Using a geographic information system to estimate an hedonic price model of the benefits of woodland access

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Summary

The hedonic price method may be used to investigate the effect that the attributes of a product have on its market price. In the case of housing, this methodology has been used to look at the premium that the amenity offered by nearby woodland adds to house prices. The interpretation of the results of these studies is difficult and is the subject of some debate. In particular, it has been argued that the aesthetic benefits of woodland, as a component of landscape, cannot be enumerated using the hedonic approach. This paper adopts a broader approach and uses hedonic pricing to estimate the amenity benefits gained by local residents from access to woodland. To accomplish this a geographic information system is used to improve the data available to the hedonic price model from which estimates of the residential access benefits of woodland are derived.

Introduction

In addition to their commercial value, forests and woodlands are an integral part of the British landscape and an important source of recreational amenity. Unlike more conventional forest outputs such as timber, the benefits associated with landscape and informal recreation cannot conveniently be measured as they do not usually attract a market price. In the past, this has meant that the economic value of any of the so-called non-market goods associated with forests has largely been ignored. Recently, it has become more widely accepted that such non-market values should be taken into account when making decisions likely to lead to changes in environmental quality.

A number of techniques are available to estimate the non-market benefits of woodland. Contingent valuation methods can be used to elicit how much the public is willing to pay for improvements to woodland quality or for improved access. Revealed preference approaches such as the travel-cost method use the cost of visiting woodland as a proxy for the price of access in order to determine demand for recreation and so estimate the magnitude of the recreational benefits.

In this study another revealed preference method, hedonic pricing, is used to investigate the benefits associated with improved access to woodland. The hedonic price method (HPM) relies on the premise that in the absence of financial constraints, the amount which an individual is willing to pay for a particular good is dependent upon the individual attributes of that good. For example, the amount that an individual would be willing to pay for a new house would depend upon the particular structural and locational attributes it possesses.

Thus, house prices may reflect a premium for proximity to significant local amenities such as shopping centres and recreational sites. Woodland is an important recreational amenity, and house buyers may pay a premium for access over and above any premium they pay for the aesthetic qualities of landscape. In this study hedonic pricing is used to investigate the premium that house buyers in and around the New Forest pay for access to woodlands.

Forests and woodlands are abundant in this area and constitute what is probably the most important local recreational amenity. Every house in the area has access to a certain quantity and quality of woodland, and the extent of this access will influence house prices. Indeed, in many cases access to woodland may be a more important factor in house purchase decisions than landscape: land around the New Forest is quite flat and many houses do not enjoy impressive views. Furthermore, most houses are located well outside wooded areas and their owners do not have the benefit of woodland views.

This study uses a geographic information system (GIS) to measure the extent of access to woodland and other amenities from a given house. GIS can measure how far away a house is from forest sites and also estimate the area of those sites. This information was used to construct a forest index measuring the woodland access potential of a given property.

This paper first discusses why it may not be appropriate to use HPM to estimate the landscape benefits associated with woodland. Following this, the method is turned towards the estimation of recreational benefits based on the index of woodland access. Finally, the implications that these results have for forestry planning and management are discussed.

The hedonic price method

The price of a good may be influenced by exogenous supply and demand factors; however, when the market is in equilibrium and consumers have perfect information about the goods available to them, the price that individuals are willing to pay for a particular good may be attributed to the utility that they have for its component attributes. In the case of housing, the amount an individual is willing to pay for a given property will depend upon the utility that he or she has for the various characteristics of that house.

HPM is a well established technique based on consumer theory (Lancaster, 1966), and explains variation in house prices by differences in preferences for the attributes of properties in question. The most common approach to HPM is to model house price directly as a function of the levels of various housing attributes and to assume that the coefficients of the estimated hedonic price function reflect buyers' willingness to pay (WTP) for those attributes. These coefficient values can then be used to derive the marginal WTP (implicit price) for a unit improvement in the level of that attribute. This is achieved by evaluating the partial derivative of the hedonic price function with respect to the attribute, while holding all other variables at their mean values. However, this approach will generally overestimate the benefits provided at the margin by the addition of a further unit of an attribute (Harrison and Rubinfield, 1978; Freeman, 1979).

