Modelling demand for recreation in English woodlands

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Summary

Previous models to describe the desire for recreation at English forest sites have tended to use fairly crude and regional measures. This study demonstrates how forest recreation demand can be modelled quite locally and using just site-specific characteristics or simple measures of available population as input. A field survey of 33 Forestry Commission sites was made in order to collect data on attractive features at each site. These data were supplemented with variables to indicate the availability of competing woodlands and population totals within set travel distances. The outputs were simple but robust stand-alone functions to describe visits across many sites.

Introduction

The impetus to create amenity woodlands in the UK has never been stronger. This follows years of increasing recognition of the many unpriced amenities that forests can provide, in addition to their market timber value (Matthews, 1994; Selman, 1997). The importance of recreation has been the subject of particular scrutiny, as demonstrated in an extensive body of relevant research by Willis and Benson (1989), Willis (1991), Willis and Garrod (1991, 1992), Garrod and Willis (1993) and Bateman *et al.* (1996). It is even arguable, at least in lowland Britain, that consideration of the possible ecological, aesthetic and recreational benefits of forests now tends to outweigh their commercial uses (see discussions by Pitt, 1992; Innes, 1993; Jones, 1994; Matthews, 1994; Selman, 1997). A change in bias towards multi-purpose forestry is also demonstrated by the establishment of a new 'National Forest' in the English Midlands (Countryside Commission, 1993), initiatives to foster a series of Community Forests throughout England and Wales, and in discussion documents issued jointly by the Forestry Commission and Countryside Commission (FC/CC, 1996, 1997). And, although support for multi-purpose forestry is not universal (see Bobiec *et al.*, 2000; Calder *et al.*, 2000), it seems likely that the push to plant amenity woodlands will continue to be strong in the near future.

However, it is noteworthy that decisions on where to encourage amenity woodland creation have largely been made at a regional scale, using somewhat crude assessments. For instance, Selman (1997) assessed the efficacy of multipurpose UK forestry policies using just six regions for the whole of Great Britain. Similarly, the FC/CC 1996 discussion document mapped several factors relevant to forest creation – including the ratio of population to current woodland cover, incidence of derelict land, agricultural quality and percentage tree cover – all on a county basis. These four variables were overlaid and a summary, five-category map produced to indicate the opportunity for new woodland sites. That this map was only preliminary the report admitted at the time, and moreover in their follow-up paper, the FC/CC reported a general response that this approach 'needs to be adapted and refined at the regional or sub-regional level. This would involve looking at a greater level of detail and incorporating a considerably wider range of information, potentially using GIS [geographic information systems]' (FC/CC, 1997, p. 22)

A GIS is a specialized set of computer programs for the storage and processing of spatially referenced data. We used the ARC/INFO package in this research (ESRI, 1996), which made manipulation of the many digital data sources both tenable and practical. Using a GIS made it realistic to identify amenity woodland needs much more locally. In particular, this study demonstrates how recreation demand at a specific location can be modelled using just site characteristics as input, or combining these with simple indicators of local population access. Note that we use the word 'demand' in the sense of want or desire, rather than as an aspect of economics, forceful request or other meaning. The simplicity of the models that will be presented here is one of their main merits. Previous and similar work to describe recreation demand in Britain (see Willis, 1991; Willis and Garrod, 1991, 1992; Bateman *et al.*, 1996) tended to concentrate on measuring the distance decay relationship between the travel costs for potential visitors and sites of interest. Considerable scepticism has been expressed about the validity of these economics-based assessments (Grove-White, 1999). Moreover, all of these studies depended upon relatively expensive and time-consuming collection and processing of visitor survey information at each site of interest. The research presented here, however, shows how less complex and yet still fairly robust modelling might be undertaken to calculate and perhaps even predict site visits at unsurveyed woodlands.

Several datasets of relevance were collected and are described at length. A field survey of 33 woodlands for which vehicle counts were available was undertaken in order to collect data on amenity features at these locations. These details were supplemented by calculation of two indices to represent the availability of competing woodland, along with some basic measures of local population access. Initially, a number of models to predict visit numbers at multiple locations were generated from the site-specific and competing woodland variables only. These functions have the advantage of being easy to implement, and are relatively successful. When measures of market population around each woodland were subsequently introduced, the resulting models yielded still more effective descriptions of recreation usage.

Data

Several types of information were needed in this analysis. Actual party arrivals statistics at existing woodlands were used as a starting point. Detailed inventories of amenity features at each location were compiled, and the extent of competing forest area along with some basic measures of possible market population estimated.

Vehicle counts at 33 English woodlands

Traffic count data at 33 English Forestry Commission (FC) sites form the basis for this work, and were taken from two sources. Guest and Simpson (1994) presented results for a vehicle-monitoring scheme at 28 locations in northern and eastern England during the period from 21 June to just prior to Christmas, 1993. Unfortunately, the authors described numerous problems with the counter devices that could be expected to introduce errors in the data, including a high incidence of batteries failing, and multiple recordings for a single vehicle. Nevertheless, by examining seasonal trends and weekday/weekend use patterns, Guest and Simpson felt able to adjust their raw data to produce annual estimates of vehicle arrivals for each site. These researchers also expected problems with the traffic counters to be resolved over time, making counts from later dates more reliable – a perception echoed informally by other FC staff. A second source of vehicle numbers at 15 English woodlands, in 1996, was provided by the FC office in Edinburgh. Ten sites occurred in both the 1993 and 1996 datasets (listed together in Table 1). In such cases, because of the general

