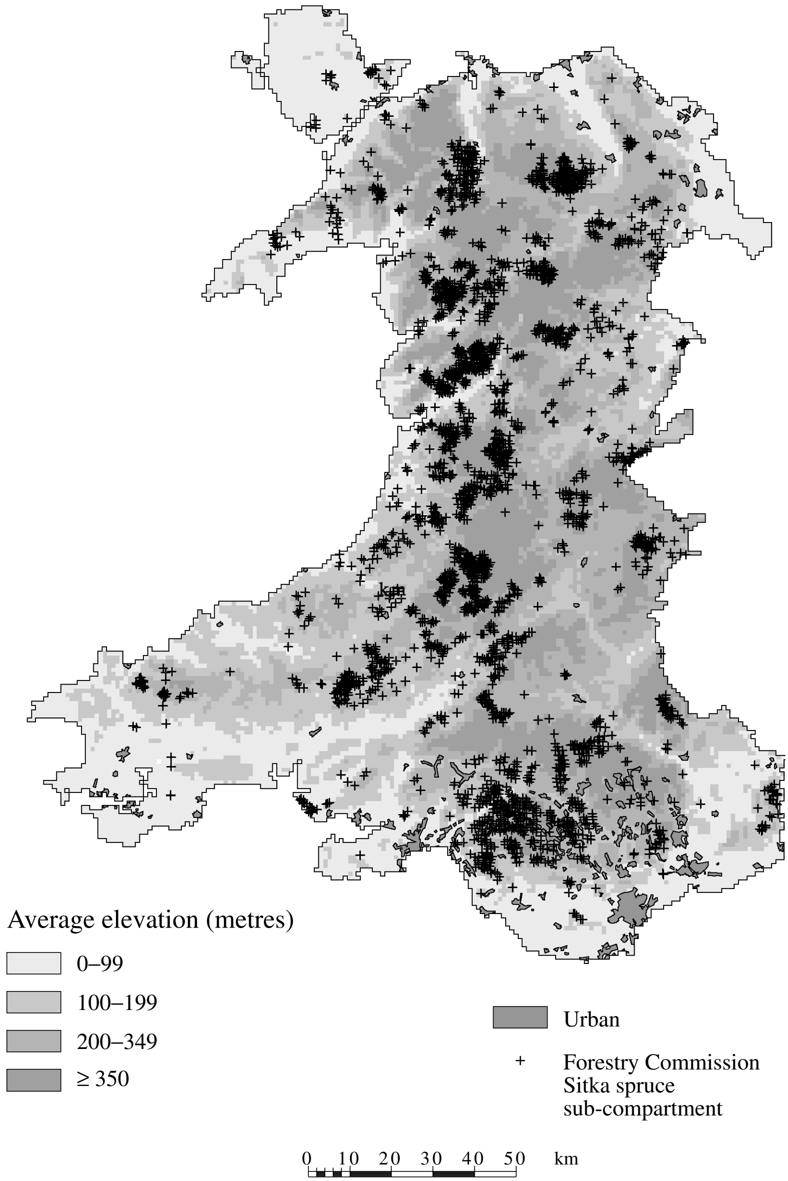

Figure 9.1. Location of Forestry Commission sub-compartments of Sitka spruce in Wales (superimposed upon elevation).

leisure time, increased affluence should raise the unit value of recreation services especially for environmental quality goods such as woodland recreation. Again, assumptions of non-declining values appear justified.

Overall, therefore, our assumptions of constant real values for the timber, carbon sequestration and recreational benefits of woodland seem reasonable and may even turn out to be conservative. Note, however, that from a farm-gate perspective only timber and related subsidies provide direct income streams to the prospective farm forester and therefore the gulf between the market and social value of woodland seems set to persist for the foreseeable future.

Turning to consider the opportunity cost of agriculture, the 1990s have been, with the exception of a few good years just before the middle of the decade, a torrid and depressing period for farming both across the UK and within Wales. Although real agricultural prices have fallen significantly over the 1990s this trend does not represent the full extent of impacts upon farm incomes in Wales. Reductions in real subsidy levels have compounded price falls such that incomes have more than halved in all major sectors over the decade. The magnitude of these losses is so large that the next decade will almost certainly see a continuation of the reduction in farm numbers seen over recent years. Those that survive may well benefit from policy measures intended to address the current problem. However, as recognised by the National Assembly for Wales, a return to general levels of profitability based upon traditional agriculture seems a distant prospect in Wales.

Taking these trends together we can see that from a farm-gate perspective the attractiveness of forestry as an alternative to conventional agriculture does seem to have improved over the course of the 1990s, making our findings appear as conservative estimates of the efficiency gains of conversions. However, this does not mean that this change will be sufficient to induce large-scale change in the near future. For the reasons explained in this chapter, farmers may be risk-averse with respect to changing activities and, while woodland may have improved somewhat in its financial viability, this may not be sufficient to overcome the perceived security offered by traditional agriculture (although this seems the security of a familiar poverty). However, what the trends of the 1990s do clearly suggest is that the superiority of multipurpose woodland over certain sectors of Welsh agriculture, when viewed from a social values perspective, is likely to have grown over the course of the decade. This means that the economic CBA case is stronger than ever for restructuring transfer payments to reflect the non-market values of woodland and so facilitate land use conversions out of the most inefficient areas of Welsh farming. Given this, our social value findings can justifiably be described as conservative estimates of the current value of transferring land out of farming and into multipurpose woodland.