Using the hedonic price method to value landscape

In an earlier hedonic price study Willis and Garrod (1992) investigated the amenity value of woodland by observing how the prices of houses varied according to differences in the type, composition and age of forests and woodland in their vicinity. The benefits measured here are derived from woodland's duel roles as both a recreational resource and as an important part of the landscape.

Price (1995), however, suggests that it is difficult to estimate a monetary value for landscape features using HPM. While the approach may, in theory, be suitable to estimate the premiums that certain clearly defined housing attributes add to house prices, Price argues that aesthetic preferences for landscape features tend to be too complex to be modelled in this fashion. The basis of this argument is the notion that the aesthetic value of landscape is based on a range of visible features and qualities some of which cannot be measured objectively. In Price's view, any attempt to separate out the effects of different landscape features, such as trees or woodland, and model their effect on house prices is problematic because of the interdependence of a much larger set of features in creating an aesthetically pleasing landscape.

In terms of estimating the hedonic price model, this is a similar problem to that of the multicollinearity often present in data measuring the levels of the various elements which make up a landscape. When various physical features integrate to give an overall aesthetic effect upon which house buyers base their premium for landscape, then it may be very difficult for them to separate the influence of one feature from another. Price's argument suggests that isolating one particular landscape feature and investigating its effect on amenity value will at best produce an estimate which describes the effect of the total landscape on house price rather than the effect of that feature. Thus, hedonic pricing may only be able to value the effect of different levels of landscape quality, and these levels would have to be determined holistically for each property in the sample using the aesthetic judgement of the researcher or an expert in landscape design. Consideration of this argument has led to the current study's concentration on valuing the benefits of woodland access.

Estimation of the hedonic price model

This section documents the procedures that were used to estimate the hedonic price model. The hedonic price function was empirically specified as:

$$Ph_0 = f(\boldsymbol{AM}_i, \boldsymbol{ENV}_i, \boldsymbol{S}_i, \boldsymbol{SE}_i, Y_i) \qquad (1)$$

where:

Ph_0 = the price at which the house is sold
$\boldsymbol{AM}_i$ = a vector of local amenities (accessibility and locational variables, including access to woodland amenity)
$\boldsymbol{ENV}_i$ = a vector of the environmental amenities in the vicinity of the ith property
$\boldsymbol{S}_i$ = a vector of the structural characteristics of the ith property
$\boldsymbol{SE}_i$ = a vector of variables describing the socio-economic characteristics of the Ward containing the ith property
Y_i = the year in which the ith property was purchased

As the main concern of this study was with the estimation of the implicit prices, or marginal costs, of access to woodland amenity, particular attention was paid to variables measuring this attribute. As the coefficients of these variables were to be used for estimating marginal costs, information about their robustness was of critical importance.

After preliminary analysis to explore the relationship between house prices and the set of explanatory variables, it was necessary to investigate the effects of multicollinearity within the data set. In general, multicollinearity in an hedonic price model only presents a serious obstacle if it affects the coefficients of the variables that are the focus of the study. Here, multicollinearity was not considered a problem unless there was evidence that it would interfere with the accurate estimation of the marginal costs of woodland access.

This issue was initially investigated by looking at the sensitivity of the coefficients of the woodland access variables to the omission of other significant explanatory variables. This procedure was designed to give both some indication of the likely effects of any omitted explanatory variables and to explore the possibilities of multicollinarity.

In order to reduce the possibility of multicollinearity within the model, principal component analysis was used to identify the independent sources of variation within the data. Identification of principal components enabled more careful variable selection to be undertaken, with one variable from each important explanatory component initially included in the model. Problems of multicollinearity were investigated further by estimating the variance inflationary factor. This showed the extent to which a given explanatory variable was correlated with the woodland amenity variables and also measured the extent to which the final model deviated from the ideal situation of no multicolinearity (see Maddala, 1992).