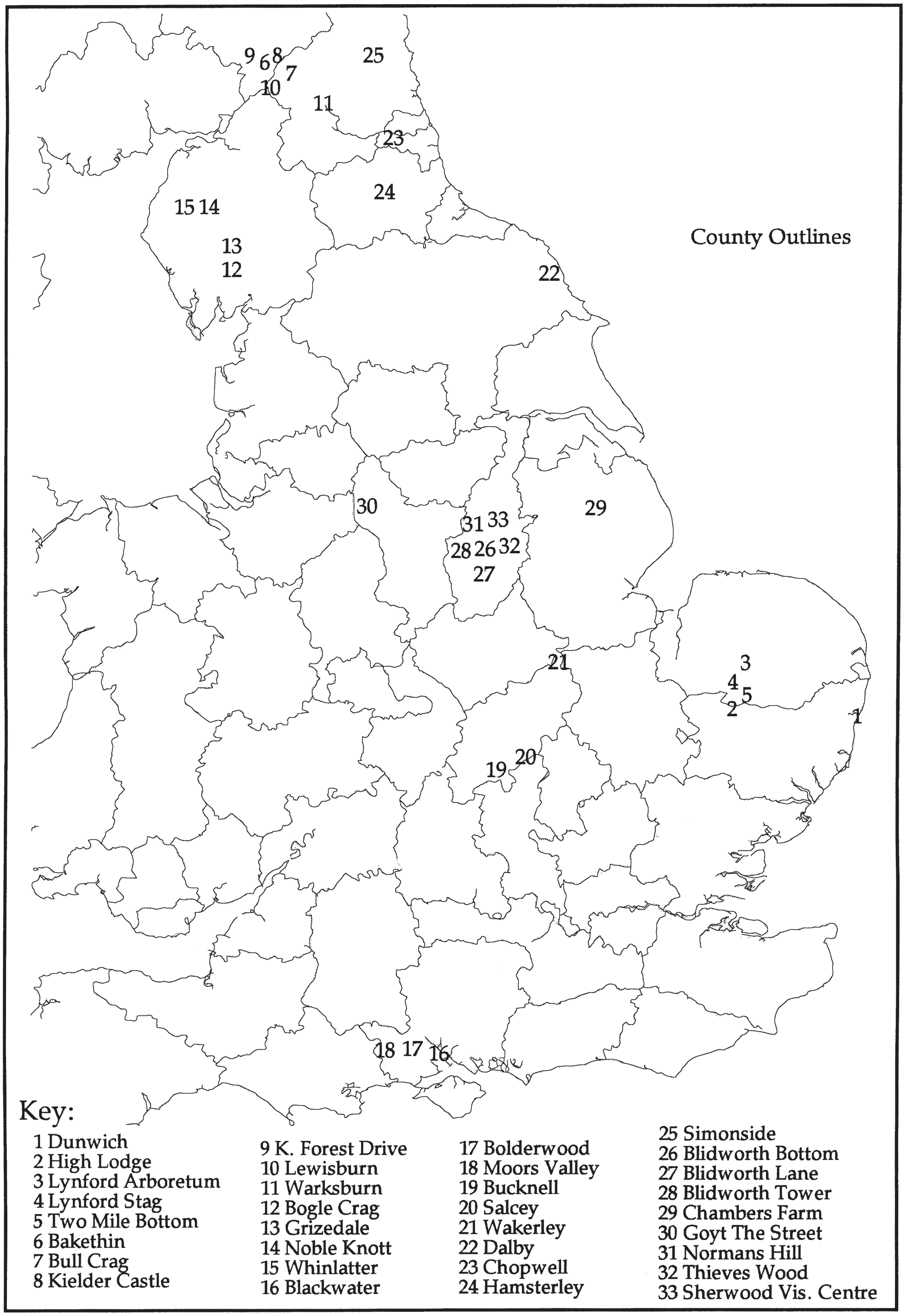

Figure 1. Study sites.

Table 1: Estimated annual vehicle counts at Forestry Commission sites in 1996 and 1993, with comments from Guest and Simpson (1994)

Forest District	Name	1996	1993	1993 Comments
East Anglia	Dunwich		18980	Estimate from weeks working
	High Lodge		14940	Estimate from weeks working
	Lynford Arboretum	7101	6346	Estimate by adding week data
	Lynford Stag		42010	Estimate by adding week data
	Two Mile Bottom		22936	Estimate by adding week data
Kielder	Bakethin		5379	Incorrect week data altered
	Bull Crag	9533	–	–
	Castle	24243	21896	Estimate by adding week data
	Forest Drive	31641	–	–
	Lewisburn		8746	Estimate by adding week data
	Warksburn	3794	4900	Estimate by adding week data
Lakes	Bogle Crag		14924	Estimate from weeks working
	Grizedale Main/Hall*		85181	Estimate by adding in month data
	Noble Knott	7543	12054	Estimate from weeks working
	Whinlatter Centre	55797	69283	Estimate by adding in month data and from weeks working
New Forest	Blackwater	39338		
	Bolderwood	58628		
Dorset	Moors Valley	165552		
Northants	Bucknell		21360	Estimate from weeks working
	Salcey		77650	Estimate from weeks working
	Wakerley		51490	Estimate from weeks working
N. York Moors	Dalby†	130151	143626	Estimate by adding month data
Rothbury	Chopwell	42298	39316	Estimate from weeks working
	Hamsterley	76796	17724	Estimate from weeks working; only ran for the last months of year and likely an underestimate
	Simonside	12430	12688	Estimate from weeks working
Sherwood/Lincs	Blidworth Bottom‡		54547	Estimate from weeks working
	Blidworth Lane‡		52754	Estimate from weeks working
	Blidworth Tower‡		37596	Estimate from weeks working
	Chambers Farm		23605	Estimate from weeks working
	Goyt/The Street		84279	Estimate from weeks working; likely an overestimate due to seasonal reading
	Normans Hill§		30936	Estimate from weeks working
	Thieves Wood§		72276	Estimate from weeks working
	Visitor Centre		38919	Estimate from weeks working

* In the original Guest and Simpson report Grizedale Main and Grizedale Hall are listed separately. However, entrances to the two car parks are <100 m apart, and signs at Grizedale Main inform visitors that overflow parking is available at the Hall. As a result, in this analysis, the two sites are treated as one.