Potential heteroscedasticity in the model was explored through residual analysis. Plotting residuals against both dependent and independent variables suggested no obvious trends, and the Park test (see Maddala, 1992) was used to confirm these findings. Use of this test on a variety of functional forms provided no evidence to suggest the presence of heteroscedasticity.

Data collection

The key source of data for this study was detailed information relating to 872 mortgage acceptances in and around Southampton and New Forest over the period 1990–92, as abstracted from the records of one of Britain's largest building societies. This provided data on the purchase price and on the structural attributes of the property. One potentially important explanatory variable was not available from the data set; this was plot size, a measure of the amount of land associated with the house. In the absence of such data, the only information on the likely plot size is incorporated into other variables that might be correlated with land area (e.g. whether or not the house is detached). However, as plot size can vary widely across house types, lack of any accurate measurement of plot size is a serious shortcoming of the data set.

The socio-economic characteristics of an area are also important in determining the demand for houses. Socio-economic data taken at enumeration district level from the 1991 Population Census was used to provide a detailed profile of the neighbourhood containing those properties included in the data set.

The most novel aspect of this study was the way in which variables measuring environmental and service attributes were derived. Previous research had either measured the level of these variables manually from maps (e.g. Garrod and Willis, 1992; Powe *et al.*, 1995) or from observation by eye (Morales, 1980). Here Bartholomew maps were digitized on to a computerized data file and the GIS software package ARC/INFO used to generate accurate data on the level of environmental and service variables.

GIS provides clear advantages over manual methods of data collection. Both methods require considerable preparation in the first instance. Using the manual approach, each house has first to be located on a map and then all required variables must be measured individually. If GIS is used all of the necessary maps have to be digitized before any variables can be derived. Once the spatial data is in a usable format, however, it is a simple task for the GIS package to derive spatial variables for each house. Both approaches can be time intensive, but the GIS approach gives the most flexibility in measuring and modifying variables. With the manual method the variable set must be decided upon before data collection and no modification is possible without relocating each individual house; the GIS method facilitates the exploration of explanatory variables without the additional effort required with the manual method. Furthermore, the speed and accuracy with which the variables can be generated using GIS, permits a greater variety of spatial variables to be generated.

The main environmental amenity considered here is access to woodland. It was hypothesized that the location of a house within easy driving distance of the New Forest would have an impact on its value, even if it was located in an urban area such as Southampton. With this in mind, the distance to the New Forest Park was calculated for each house: a negative distance from the park boundary was recorded for those houses located within the park. With the New Forest Park providing attractive healthland as well as woodland, any implicit price estimated would include both of these aspects of the landscape. Access to woodland was also measured by calculating the distance to the nearest woodland with either a picnic area or car park.

The amenity aspects of living in close proximity to woodland were also considered, and a dichotomous variable for location within the New Forest Park was generated. Proximity to woodland was also modelled by a dichotomous variable indicating location of the house within 500 m of woodland, and by a variable giving distance from the nearest woodland.

Although the variables mentioned above measure access to both local amenity and recreational opportunities, significant correlations were found between some of these focus variables. In order to incorporate the various amenity aspects of woodland into one variable, a forest access index with the following form was estimated:

$$\text{forest access index} = \Sigma_i\ (\text{area}_i/\text{distance}_i^2) \quad (2)$$

This index was calculated for each house sampled, and each area of woodland digitized within the study region was included in the index. As the magnitude of the index will increase with both proximity and area of woodland, it is sensitive both to woodland in close proximity to the house and to larger areas of woodland within easy driving distance. By squaring the distance between the house and the woodland a higher weight has been given to distance from woodland than to area. Although details of woodland composition were not incorporated in the index, the mix of species and ages does not vary greatly across the area, and this should mean that the index is still useful for the valuation of the majority of woodland.