† Dalby Bickley and Pexton are the two ends of a long forest drive. These were treated separately in the Guest and Simpson data, but as one site (which seems proper) in the 1996 FC counts.

‡ The three Blidworth sites are all access points for the same small woodland, and share a common set of marked walks.

§ Normans Hill and Thieves Wood are quite close together (entrances are <700 m apart). Arguably, like the Blidworth or Grizedale sites, they could be treated as one.

Table 2: Site attributes recorded in field survey or calculated using GIS

	Short names
Presence/absence variables	
Cafe/hot food snack bar	CAFE
Bicycle hire	BIKEHIRE
Special bicycle routes or areas	CYCLEAREA
Facilities for disabled persons	HANDICAP
Ice cream/snack food van	ICEVAN
Information centre	INFOCEN
Lake	LAKE
In a national park	NATPARK
Notice board	NOTICEB
Orienteering course	ORIENT
Playground(s)	PLAYGR
River	RIVER
Signposted	SIGN
Toilets	LAV
Viewpoints	VIEWS
Numeric items	
Percentage broadleaf trees a visitor is likely to see	BROADPC
Car park capacity	CARCAP
Distance to the nearest main (B class or better) road	KM2R
Number of marked trails	NOWALK
Charge for pay parking/access to forest drives (if any)	PARKFEE
Total distance of marked trails	WALKKM
Calculated using GIS	
Distance-weighted index of 'broadly' defined available woodland	WBROAD
Distance-weighted index of 'strictly' defined available woodland	WSTRICT
Distance-weighted population score	PSCORE
Population within 120 min	PW120

preference for information from later dates, the 1996 vehicle count was taken as the 'official' value.

Site characteristics

The combined 1993/1996 data gave 33 FC locations, shown in Figure 1, as potential sites in a study of regional forest-based recreation. These locations are quite variable with regard to species predominance, level of facilities, and overall visitor numbers. A field survey of the 33 woodlands was made in the spring of 1997 to collect information on factors thought likely to influence visitor numbers; a partial listing of the variables is shown in Table 2. In addition to these attributes, nearly all locations featured a dedicated parking area, marked walks and picnic tables. Dog-walking was allowed virtually everywhere.

Two of the items in Table 2 are particularly subjective: car park capacity and percentage broadleaved species. For larger or busy sites, local FC staff could usually give indication of the maximum number of vehicles able to fit in the car park at any one time, but corresponding estimates for smaller woodlands were more difficult to obtain. To ensure consistency between sites, it was therefore decided to measure the dedicated car parking area at each location, and divide this by a standard, assumed vehicle space (~27 m^2). However, the estimation was complicated by difficulties in accurately measuring car park size, and the likelihood of vehicles stopping on verges and other non-dedicated areas. The values that entered this analysis must therefore be considered as relative rather than absolute.

Percentage of deciduous trees (BROADPC in Table 2) seemed like a valuable predictor of site usage, as some studies (Hanley and Ruffell, 1993; Garrod and Willis, 1993) report strong public preferences for broadleaves over conifers. One possible source for this indicator was the Forestry Commission subcompartment database, which specifies accurately the exact percentage of deciduous cover at each of their sites. However, research by Bateman (1996) strongly suggested that most forest visitors confine themselves to an area only 100–200 m from the car park. In consequence, we focused not on the absolute measure of broadleaf presence at any location, but rather which tree types a typical visitor would see. The variable could therefore only be calculated somewhat subjectively, as it was up to the field surveyor to assess which areas at a site most people were likely to visit, and what the typical composition of the tree species around those areas was.

An additional measure, NOFACS ('number of facilities'), intended as a summary item to describe the overall level of services at each site, was also considered. NOFACS was calculated by giving each woodland a score for the number of features it had that would be expected to raise visitor counts: one point per amenity. Thus, for example, Chopwell Forest has parking, a special cyclists' area, a notice board, marked walks and is signposted from the nearest main road – yielding a NOFACS score of 5. The appeal of this variable was that it might be used in lieu of individual factors, to circumvent problems of multicollinearity in trying to incorporate many site traits. However, NOFACS was not a significant anticipator of visits. This may be due to the crude way in which it was devised: e.g. it allowed no explicit weighting for less or more attractive features, such as a lake versus an information centre. At the same time, the frequency at which certain types of features usually co-exist, e.g. bicycle hire and cafe facilities usually coincide with a visitors' centre and toilets, implies that some indicators will tend to serve as surrogates for others, anyway.

Simple measures of market access

Two types of simple indicator of local population access were calculated. Both relied on the same core datasets: population distribution and the available road network. An interpolated surface, depicting the number of persons in 200×200 m^2 cells at the time of the last (1991) national census, was available from the MIDAS service at Manchester University. For practical reasons and especially to reduce the size of this layer, it was resampled to yield the total persons in 500×500 m^2 squares. Digital map details of the extent and quality of the available road network were extracted from the 1 : 250 000 scale Bartholomew database (Harper Collins, 1998). A lengthy calibration exercise was undertaken (reported in Bateman *et al.*, 1995) to find realistic travel times and typical velocities for each class of road (which ranged from country lane to motorway). The road network was next translated (or 'rasterized') onto a surface of 500×500 m^2 cells such that each cell was assigned the time that it would take to cross it. The resulting values can be considered as 'impedances', or traverse times in minutes. By assuming that most travellers would choose to minimize their journey time (or impedance), these data could then be used to identify travel time bands around any particular location.