Other environmental amenities and disamenities were also considered in the model. In terms of recreational amenity the distance from each house to the sea front was measured, and dichotomous variables were generated both for location within 500 m of the sea and location within 200 m of a river. Environmental disamenities may have a number of causes. Roads and railways can be both noisy and spoil the view, and industrial or business areas can lead to congestion at peak times of the day. It was assumed that any negative effects on house price would increase with closer proximity of the disamenity. In view of this a number of variables were defined as possible measures of environmental disamenity.

A list of variables available for inclusion in the hedonic price model is given in Table 1.

Table 1: List of explanatory variables available to the model

1. Woodland Variables
Distance to the nearest woodland
Distance to the New Forest Park
Location within 500 m of woodland (0–1)
Location within the New Forest Park (0–1)
Woodland Index
2. Other amenity/disamenity characteristics of the property
Distance to the sea
Location within 500 m of the sea (0–1)
Location within 200 m of a river (0–1)
Distance to the nearest large urban area (area >10 million m^2) (0–1)
Location within a large urban area (area >10 million m^2)
Location within 500 m of an oil refinery (0–1)
Location with 100 m of a railway line (0–1)
Location within 100 m of an A road or motorway (0–1)
3. Structural characteristics of the property
Floor area
Number of bathrooms
Number of bedrooms
Detached (0–1)
Semi (0–1)
Terraced (0–1)
Garage (0–1)
Full central heating (0–1)
Age
4. 1991 Census enumeration district-level socio-economic variables
Proportion of children (age <18)
Proportion of families with no car
Cars per person
Proportion of professionals
Proportion of unskilled
Proportion of retired
Rate of male unemployment
Rate of unemployment
5. Other variables
1990 Purchase (0–1)
1991 Purchase (0–1)
Distance to nearest A road or motorway

Empirical results

The issues surrounding the choice of an appropriate functional form for the hedonic price function has been summarized by Garrod and Allanson (1991), with the conclusion that a linear Box–Cox functional form is the most appropriate for this form of analysis. A search across the parameters of the linear Box–Cox functional form was undertaken to find the best fitting specification for this model.

This was achieved by taking the natural log of both the dependent variable and the forest index while leaving the remainder of variables untransformed: Table 2 shows the coefficient values associated with the 'best' model for this particular functional form. Within the model all of the explanatory variables were significant at the 95 per cent level, had the expected signs, and a respectably high goodness of fit was achieved.

Further analysis showed that there was a high correlation between the dichotomous variable indicating location in a large urban area, and variables measuring unemployment and car ownership. The variable measuring the proportion of children in the area of the house had a negative coefficient, reflecting the fact that areas with a higher proportion of young families tended to be composed of houses of lower value.

In order to test the robustness of the model, each variable was removed in sequence and the change in the coefficient value of the woodland index noted. The model was judged to be robust for the estimation of the implicit price of woodland access, as the woodland access index coefficient always remained within one standard error with the omission of the other explanatory variables. Special care should be taken when interpreting the coefficients of the structural variables as there was evidence of multicollinearity between these variables.

As the estimated hedonic price model was non-linear, the marginal price of any characteristic was dependent on the level at which that characteristic was present. With the exception of the woodland access index, the model is of the log-linear form. The marginal or implicit price of a given characteristic under this specification can be estimated as the product of the regression coefficient and mean house price. For illustrative purposes the marginal value of a unit increase in a characteristic with respect to mean house price was estimated: these values are given on the right-hand-side of Table 2.

As a test of comparative validity the implicit price associated with the 1990 purchase dichotomous variable was compared with the house price trends over the period for the south-west of England (Department of Environment, 1994). The data was collected over the years 1990–92, and between 1990 and 1991 there was a fall in average dwelling price of £4695 which is com-

Table 2: Hedonic price model

	Coefficient	*t*-ratio	Implicit price* (£1991)
Intercept	10.27	330.3	
Log (Woodland Index)	0.0461	7.8	
Proportion of children (aged <18)	−0.0076	−7.3	−482
Within large urban area (0–1)	−0.0736	−4.9	−4 672
Floor area	0.0057	30.0	362
Detached house (0–1)	0.3307	18.4	20 993
Semi-detached house (0–1)	0.1115	7.0	7 078
Age of property	−0.0004	−2.4	−25
Full central heating (0–1)	0.1003	6.6	6 367
1990 purchase (0–1)	0.1073	3.3	6 812
Garage (0–1)	0.0736	5.1	4 672

R^2 = 0.81, F-value = 362.8, Degrees of freedom = 854.

Note: Dependent value = Log (house price)

*This figure represents the implicit price for a unit increase in a characteristic from the mean value.

parable to £6812 given by the final model. Furthermore, between 1991 and 1992 the average dwelling price in the south-west fell by rather less (£1483), providing some explanation of why the 1991 purchase variable was not significant at the 90 level.

The functional form of the relationship between house price and the woodland index is double-log, and the marginal price for this specification was estimated using the following expression:

Marginal price of woodland = (regression coefficient/access index)* house price

As the functional relationship between house price and the woodland access index was non-linear, the marginal price of woodland access at any time was not constant but rather a function of the current level of access. The expression above illustrates the diminishing marginal utility of woodland access: for example access to additional woodland will add more to house prices in areas with poorer woodland access than in areas, such as those near the New Forest Park, which have better woodland access.

The sample mean of the woodland access index was 54: this was heavily skewed upwards by a few extreme values, and the median value of 5.4 more closely represented the average house. When it is considered that planting an additional hectare of woodland within 100 m of a house would increase its forest index by one unit, the size of both median and mean index values emphasizes the high concentration of woodland in the study region.

As an illustration, an estimate of marginal price was calculated for the average house with the average woodland access index. For a unit increase or decrease in the forest access index the hedonic model estimated that there would be a £543 change in house price. This figure represents the marginal value of the change in woodland access with all other attributes of the house unchanged.

Application to woodland planning and management

Hedonic pricing can be used to estimate the change in the amenity benefits derived by local house owners from a marginal increase or decrease in access to woodland in a given area. The welfare economic implications of such marginal changes may be relevant to woodland planning and management.

The benefit estimates generated from the hedonic price model represent the amenity benefit associated both with living in close proximity to woodland and within easy reach of larger areas of woodland. Aggregate estimates of woodland access benefits were obtained by aggregating the estimated marginal benefits across all households in the study region.

The hedonic price model may be used to investigate how changes in the provision of woodland (and therefore woodland access) may affect levels of social welfare as measured by woodland access benefits. As long as the change in provision is relatively small the model should be robust enough to be used to predict the effect on marginal benefits. Changes of up to 100 ha were used for marginal analysis, representing less than 5 per cent of the area of woodland in and around the New Forest Park.

The impacts of felling existing areas of woodland (i.e. L1, L2, L3, L4) were first considered. In addition, the effects of new planting on four unwooded sites each of 100 ha (i.e. G1, G2, G3, G4) were also investigated. These areas (illustrated in Figure 1) were chosen to highlight the strengths and weaknesses of this approach to benefit estimation. With the exception of L4, each of the areas chosen was close to the centre of the study region. This ensured that any errors caused by ignoring the effects of woodland outside of the study region (which are neglected in the woodland access index) would be kept to a minimum.

The woodland access index was re-calculated to measure the effects on access associated with felling each of the four existing woodland areas and with planting new woodlands in each of the four unwooded areas. The changes in residential access benefits were estimated across all households in each urban centre and then aggregated across the study region to give estimates of the total changes in marginal benefits which would occur for each change in woodland area.