Combining the travel time map around any particular site with the population details made it possible to calculate the number of persons living within set driving times from each study site. Seven time bands were delineated (0–5, 5–10, 10–15, 15–20, 20–30, 30–60 and 60–120 min) and the residential population summed separately for each of these areas around the study sites.

In addition, we derived a single distance-weighted measure of population access to each study site. The number of persons in 5-min-wide time bands around each site was calculated, and this value divided by the square of the time value, to give a population 'score' for that time band. Use of an inverse relationship with time to a squared power was suggested by previous work by Rich (1980) on potential surfaces, and performed very well in our own sensitivity analysis. These scores were cumulated to derive a single, 'PSCORE' value for each FC study site, or

$$\text{PSCORE} = S\,[(\text{population}_i)/\text{travel\_time}_i^2]$$

where i = travel time area in 5-min intervals (i.e. 0–5, 5–10, 10–15 min, etc.)

Access to competing woodland

Two indicators for proximity to substitute forests were estimated, using three digital maps of woodland coverage across the UK. One source is based on the Forestry Commission's own sub-compartment database. As part of a study of recreation on FC lands, Whiteman (1995) defined valuation blocks comprising multiple subcompartments. These areas were identified from a multi-year survey of over 1000 households across the UK. Respondents were asked to name places they had visited in the preceding 3 months for the purpose of outdoor recreation. The data have the advantage of indicating woodlands that were actually frequented by recreationists, thus excluding parts of the Forestry Commission estate not designed or intended for public access. Whiteman grouped places on FC land named by the survey respondents into valuation blocks, and represented each by a single grid reference with a corresponding area attribute. Although these data lacked explicit boundary information, this could be somewhat approximated by defining a circular area (or 'buffer zone') around each centroid that encompassed the given hectarage for that reference point (Figure 2). However, the Whiteman data are restricted in that they refer only to FC lands, whilst omitting public-access forests owned by

Figure 2. Buffered Whiteman valuation blocks.

other agencies (e.g. county councils or conservation organizations), that may also compete for visitors.

Two sources of forest cover in the UK were available to supplement the Whiteman details. Within the 1 : 250 000 Bartholomew digital database is a topography layer that includes a woodland theme (Figure 3). As an indication of general forest land-use, this source is more complete than the Whiteman layer because it incorporates non-FC areas. It also, compared with our final data source (see below), more directly reflects land use rather than land cover. However, because of the cartographic nature of the database, it was expected that while coverage would be fairly complete in rural areas, it would be less so in or near urban zones (where showing woodland might conflict with other map information). The Bartholomew layer also fails to distinguish between public-access and other forested areas.

A third source of woodland cover was the Institute of Terrestrial Ecology's (ITE) Land Cover Map of Great Britain (LCMGB; Fuller *et al.*, 1994a), which gives the percentage of deciduous or coniferous tree cover in 1 km^2 squares. These data were derived from classification of winter/summer pairs of satellite images acquired between 1987 and 1993. For our purposes, the two species types were combined to generate a single percentage woodland map; experiments with keeping the coniferous and broadleaved trees separate produced insignificant differences

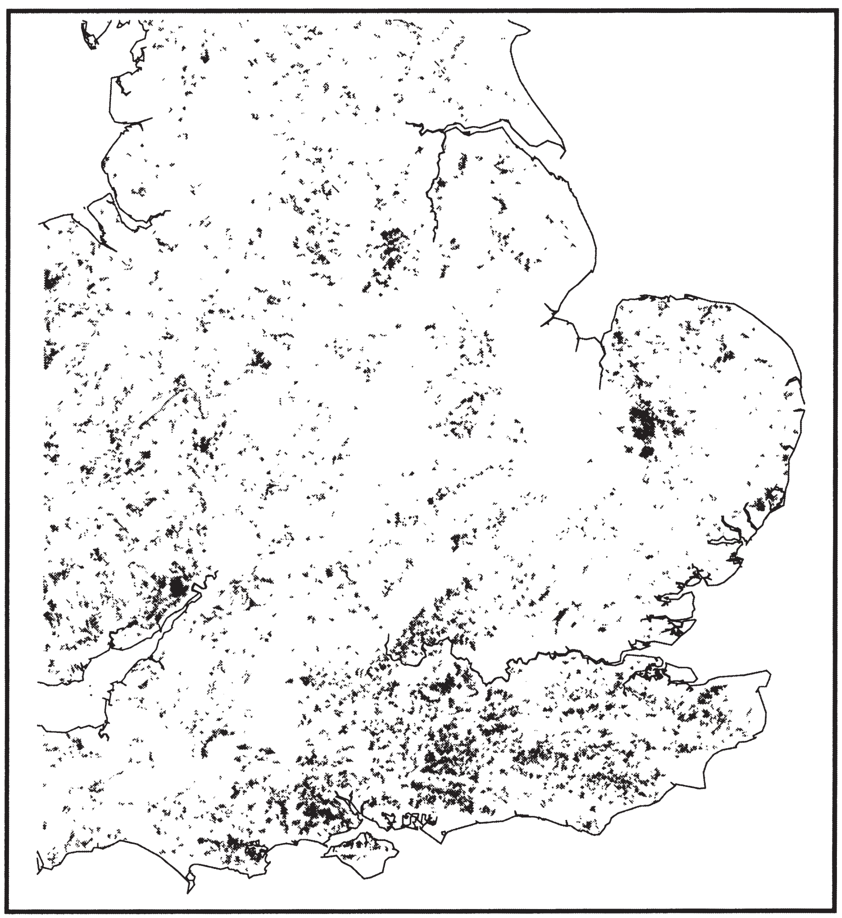

Figure 3. Bartholomew's woodland layer.