The woodland area with the lowest residential access value (L1) is located in the centre of the New Forest (see Figure 1). This area has a

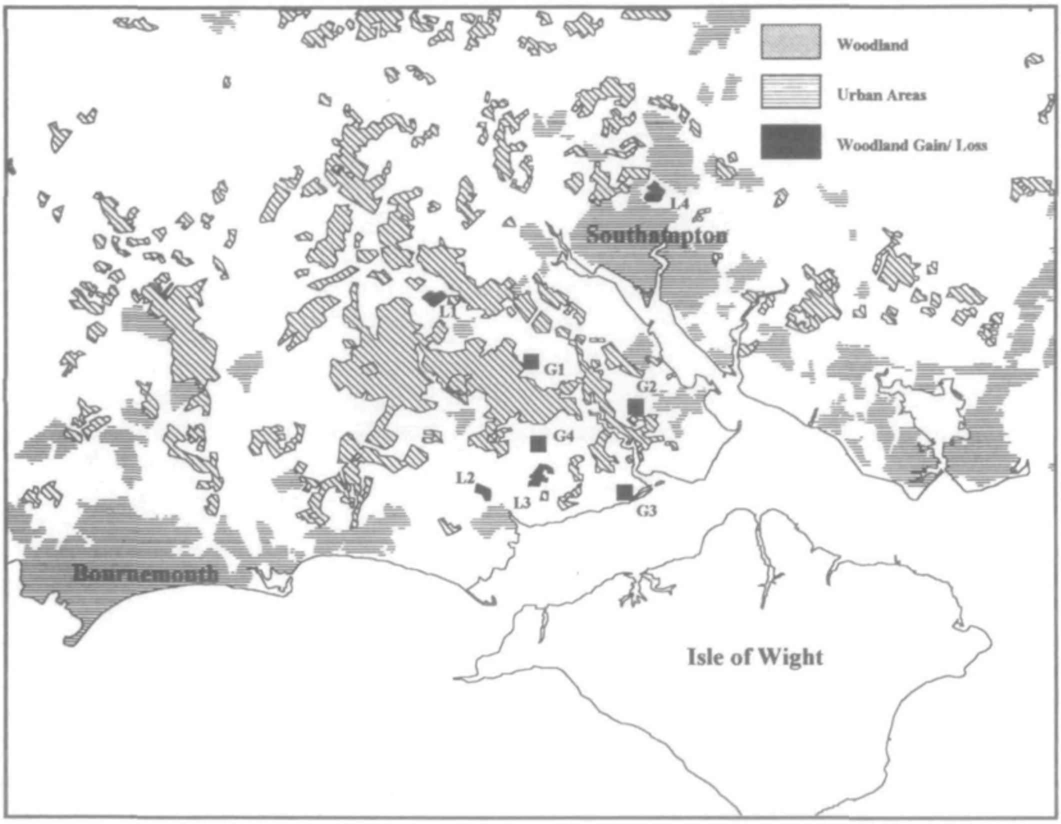

Figure 1. Areas used in Woodland Planning Scenarios

high concentration of woodland, so the marginal cost of losing 97 ha would be relatively small. The highest marginal cost of felling was observed for L4, an area of 105 ha located on the edge of Eastleigh and Southampton. This proximity to two important population centres explained the high cost at the margin of losing this forest. Felling each of the remaining two areas of hypothetical woodland loss was found to result in similar losses to local residents: while L2 (63 ha) is clearly much smaller than L3 (103 ha), it is closer to urban populations and thus of similar importance in terms of access.

Although area G1 is of similar size and located close to the existing area of woodland L1, it was found to have a higher access value. This can be explained by the fact that it is closer to population centres and is in an area with a lower concentration of woodland. Parallels can also be drawn between areas L4 and G2, but G2 is on the edge of much smaller urban areas. The slightly higher value of G2 compared with L1 can be explained by the lower concentration of woodland around the former.

G4 was chosen to illustrate the importance of

Table 3: Loss in residential access benefits associated with a reduction in woodland

	Area (ha)	Total marginal benefits losts through felling (£)	Present value of the annual opportunity cost (£)
L1	97	927 393	8 523
L2	63	1 100 661	10 115
L3	103	1 046 742	9 620
L4	105	25 330 821	232 802

alternative land uses when determining the value of woodland. Using the hedonic price method, the total residential access value of planting woodland on that 100 ha site was estimated at approximately £1 million, but, as this area was previously heathland, the amenity value of the existing land use has to be subtracted from this value to obtain a more representative picture of the change in benefit. Where the existing land use provides little amenity value, this difficulty can be discounted, but for the G4 scenario the existing amenity benefits may be considerable. Furthermore, where the existing land use may generate large non-use benefits, for example wetlands, the additional benefits of planting woodland may be less than the benefits foregone in the change of use.