in subsequent modelling, a result which may be due to the resolution of the data. Close examination of the resulting layer, however, did reveal that it contained classification procedure artefacts. For instance, on Figure 4, a somewhat L-shaped streak from near north London towards Lincolnshire coincides closely with a specific set of summer/winter pairs used to derive the LCMGB (as depicted in Fuller *et al.*, 1994b). The L-shaped streak is caused because the images in this area were processed with a slightly different (statistically based) algorithm from the other image pairs that went into the LCMGB, to distinguish vegetation types. As a result, woodland cover is somewhat overestimated in the L-shaped area. Also, like the Bartholomew data, the LCMGB did not distinguish between public-access and other forested areas.

In view of the known shortcomings in all of the potential forest datasets, we derived two versions of likely tree cover in Great Britain. One map allowed for a broad definition of woodlands, under which it was assumed that an area was forested if it had at least 10 per cent presence in

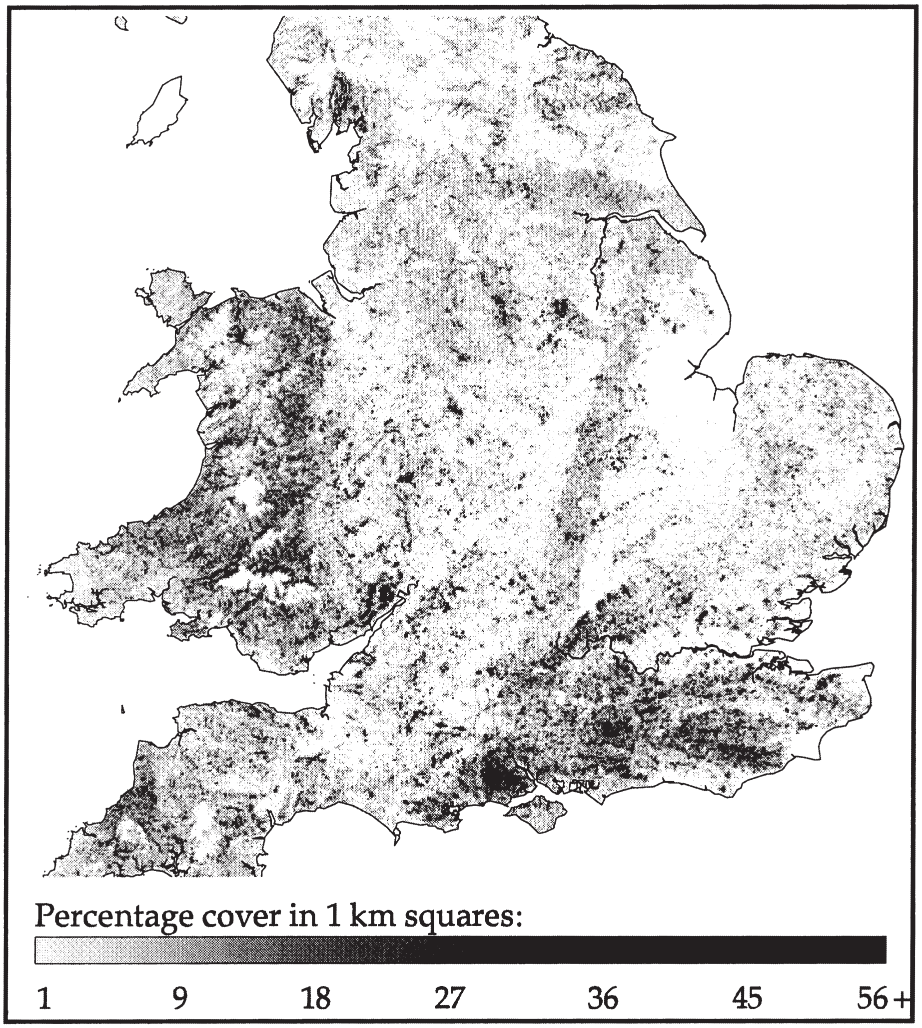

Figure 4. Percentage woodland cover according to ITE land cover map.

the ITE data, and was confirmed by the Bartholomew or Whiteman layers. This map thus included non-FC lands, as well as many areas that may not be open-access. An alternative, stricter approach was to require that woodland be depicted on the buffered Whiteman map *and* confirmed by either the Bartholomew source or at least 10 per cent ITE cover. This second map is thus confined only to FC lands known to be frequented by recreationists.

The broadly and strictly defined layers were converted into recreation potential surfaces (following suggestions in Rich (1980)) as follows. Sampling points were placed every 5 km and the total amounts of available woodland – according to either the 'strict' or 'broad' definitions – were summed in 5-min time bands (along the available road network; see previous section) around each point. Related work (Brainard *et al.*, 1997) revealed that visit rates (i.e. number of visitors per head of population) were well described by a function in the form of:

$$\log(\text{Visit\_Rate}) = \text{coefficient} * \log(\text{Time\_in\_minutes}) + \text{constant}$$

where log refers to transformation by natural logarithm. Model performance was maximized when the coefficient on the time element performed took on a value about –1.65. The forest totals in each time band were consequently divided by the travel time raised to the power of 1.65, and the resulting scores multiplied by an arbitrary value of 1000 to make the range of values more convenient to manipulate. The scores in each time band were then summed to produce single broadly and strictly defined woodland index values for each sampling location. These calculations are summarized below:

$$\text{Recreation\_Potential\_Surface} = 1000 * \sum_{\text{timeband}=5}^{\text{timeband}=240} \left[\frac{\text{Woodland\_Area}}{\text{timeband}^{1.65}} \right]$$

Timeband was incremented in 5-min intervals. The sampling points were resolved as 500 × 500 m^2 grid cells, and interpolation used to estimate index values in cells between these sampling points. Two maps of woodland access, one 'strict' and one 'broad' were generated, hereafter referred to as WBROAD and WSTRICT (Figures 5 and 6). WBROAD and WSTRICT are very similar and, for the most part, the WSTRICT layer can be interpreted as a subset of the WBROAD map. However, the importance of the road network is shown more clearly in the WBROAD layer, and the two layers did have different levels of statistical significance in subsequent modelling, as shown below.