Table 4: Residential access benefits associated with woodland gain

	Area (ha)	Total marginal benefits gained from planting (£)	Present value of the annual opportunity cost (£)
G1	100	1 608 428	14 782
G2	100	2 738 584	25 169
G3	100	960 551	8 828
G4	100	1 022 507	9 397

The access benefits in Tables 3 and 4 do not appear to be unreasonable. Although the sums involved are large, they represent only a small proportion of housing land prices in the south-east. For a 100 ha woodland, with £1 million of residential access benefits, the residential benefits per hectare only represent 3 per cent of the average price per hectare of private sector housing land in 1991 (Department of the Environment, 1992).

The benefit estimates given in the third column of Table 3 represent the present value of the premiums that have been paid by households for access to the areas L1–L4; the corresponding column in Table 4 reports the estimated additional house price premiums resulting from planting areas G1–G4.

If house buyers could be sure that additional woodland would be available for access indefinitely, then the marginal access benefits of G1–G4 given in Table 4 would represent the total flow of marginal benefits over the remaining lives of houses located within the study region. This assumption seems unrealistic, and it was considered more appropriate to look at the access benefits generated over a specific time period, say the length of a typical commercial forest rotation.

Consider the scenario where the rotation is for 60 years, with felling occurring at the end of this period and the land returning to its original use. The value of access to the woodland for residents is assumed to remain constant over this period, with successive house owners regaining this value upon the sale of their houses. One way of measuring the benefits received by the house owners over the remaining life of the woodland would be to estimate the opportunity cost of paying a premium on house price for woodland access. This opportunity cost would measure the benefits forgone by not investing that capital in some other way.

The price paid for access to the existing woodland areas L1–L4 by households in the study region is given by the total marginal benefit measures in the third column of Table 3. The opportunity cost of paying this premium for woodland access was based on the assumption that, over the 60-year rotation, house owners could earn the equivalent of an average Treasury Bill yield, adjusted for inflation, on this investment. These flows were discounted over the whole period using the 6 per cent discount rate adopted by Forest Enterprise for appraising land acquisitions and management decisions.

The discounted total yield on investment was divided by 60 to give the present value of the annual opportunity cost (see Table 3). The effects of new planting (e.g. G1–G4) were investigated in a similar way and the results are shown in Table 4. Annual changes in benefit could be as little as £85 ha^{-1} in areas with existing good woodland access, rising to over £2300 ha^{-1} in areas with much poorer access.

Conclusions and discussion

It has been argued that it may sometimes be inappropriate to use HPM to measure the effects that individual components of landscape have on the prices of nearby houses (Price, 1995). Even when this is the case, the methodology can be used to estimate the premiums added to the price of a house by its location in a particular type of landscape or by the superior access it offers to desirable environmental amenities.

In this paper, HPM has been used to estimate the benefits that local residents gain from access to woodland in the New Forest area. Residential access to woodland was measured using a woodland access index calculated using spatial information generated by a GIS. The functional form of the estimated hedonic price model meant that only the marginal benefits associated with access to additional areas of woodland could be calculated (or conversely the benefits lost if existing woodland was felled).

The major benefit of using a GIS in this context was that it permitted the location of existing or proposed areas of woodland, in relation to centres of population, to be fully taken into account in the calculation of gross marginal changes in access benefits. Thus, the effects of a number of scenarios relating to the planting and felling of specific areas of woodland could be investigated. The subsequent analysis revealed that areas of woodland located close to urban centres, where the provision of amenity woodland was otherwise poor, generated substantial access benefits for the adjacent population. This finding has important consequences for initiatives, such as the Forestry Commission's Community Woodland Supplement (CWS), which seek to improve the provision of woodland close to urban populations.