Models to predict forest arrivals

A number of models were generated to forecast arrivals at English woodlands from the preceding datasets. Several of these are striking in their combined simplicity and high explanatory power.

Simple models to forecast visitors on site traits only

Of all the site-specific variables, car park capacity had by far the strongest correlation with total arrivals. A linear regression to predict vehicle numbers as a function of this variable yields (*t*-values for the coefficients are in parentheses):

Model 1 VIS_COUNT = 25 104.64 + 176.99 * CARCAP
(5.0998) (6.5633)

The R^2 value is 0.5815. Following on from this, a simple but effective model is to predict visitors from just car park capacity and signposting, yielding an R^2 of 0.6336:

Model 2 VIS_COUNT = 35740.70 + 192.80 * CARCAP – 1822.91 * SIGN
(5.1335) (7.2020) (–2.0643)

There are difficulties, however, with accepting either of these last two models at face value. Car park capacity (CARCAP) is positive as expected, while signposting (SIGN) is negative, which probably reflects adjustments made for the appeal of small and non-signposted sites that receive much local use. Such small woodlands may well be very attractive if they are much less congested than their larger counterparts, and thus the negative sign on the variable is plausible. But like CARCAP, both effects are rather more correlative than causative – big car parks themselves are not inherently more attractive than little ones, and it is illogical to propose that advertising a site should generally tend to drive visitor numbers down.

It is clearly desirable to predict visitor numbers

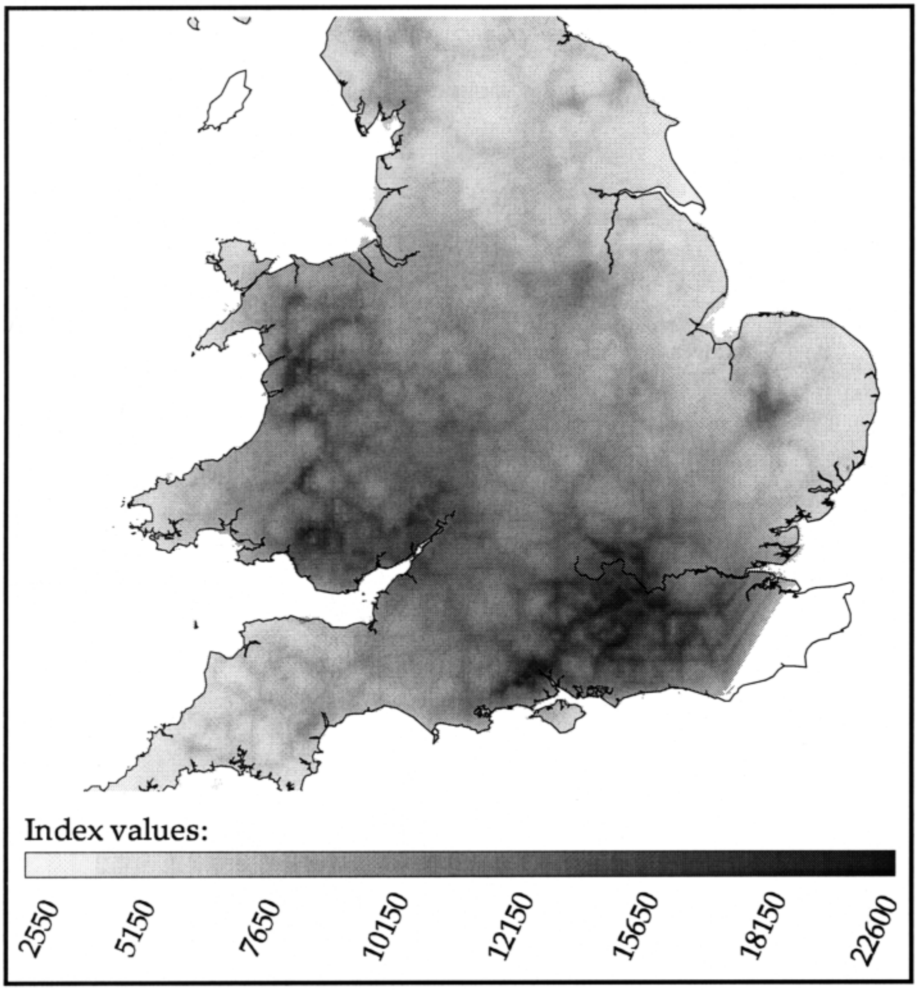

Figure 5. WBROAD potential woodland surface. No data were calculated for part of the south-east remote from any study site. Scale is non-linear.

using variables that are more likely to be causative rather than correlative, as in Model 3.

Model 3		(*t*-statistics)
log(VIS_COUNT) =	8.0285	(19.4028)
	+ 0.5217 * BIKEHIRE	(1.9801)
	+ 0.0598 * WALKKM	(3.7544)
	– 0.000000050990 * $WSTRICT^2$	(6.2172)
	+ 0.00026757 * WBROAD	(6.1597)

$R^2 = 0.7164$

[Note: 'log' in all models refers to transformation by natural logarithm. VIS_COUNT = FC annual vehicle counts, $WSTRICT^2$ = strictly defined woodland index raised to the power of two; WBROAD = broadly defined woodland index. Other variable names as in Table 2.]

Note that the woodland indices have been incorporated in a quadratic form. Recalling that these are site-specific readings, the quadratic form suggests that visits rise with adequate, but not excessive, forested areas nearby. The use of WSTRICT and WBROAD together worked rather better than a more conventional WBROAD + $WBROAD^2$ or WSTRICT + $WSTRICT^2$ format. Recalling that WSTRICT is a reduced form of WBROAD, incorporating them

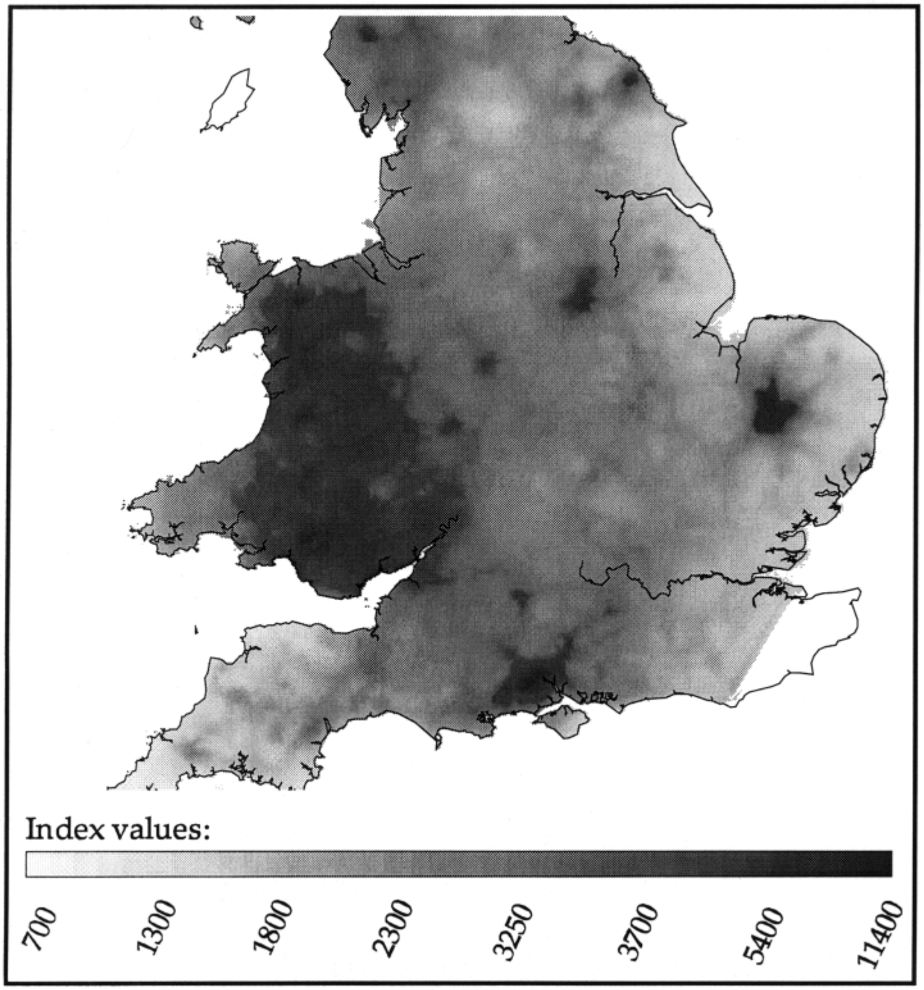

Figure 6. WSTRICT potential woodland surface. No data were calculated for part of the south-east remote from any study site. Scale is non-linear.

jointly seemed to lead to an improved, quasi-quadratic response to substitute availability. The shape of the curve is only moderately convex at low values, and soon tails off to a fairly linear decline. We believe that there are two reasons why this quasi-quadratic form works so well in our models. First, in a region with a reputation for pleasant woodlands, it is more likely that any holiday visitors will take the time to visit any one of them. Effectively, the presence of some woodland nearby will tend to drive up visits to any single site located therein. Secondly, residents in this region are also going to be influenced by the area's reputation, and will also be inclined to spend more recreation time than they might otherwise do in public-access woods. It is even possible that some persons who especially enjoy forests will choose to live in such regions, specifically to increase access to woodland recreation. However, it must be kept in mind that the WSTRICT and WBROAD surfaces are both probablistic rather than known, actual extents of public-access woodland. Thus, we must caution that we cannot be absolutely certain that the quasi-quadratic form is capturing the true relationship between substitute woodland occurrence and visits.

BIKEHIRE and WALKKM are both positive, and probably indicate seasonality and recreational quality respectively. Effectively, BIKEHIRE in Model 3 seems to allow for a seasonal adjustment upwards where cycle hire is available, generally only during the summer months and on weekends at the larger sites. However, the variable lacks statistical significance at a 95 per cent level of confidence, and its importance should be interpreted cautiously. Total kilometres of walks (WALKKM) seems to work well as a proxy for overall site development and quality. Many small woodlands are relatively well-developed and have more walking trails (and possibly for longer distances) proportional to their area than larger locations. This is especially true of older, more established sites that are often heavily used by local people and much less frequented by remote visitors.