In addition to the existing establishment grant, the CWS offers a once and for all supplement of £950 ha^{-1} to landowners who are willing to give land over to the scheme. This can then be supplemented for farmers by annual grants from the Farm Woodland Premium Scheme, but these are only payable for a limited time and reach a maximum of £250 ha^{-1} for prime arable land. The CWS has had limited success and by January 1995 only 4099 ha of land had been entered into the scheme (Bateman *et al.*, 1995).

This study implies that the amenity benefits of planting woodland close to urban areas where there is currently low access to woodland are likely to be very large. This suggests that higher levels of payment may be worthwhile if they encourage more farmers to put land into the scheme.

Before taking this speculation any further, it must be emphasized that the benefit estimates reported here apply only to the study region and are conditional on the specification of the model. Applying them to other areas in the UK without further analysis would be inappropriate. Further work needs to be done before it can be shown in what circumstances, if any, such benefit transfers are appropriate (see Garrod and Willis, 1994). Like all applications of environmental valuation techniques, hedonic price studies are very much influenced by their context, and the benefit estimates for woodland access reported here, will be affected by the general high quality and high provision of woodland that exists in and around the New Forest. Other areas with a lesser provision of woodland of lower quality may well exhibit much smaller marginal benefits for woodland access.

Even so, studies like this can still help inform general forest management by demonstrating the effects that various planting and felling decisions could have on amenity values. A more refined model, incorporating information about the characteristics of woodland, would be more useful but could prove difficult to construct. Even so, the study reported in this paper represents a step forward, in that its use of GIS technology allows more accurate definition of access variables and permits subsequent aggregation of benefits to be more precise.

Acknowledgements

We are grateful to the Nationwide Building Society for the use of data on individual house purchases and to an anonymous referee for his or her comments.

References

Bateman, I., Garrod, G.D., Diamond, E. and Langford, I. 1995 An economic appraisal of the viability of the Community Woodland Scheme. *Working Paper* No 15, Centre for Rural Economy, University of Newcastle upon Tyne.

Department of Environment 1992 Housing and Construction Statistics. HMSO, London.

Department of Environment 1994 *Housing and Construction Statistics*. HMSO, London.

Freeman, A.M. 1979 Hedonic prices, property values and measuring environmental benefits. *Scand. J. Econ.* 81, 154–173.

Garrod, G.D. and Allanson, P.F. 1991 The choice of functional forms for hedonic price functions. *Countryside Change Initiative, Working Paper* No 23, Department of Agricultural Economics and Food Marketing, University of Newcastle upon Tyne.

Garrod, G.D. and Willis, K.G. 1992 Valuing goods' characteristics: an application of the hedonic price method to environmental attributes. *J. Env. Manage.* 34, 59–76.

Garrod, G.D. and Willis, K.G. 1994 The transferability of environmental benefits: a review of recent research in water resources management. *Working Paper* No 12, Centre for Rural Economy, University of Newcastle upon Tyne.

Harrison, D. and Rubinfield, D.L. 1978 Hedonic housing prices and the demand for clean air. *J. Env. Econ. Manage.* 5, 81–102.

Lancaster, K.J. 1966 A new approach to consumer theory. *J. Pol. Econ.* **74**, 132–157.

Maddala, G.S. 1992 *Introduction to Econometrics*, 2nd Edn. Macmillan Publishing Company, New York.

Morales, D.J. 1980 The contribution of trees to residential property value. *J. Arboric.* 6, 305–308.

Powe, N.A., Garrod, G.D. and Willis, K.G. 1995 Valuation of urban amenities using an hedonic price model. *J. Prop. Res.* 12, 137–147.

Price, C. 1995 The pros and cons of alternative valuation methods. In *Environmental Valuation New Perspectives*. K.G. Willis and J.T. Corkindale (eds). CAB International, Wallingford.

Willis, K.G. and Garrod, G.D. 1992 Amenity value of forests in Great Britain and its impact on the internal rate of return from forestry. *Forestry* 65, 331–346.

Received 17 August 1995