The preceding functions are not meant to be definitive, but they do suggest that such analysis is both possible and effective. In some ways, the success of models 1–3 is surprising, considering that they take no account of the market demand (in economic terms) or even population access around each location. There may be geographical reasons for this, with regard to both woodland availability and population. England is relatively densely populated, and all of the study sites are within a 2 h drive of a least one large population centre. The relative scarcity of public-access forests in England may even mean that the appetite for woodland recreation tends to be universally high, almost regardless of localized variations in population density. Instead, inaccessibility, lack of publicity and/or specific amenity features (e.g. toilets) may be the most important limiting factors in site visitation rates. However, it is noteworthy that significant improvements in model performance were achieved upon the addition of the population measures, as shown in the next section.

Incorporating simple measures of population access

The previous models were simplistic with regard to the treatment of user demand. Specifically, they assumed that the population distribution around all sites was identical – a situation rather unlikely to be true in reality. We have therefore tried various measures of population access in multisite participation models. In our experience the best measures are actually the simplest ones. This may seem a limited perspective, in that it ignores other issues likely to be of relevance in determining recreation demand, such as the socio-economic profile of the local population, or their direct access to surrogate woodlands. However, with regard to describing woodland recreation in the UK, we have found that the distance–decay relationship between a site and its users significantly dominates any other population-related factors. Moreover, our related efforts to incorporate such elements into models of attendance at English woodlands resulted (Brainard, 1998) in weaker predictions than the outputs described here. As a consequence, this paper focuses on models that are both more successful and easier to implement.

Of the variables derived to indicate the numbers of persons within a set driving distance, the 120 min time was the best predictor of total site arrivals, with the following being the strongest resulting function:

Model 4		(*t*-statistics)
log(VIS_COUNT) =	7.5612	(0.2982)
	+ 0.00000005.4594 * PW120	(6.9306)
	– 0.1241 * log(KM2R)	(2.2465)
	+ 0.3863 * log(CARCAP)	(5.0284)
	+ 0.05724 * WALKKM	(4.5180)
$R^2 = 0.8272$		

[Note: PW120=population within 120 min, VIS_COUNT = FC annual vehicle counts. Other variable names as in Table 2.]

In Model 4, an arbitrary, small value (0.1) was added to KM2R in order to take the natural logarithm of this variable (for sites with entrances directly on the nearest main road and thus a KM2R value of zero). All variables except KM2R are highly significant and have positive influences on arrivals. Here, as in Model 3, WALKKM is a highly important anticipator of visitor numbers. However, as stated previously, interpreting the role of CARCAP is problematic. Its primary shortcoming is that it is non-specific about what exactly might be the attractive single elements at a particular woodland, but it is also very indicative of overall capacity, or how many visitors a site's facilities can serve at any one time.

Like the population-within-120-min, the weighted PSCORE variable is an effective indicator of party visitors. Model 5 shows a single variate regression to predict visitors from the PSCORE variable.

Model 5 log(VIS_COUNT) = 5.3936 + 0.5979 * log(PSCORE)
(4.0717) (3.7033)

$R^2 = 0.3067$

In combination with just a few site-trait variables, the significance of PSCORE and strength of the predictive model improve substantially:

Model 6	(*t*-statistics)
log(VIS_COUNT) = 13.2010	(4.0924)
+ 0.6006 * log(PSCORE)	(6.0831)
+ 0.4060 * log(CARCAP)	(4.7852)
+ 0.04320 * WALKKM	(3.2633)

$R^2 = 0.7716$

Like the PW120 indicator, PSCORE is clearly a valid indicator of recreation demand. However, it is interesting to note that the simpler variable to estimate, PW120, is the more effective predictor (see both individual *t*-statistics and model R^2 values). This may reflect inaccuracies in the input data sources and assumptions used to calculate these variables. It would be interesting to see if this result is more generally replicable for other British woodlands and outdoor recreation areas. Nevertheless, the 'population within 2 hours' and 'population score' approaches should both hold considerable appeal to anyone interested in predicting arrival numbers to English forests.

Conclusions

This paper presents a valuable line of research with regard to predicting patterns of woodland recreation demand across England. Many authors, including ourselves, have produced recent studies featuring much more sophisticated approaches for describing recreation demand and benefits. Relevant work by Willis and Garrod (1992), Benson and Willis (1993) and Bateman *et al.* (1996) all explained arrivals to British woodland sites in terms of the travel costs of surveyed visitors. Second-stage models have also been derived by Lovett *et al.* (1996) and Brainard (1998) to incorporate socio-economic traits in the site users' population and substitution effects in models to predict visit numbers. These outputs were subsequently used to generate monetary estimates of users' recreation benefits at one or more sites. The problem with such modelling is that it requires relatively rare data that are costly and tedious to collect reliably, as well as sophisticated data-handling techniques and statistical analysis to process. In contrast, this study suggests that it may be possible to measure the demand for forest recreation in England in more tangible terms, as visitor party arrivals, and more simply – using variables that are much easier to obtain. The lack of complexity in such modelling is its very strength. Policy analysts would be remiss to overlook the opportunity to achieve the same goal – the acquisition of reliable indicators of recreation demand – using much simpler techniques.

Transferral of these models to predict visitor numbers at new or unsurveyed sites is not yet a statistically defensible option, however. To further advance this work along those lines would require *many* more observation sites than seen in this study (33). This would facilitate the development of separate and more precise equations to forecast user demand for different types of woodlands and particularly for distinct combinations of recreation facilities. It may be sensible to derive diverse model forms for different types of forest users (i.e. dog-walkers, mountain-bikers, families, etc.) The other possible limiting factor would appear to be quality constraints for the model inputs. None of the data sources used in this study were perfect, and their defects may have biased the results in unknown ways. This is a recurring and ongoing issue when using GIS to model spatially referenced phenomena, but it should not be seen as an insurmountable problem. Instead, what this line of research amply demonstrates is how well-suited GIS is to the derivation of tools that are simultaneously both more precise and simpler than have previously existed for estimating woodland recreation demand at any one location.

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